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WFC3 Ambient-2 Testing: UVIS Readnoise

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ABSTRACT

The WFC3 UVIS readnoise levels have been measured using recent ambient-level data obtained with the integrated instrument in the Space Systems Development and Integration Facility (SSDIF) clean room at Goddard Space Flight Center (GSFC). The UVIS-2 detector was in place, operating at -54C. Under these conditions, the readnoise levels in full-frame, four-amp bias image readouts, using a gain level of 1.5 e^-/DN, are 3.1, 3.2, 2.8, and 3.1 e^- for amps A,B,C, and D, respectively; errors are <0.1 e^-. Application of the measured UVIS-2 gain values will increase the values by 3-10%, depending upon the specific amp. The readnoise has been measured in bias frames using the overscan region and the science area pixels; both methods yield effectively the same result. The overscan method has also been applied to non-bias images; the resulting readnoise levels differed from the bias frame results by 1-6% (0.02 to 0.2 e^-), usually higher in the non-bias frames but not always. The readnoise in subarray images has also been evaluated; in 200x200 pixel subarray biases, the levels are slightly lower in amps A,B, and D (by ~0.02-0.15 e^-) and slightly higher in amp C (~0.04e^-) compared to the full-frame biases. Finally, an ambient superbias has been constructed from a stack of all good, full-frame, four-amp bias frames and its characteristics are described. There is some low-level systematic behavior to the noise in quadrant B: the bias level is slightly higher in odd-numbered columns than in even-numbered columns (~0.2 e^- peak to peak). If this characteristic persists in images taken during the upcoming thermal vacuum tests and is found to vary with time, the pipeline algorithms could be modified to provide a column-dependent overscan correction.

Background

A relatively short ambient-level test was performed with WFC3 in April 2007, in preparation for more extensive testing under thermal vacuum conditions expected to start in June 2007. During the ambient tests, the instrument was in the GSFC SSDIF clean room; the UVIS-2 detector was in place and cooled to -54C. To evaluate the readnoise, measurements were made using the overscan pixels and the science area pixels. For the latter, all full-frame, four-amp biases were examined, including those from the standard bias+dark proposal (UV01S01) and superbias proposal (UV01S06), as well as those biases taken as part of other proposals during ambient with the exception of special tests such as charge injection (UV06), crosstalk (UV31), and EPER (extended pixel edge response, UV02). The readnoise in subarray data was investigated as well; since WFC3 subarrays typically have no overscan area unless they happen to include some of the physical overscan region (which the ambient subarrays did not), the readnoise is measured using the pixels in the science area pixels. As part of the analysis of the noise measured from overscan pixels, other image types are used in addition to the bias frames, and the results compared to each other and to the overscan readnoise results.

Readnoise from the Overscan Pixels

The first method used to evaluate readnoise takes advantage of the virtual overscan region for each channel. The standard deviation of the serial virtual overscan pixels is measured; no clipping is performed but to avoid possible bad pixels, the first and last 3 columns have been omitted and only rows 100-2000 have been used. To be consistent with previous ISRs, readnoise results as measured in DN are converted to electrons assuming a gain value of 1.5 e^-/DN; the true readnoise for UVIS-2 is 3-10% higher, depending upon amp, if the measured gains are applied (1.58, 1.55, 1.65, 1.61 e^-/DN for amps A,B,C, and D, respectively; Baggett, 2007).

The table below lists readnoise values determined from the overscan pixels; each value is an average based upon a set of images and the error is the standard deviation. The results for several image types were computed separately. Not unexpectedly, there is excellent agreement between the standard biases (taken with UV01S01 procedure) and the other biases (taken with any other procedure but excluding tests such as the bias vs bus voltage, crosstalk, and EPER). However, there can be small differences in readnoise when the overscans from other image types are used, ranging from effectively no difference between bias and non-bias results (<1% for the amp A) up to ~6% difference (amp C).

Table 1. Readnoise values determined from overscan pixels, in units of electrons assuming gain=1.5 e-/DN. All images were taken during the April 2007 ambient campaign.

amp	standard biases (UV01S01)		other biases		external flatfields		internal flatfields		external images	
	RN	error	RN	error	RN	error	RN	error	RN	error
A	3.12	0.01	3.13	0.01	3.14	0.1	3.14	0.05	3.12	0.03
B	3.18	0.04	3.15	0.05	3.15	0.06	3.08	0.06	3.18	0.04
C	2.84	0.02	2.84	0.02	2.87	0.08	3.00	0.05	2.83	0.04
D	3.11	0.03	3.13	0.01	3.14	0.04	3.20	0.03	3.11	0.04

Readnoise from the Science Area Pixels

Readnoise can also be measured directly from the science area pixels of bias frames. To accomplish this, the images are first processed through calwf3, performing the overscan correction (BLEVCORR) and using versions of CCDTAB and OSCNTAB generated in Mar 2005 and Nov 2003, respectively. Difference images are formed from pairs of calibrated bias frames to remove any two-dimensional structure; the readnoise is taken as the standard deviation of the science area pixels (divided by the square root of 2 to account for the differencing). To allow for bad pixels, the statistics are computed using 3 iterations of 3-sigma clipping. The results in DN are converted to electrons assuming gain=1.5 e^-/DN.

