

Bias Subtraction and Correction of ACS/WFC Frames

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Abstract. Calibrated ACS/WFC science frames processed through the CALACS pipeline exhibit a residual offset in their absolute levels at the edge separating the Amp A-B and Amp C-D quadrants. This effect can be attributed primarily to uncertainties in the bias level subtraction. We present an analysis of the overscan levels and of the amplitude and behavior of the residual offsets for a large sample of bias frames. The scientific impact of this residual is discussed.

1. Introduction

One of the most fundamental steps in exploiting the new capabilities of the Advanced Camera for Surveys (ACS) consists of accurately subtracting bias frames and offsets level from scientific images. In the routine pipeline processing (CALACS; Hack 1999), the bias level measured in selected columns of the leading physical overscan is subtracted from the active area, which always shows a slightly higher bias level. In principle, if the residual offset between the imaging area and the overscan region were always of the same amplitude, a full-frame superbias subtraction would remove any residual difference. Unfortunately, the offset is not constant but shows random variations, resulting in a small but noticeable jump in the middle of each chip along the amplifier edges (see Figure 1).

We present an analysis of the structure of the WFC bias frames, statistics of a sample of bias frames acquired since ACS installation and the amplitude of their residual offset. We look into the scientific implications of such a residual and present a possible approach that could mitigate the problem.

2. Description and Behavior of the Problem

Normal WFC images are read-out using the four amplifiers, two for each detector (A-B for WFC1 and C-D for WFC2). Hence, one amplifier is used to read a single $2k \times 2k$ quadrant and so each quadrant needs to be treated independently in the calibration process.

Each amplifier has a specific bias level and bias structure. It is therefore normal that the raw bias frame (and any other raw WFC frame) shows a “natural” jump in the center of the image. Figure 2 shows an averaged horizontal profile of the WFC1 bias frame used to calibrate the image in Figure 1 (see also Sirianni, Martel, & Hartig 2001). The plot shows that the bias level measured in the physical overscan is lower than the bias level in the active area. The difference between these two bias levels varies between each quadrant. Since the bias level is measured in the leading physical overscan and subtracted from the active area of each quadrant, the center of the resulting image shows a “residual offset” or jump between the two adjacent quadrants, A-B or C-D (central panel in Figure 2). In calibrated ACS/GTO data, the amplitude of this residual offset is typically of the order of 1% of the adjacent background level (typically < 4 DN), with extreme cases of $\sim 3\%$.

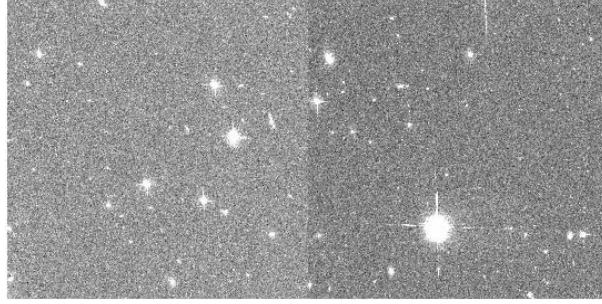


Figure 1. A calibrated WFC1 field (F775W) showing the offset.

In principle, if the difference between the active area and the overscan regions were of the same amplitude in all frames, the full-frame superbias subtraction performed at a later CALACS stage would remove the residual difference between the two quadrants.

To establish the temporal dependence of the bias levels and the residual offsets, we analyzed the stability of all the bias frames acquired as part of SMOV and monitoring campaigns over the period Apr–Jun 2002. The results are shown in Figure 3. The top panels show the variation of the bias overscan level with time. For all four amplifiers, the levels are fairly stable with small variations. Each month the TECs are turned off to allow the CCDs to warm up to ~ 19 C and anneal hot pixels created by radiation damage. When this occurs the bias level is higher than normal, but within a few hours it will assume the normal value it had just before the anneal. Ignoring this monthly feature, the overscan level for all four WFC quadrants turns out to slowly decrease with time by about 0.02–0.03 DN per day. Finally, in addition to the monthly feature, Amp B shows an intrinsic scatter of about 15 DN (peak to peak). Such behavior was already known from ground testing and does not represent a concern because the bias level in the active area changes accordingly with the same amplitude.

