MIT Center for Space Research
1 Hampshire Street
Cambridge, MA 02139-4307

Tel: 617-253-7277
Fax: 617-253-8084

report

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To: ACIS Instrument Team

From: Peter G. Ford, NE80-6071 <pgf@space.mit.edu>

Re: ACIS CC-Mode Bias Algorithm, Part 2

Cc: Chandra Science Operations Team

As reported in a previous memo,[1] many bias maps computed for front-illuminated CCDs in continuous clocking mode show anomalously high values due to background charge amounting to tens of ADUs. The subsequent use of these bias maps to identify events has led to subtle errors in computing the x-ray flux over the affected CCD columns. As discussed in that memo, the error was exacerbated by the particular bias algorithm then in use—the mean *algorithm. It was suggested that a version of the* median *algorithm would be a superior choice.*

In the current report, I discuss the results of 4 science runs that were performed to compare bias algorithms. I conclude that the median *algorithm is superior in all respects and should be adopted for all future continuously clocked observations.*

Introduction

In continuous clocking (CC) mode, bias maps are constructed from a pair of 512-row pixel "frames". They are therefore particularly sensitive to any systematic charge deposition that extends along the column direction—if all pixels in that column are affected, the resulting bias value will be erroneous. This problem is avoided in timed-exposure mode because its bias maps are created from multiple frames and the location of background charge is essentially uncorrelated from frame to frame.

As was demonstrated in the previous memo,[1] front-illuminated (FI) CCDs are especially prone to "charge blooming", where an x-ray or charged particle triggers a shower of charge within the CCD. A fraction of these showers will be oriented nearly in the plane of the CCD and the charge bloom will be recorded as a streak of anomalous charge. In some instances, the nominal CC-mode bias algorithm has proven inadequate to filter out the effect of these blooms.

Analysis

Before the four runs analyzed in this report, the only CC-mode data available from orbit comprised the bias maps from 64 science observation runs and three raw-mode calibration runs. The former, which were processed by the default algorithm termed "*mean with 5-σ rejection*"[2] showed clear evidence of systematic error, and the latter, when used as input to bias computations on the ground, suggested how the errors might have arisen, and pointed the way to a better choice—the "*median (37.5% quartile)*" algorithm.[2]

It remained for us to test the old and new algorithms in flight, to convince ourselves that the new algorithm would be a substantial improvement, that it had no unforeseen side effects, and that any change in gain or quantum efficiency would be slight and reproducible. The runs, undertaken between June and October, 2002, are summarized in Table 1.

Table 1: Cc3x3 Runs to Test Bias Algorithms

OBSID	Date	Phase[a]	ksec	fptemp	algorithm	arg1[b]	arg2[c]
61148	06/28/02	outbound	9.6	-118.0	mean, 5-σ rejection	0	5
61143	07/01/02	outbound	9.5	-118.8	median, 37.5% quartile	1	384
61005	10/09/02	inbound	8.9	-119.7	mean, 5-σ rejection	0	5
60993	10/17/02	inbound	8.9	-119.8	median, 37.5% quartile	1	384

a. All runs were made with the SIM in the HRC-S position, either immediately before perigee shutdown (inbound) or after (outbound).

b. The value of the **biasAlgorithmId** parameter[4] for FI chips. The value for BI chips was 0.

c. The value of the **biasRejection** parameter[4] for FI chips. The value for BI chips was 5.

The resulting bias maps are shown in Figure 1. The colors denote the particular CCD. S1 and S3 are back-illuminated (BI) and show no evidence of background-charge artifact, although S1 has two bad columns. The remaining CCDs, all FI, show systematic increases in bias values of tens of ADU when processed by the *mean* algorithm, but only a few isolated high values from the *median* algorithm. The BI bias maps were always processed with the default

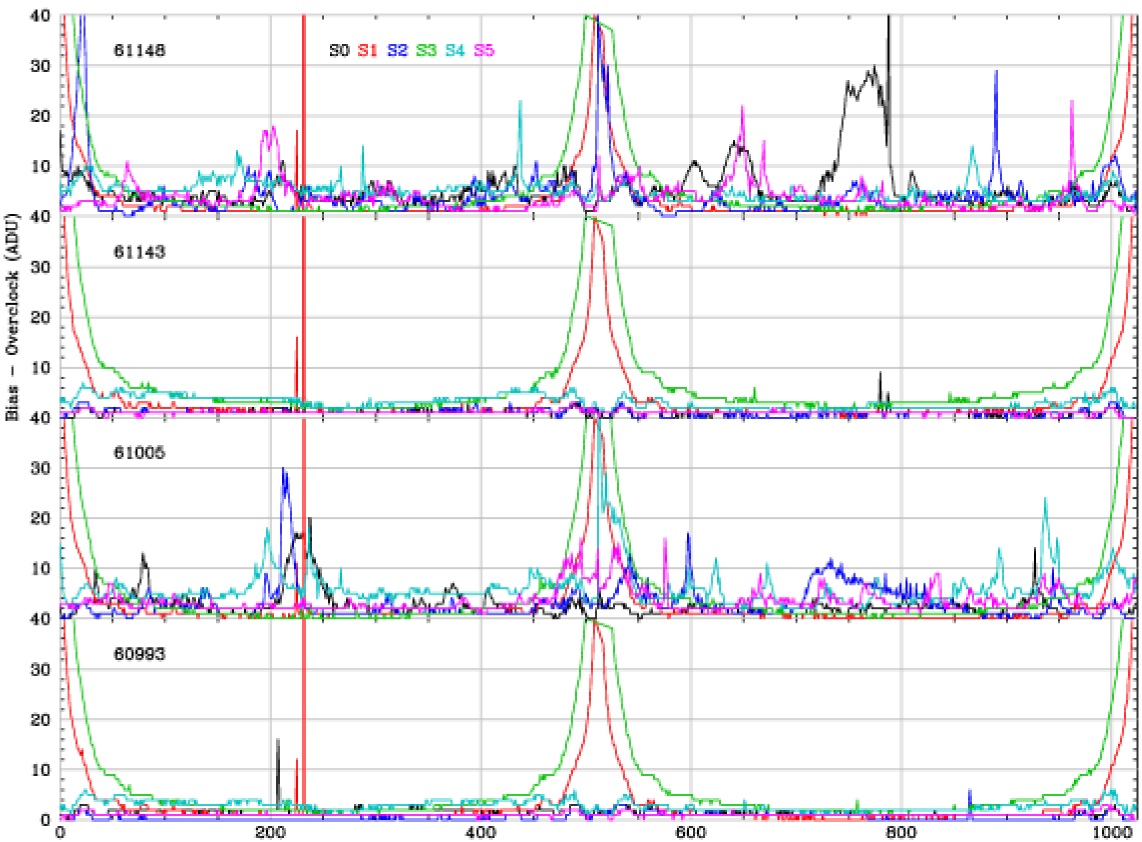

Figure 1: The 1-dimensional bias maps from the 4 runs. 61148 and 61005 used the default *mean* algorithm. Artifacts are clearly visible in each FI CCD (S0, S2, S4, S5). 61143 and 60993 use the *median* algorithm, and few artifacts are visible. The gradual increase in bias values near the output nodes of S1 and S3 (CHIPX=1,512,513,1024) are caused by instability in the ACIS video amplifiers. Isolated peaks at CHIPX=226 and 233 of S1 result from pre-launch damage.