The two panels at the bottom of Figure 3 show the residual offset variation with time for the four amplifiers. Each amplifier shows a positive residual offset, meaning that the active area has a slightly higher bias level than the region used to estimate the bias offset in the physical overscan. For all quadrants, the residual offset does not correlate with time and varies by a few tenths of a count (Table 1). Moreover, its apparently random amplitude does not appear to correlate with the bias level in the active area nor with the detector temperature. On the other hand, there seems to be a correlation between the residual offset variations in each amplifier. When the difference between the active area and the leading physical overscan increases or decreases in one quadrant, it shows the same behavior in the other amplifiers.

The cause of the residual offsets and their variation with time are still under investigation. The accuracy of the bias level subtraction in a single frame is limited by this random effect.

Table 1. Residual Offset Instability

WFC1			WFC2		
AMP	MEAN	σ	AMP	MEAN	σ
A	1.16	0.27	C	3.13	0.16
B	2.13	0.23	D	0.63	0.26

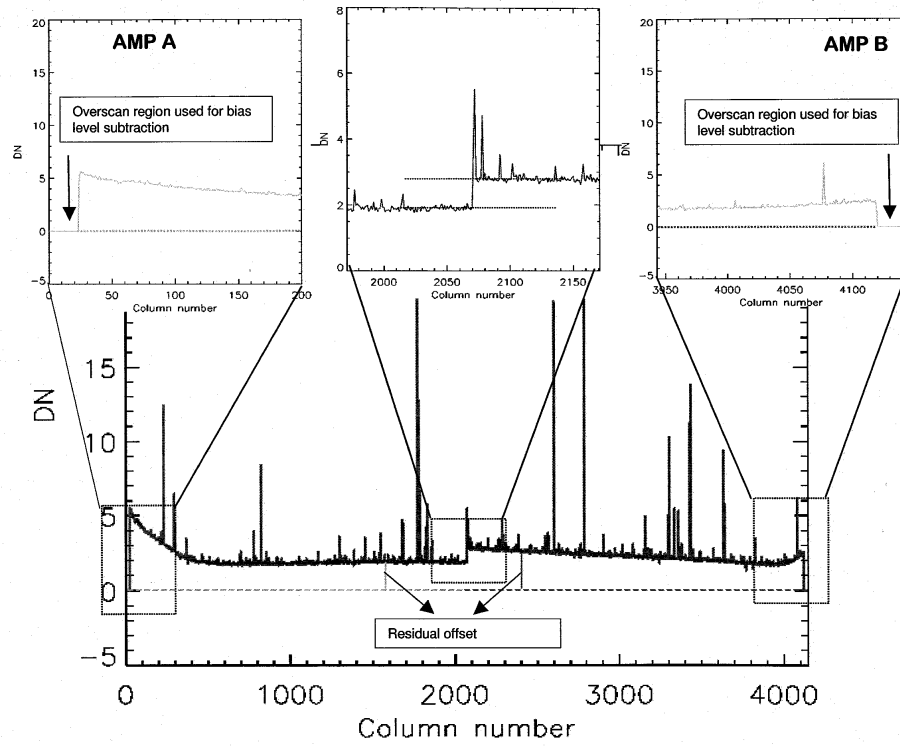


Figure 2. Horizontal profile of the bias frame used in the image of Figure 1.