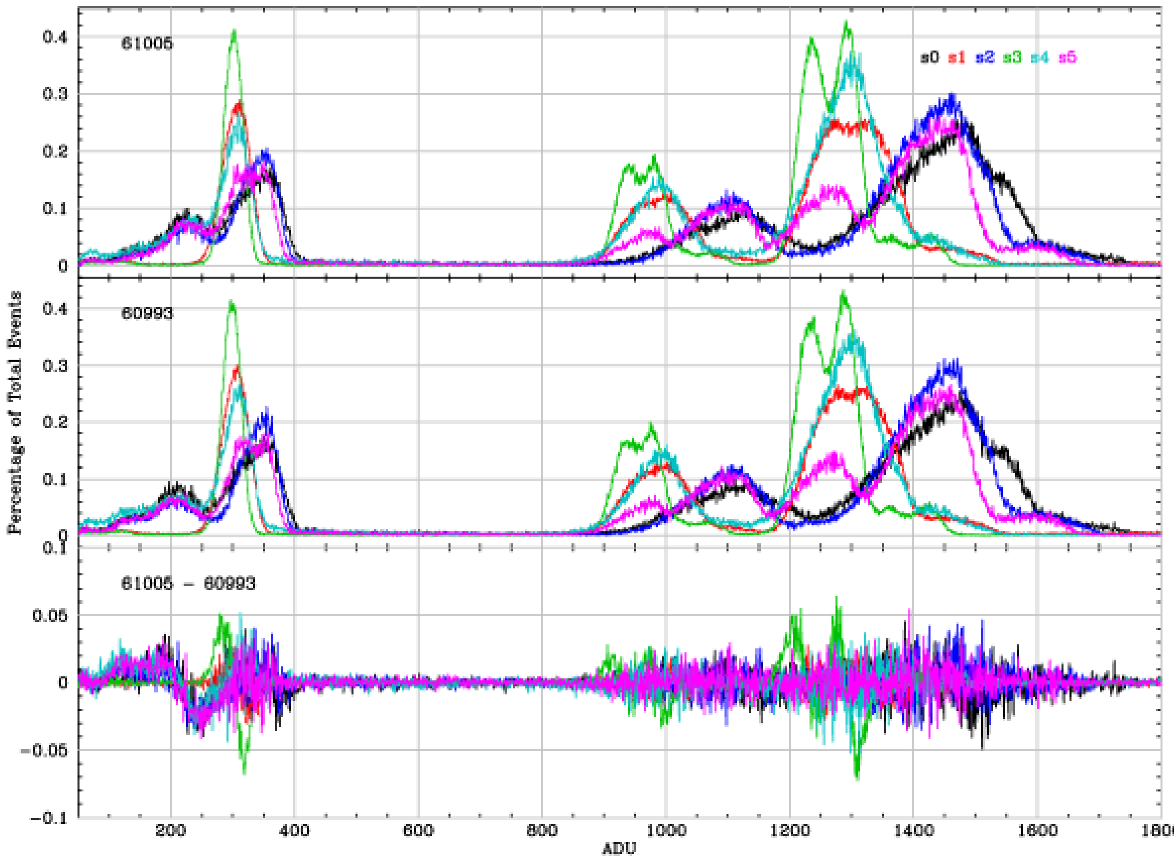

Figure 2: The calibration-source spectra from run 61005 (old bias algorithm) and 60993 (new algorithm) and their difference. Colors denote individual CCDs. BI devices S1 & S3 used the default bias algorithm for both runs. Nevertheless, S3 shows more variation than the FI chips.

algorithm. The mean values of the FI bias maps are shown in Table 2, after filtering out the anomalously high values. The last row shows the average difference between *mean* and *median* values for all runs.

Table 2: Mean bias values (ADU) for each run

OBSID	Algorithm	s0	s2	s4	s5
61148	mean, 5–σ rejection	4.278	3.129	4.767	3.308
61143	median, 37.5% quartile	0.966	1.004	3.062	1.033
61005	mean, 5–σ rejection	2.179	2.550	5.028	3.247
60993	median, 37.5% quartile	1.618	0.478	2.841	1.081
Average difference (mean–median)		1.936	2.099	1.946	2.221

Each run took data from the external ACIS calibration source for ~10 ksec. The resulting events were graded and summed, and a constant factor of 2.1 ADU was added to all *median* bias maps (runs 61143 and 60993) to account for the lower average values shown in Table 2. The results for the second pair of runs are displayed in Figure 2. The corresponding spectra from the first pair are very similar. The greatest deviation is seen in S3, a BI chip, but the count rate from all FI CCDs changed by no more than 0.05% over the entire energy range. The differences in spectra for each individual CCD are shown in Figure 3.