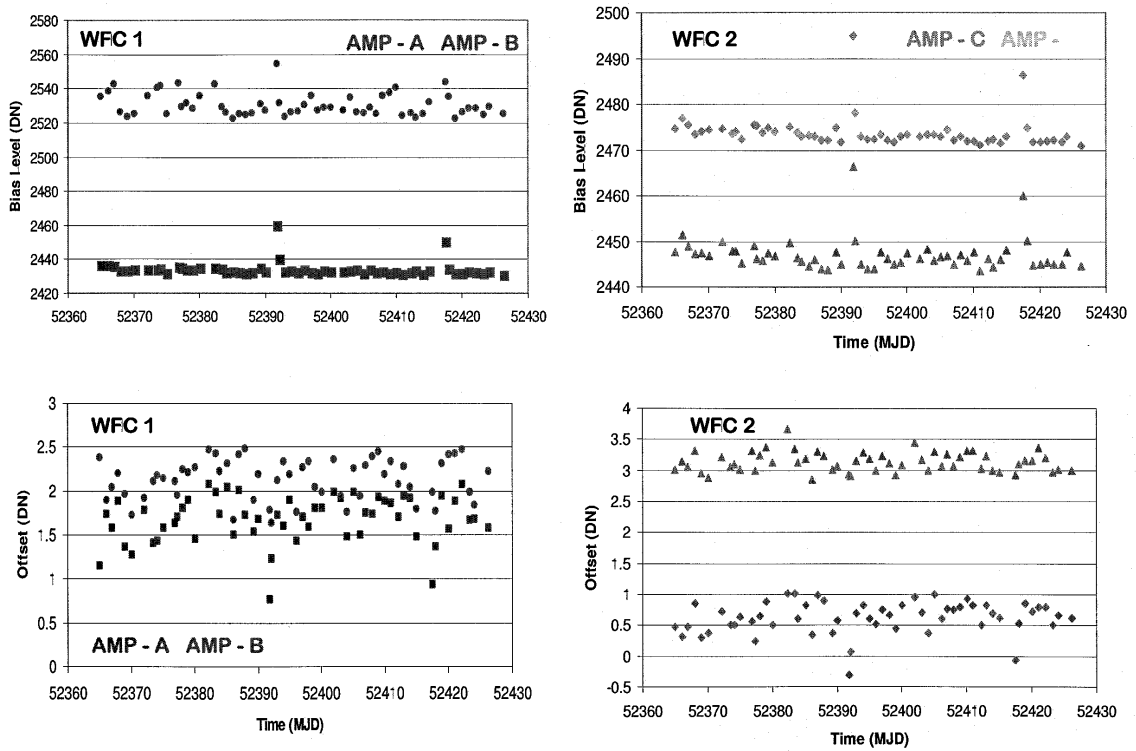


Figure 3. Variation with time of the bias overscan levels and the residual offsets.

3. Scientific Impact

We investigated the scientific impact of the uncertainty in the bias level subtraction. For point sources, the local background is typically subtracted in an annular region so the residual offset has essentially no impact on the integrated magnitudes. Extended objects such as galaxies may be spread over two or more quadrants, so their surface brightness profiles will suffer from the residual offset. But even at low counts near the sky levels, a 3% jump translates to a change in magnitude of only 0.03. With the addition of the object counts superimposed on the sky, this value is correspondingly smaller. We conclude that the scientific impact of the variation of the amplifier residual offset is negligible.

4. Conclusion

All ACS/WFC images will suffer from small uncertainties in bias level subtraction due to the random variation in the difference between the bias level in the leading physical overscan and the bias level in the active area. Due to the random nature of this variation, the error associated with reference frames, such as the superbias and the superdark, will be reduced by the square root of the number of bias and dark images used to build the reference files.

Update on Amp B fluctuations: We recently discovered a different problem, associated with the bias level in Amp B, that can produce a final image where the jump at the amplifier edges is noticeably larger than the one due to the residual offset instability. Some calibrated images show an amplifier edge jump in WFC1 of up to 0.8 DN (A-B). If the final image is a combination of n frames (CR-SPLIT or dithered observations) the bias jump at the center of the WFC1 frame is $n \times 0.8$. As noted above, the bias level of the B quadrant shows an instability peak-to-peak of ~ 15 DN. Such an instability is also visible in the bias level of science frames. However, the distribution of the bias level in frames with a non-zero exposure time seems to be bimodal with a “high” and “low” status which best match the high and low ends of the “15-DN” range. When the bias level in B is in the “high” status, the jump between A and B is only due to the residual offset instability and can be neglected. However, when the bias level in B is “low,” then in addition to the amplifier residual offset, there is a contribution of ~ 0.8 DN from the bias frame subtraction.

More studies are in progress to better characterize this new problem and find a solution or develop a correction to apply directly into the calibration pipeline. At the moment we suggest that ACS users fit the sky level in each quadrant separately.

References

- Sirianni, M., Martel, A. R., & Hartig, G. 2001, *WFC4 Overscan Analysis and Bias Subtraction*, The ACS Calibration Web Pages—Results (Johns Hopkins University)
- Hack, W. 1999, “CALACS Operation and Implementation,” *Instrument Science Report ACS 99-03* (Baltimore: STScI)