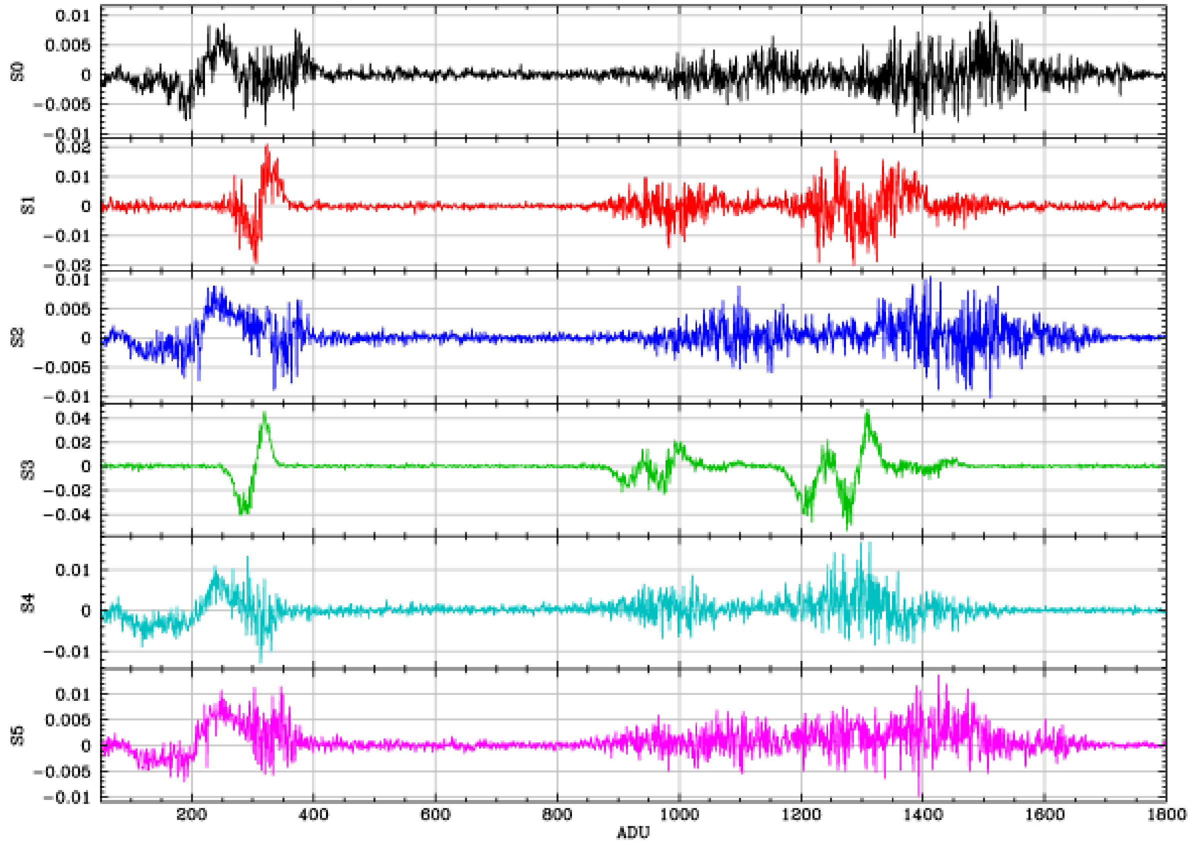

Figure 3: The difference in cal. source spectra between runs 61005 and 60993 for each CCD.

Conclusions

1. The *mean* bias algorithm is prone to systematic errors caused by background charge blooms. It should be replaced by the "*median (37.5% quartile)*" algorithm for all front-illuminated CCDs.This entails changing the **`biasAlgorithmId`** and **`biasRejection`** fields assigned to FI CCDs in ACIS CC parameter blocks[3] from their current values of 0 and 5, respectively, to 1 and 384. The flight software is able to use different algorithms for each chip, and the ACIS uplink parameter block generation process, controlled by a Ruleset[4], is fully capable of assigning the parameters appropriately.
2. Since the average column bias value from the *median* algorithm is ~2.1 ADU lower than that from the *mean* algorithm, this value should be added to all *median* bias maps before comparing the results against runs using the *mean* algorithm.
3. BI CCDs are not subject to charge blooms. They should continue to use the original *mean* algorithm.

References

1. ACIS CC-Mode Bias Algorithm, P. G. Ford, MIT CSR Report, June 4, 2002. (ftp://acis.mit.edu/pub/ccbias.pdf)
2. ACIS Software Detailed Design Specification, MIT CSR 36-53200, Rev. 01, November 1995, section⁄45.6. (acis.mit.edu/acis/sdetail-01pp/sdetail.pdf).
3. ACIS Instrument Parameters and Command Language, MIT CSR 36-53204.0204 Rev. N, March 2001. (acis.mit.edu/acis/ipcl/loadCcBlock.html).
4. ACIS Parameter Block Ruleset, MIT CSR Rev. 1.5, May 1999. (acis.mit.edu/axaf/napcat.html).