The first five columns in Table 2 below summarize the results for two groups: the full-frame biases from the standard procedure (UV01S01) and the full-frame biases taken from all other procedures (except, as mentioned earlier, for special tests like bias vs bus voltage, crosstalk, and EPER). As expected, there is excellent agreement between the results from the two different bias image groups: the readnoise is the same to within the error. The bias image science pixel area results also agree well, to 1% or better, with the bias image overscan results (Table 1).

The last two columns in Table 2 summarize the readnoise results for 200x200 pixel subarray bias images, data acquired as part of the PSF evaluation procedure (UV11). Image differences are formed from pairs of subarray biases taken in the same location in the WFC3 field of view and the readnoise measurement follows the procedure used for the full-frame biases described above. As can be seen from the table, the readnoise in the subarrays is slightly lower in amps A,B, and D (1-5%, or 0.02-0.15 e^-) and higher in amp C by about 2% (~0.04 e^-) than that measured on the full-frame biases. It was also noted that the absolute level of the subarray bias difference images fluctuated somewhat more (-0.4 DN to 1.0DN) than in the full-frame bias difference images (-0.1 to 0.1DN), likely a result of the lack of an overscan correction (subarrays typically have no overscan region).

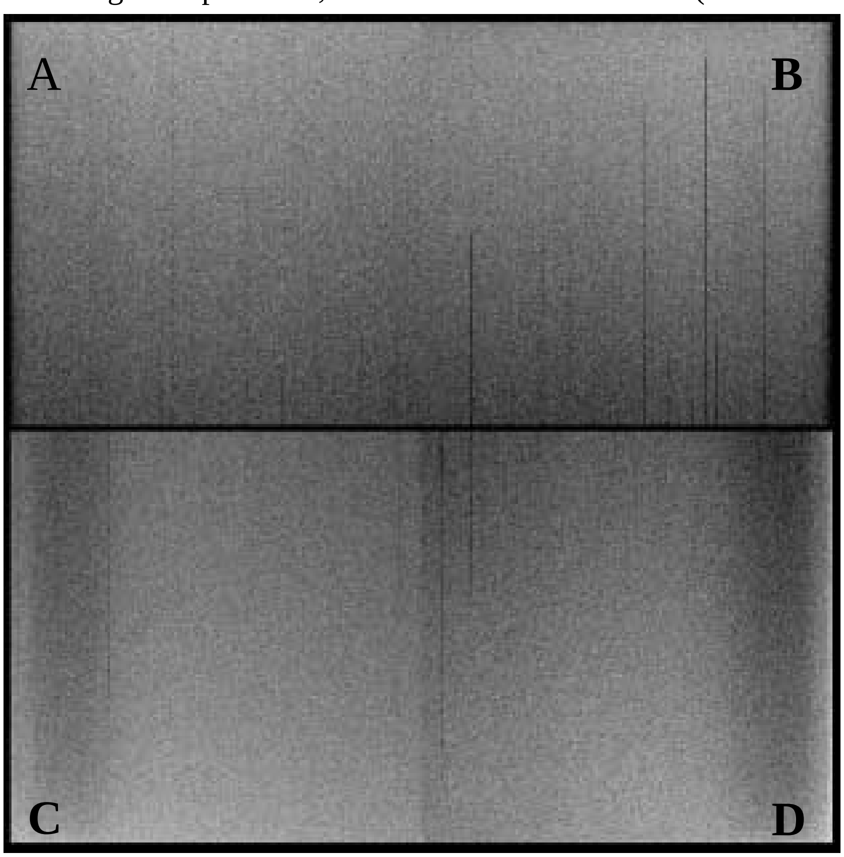
Table 2. Readnoise values determined from science pixels in April 2007 ambient campaign bias frames; units are electrons assuming gain=1.5 e-/DN.

amp	standard biases (UV01S01)		other biases		subarray biases	
	RN	error	RN	error	RN	error
A	3.14	0.01	3.14	0.01	3.07	0.04
B	3.20	0.04	3.17	0.04	3.05	0.01
C	2.88	0.02	2.87	0.02	2.92	0.02
D	3.14	0.03	3.15	0.02	3.12	0.03

Superbias File

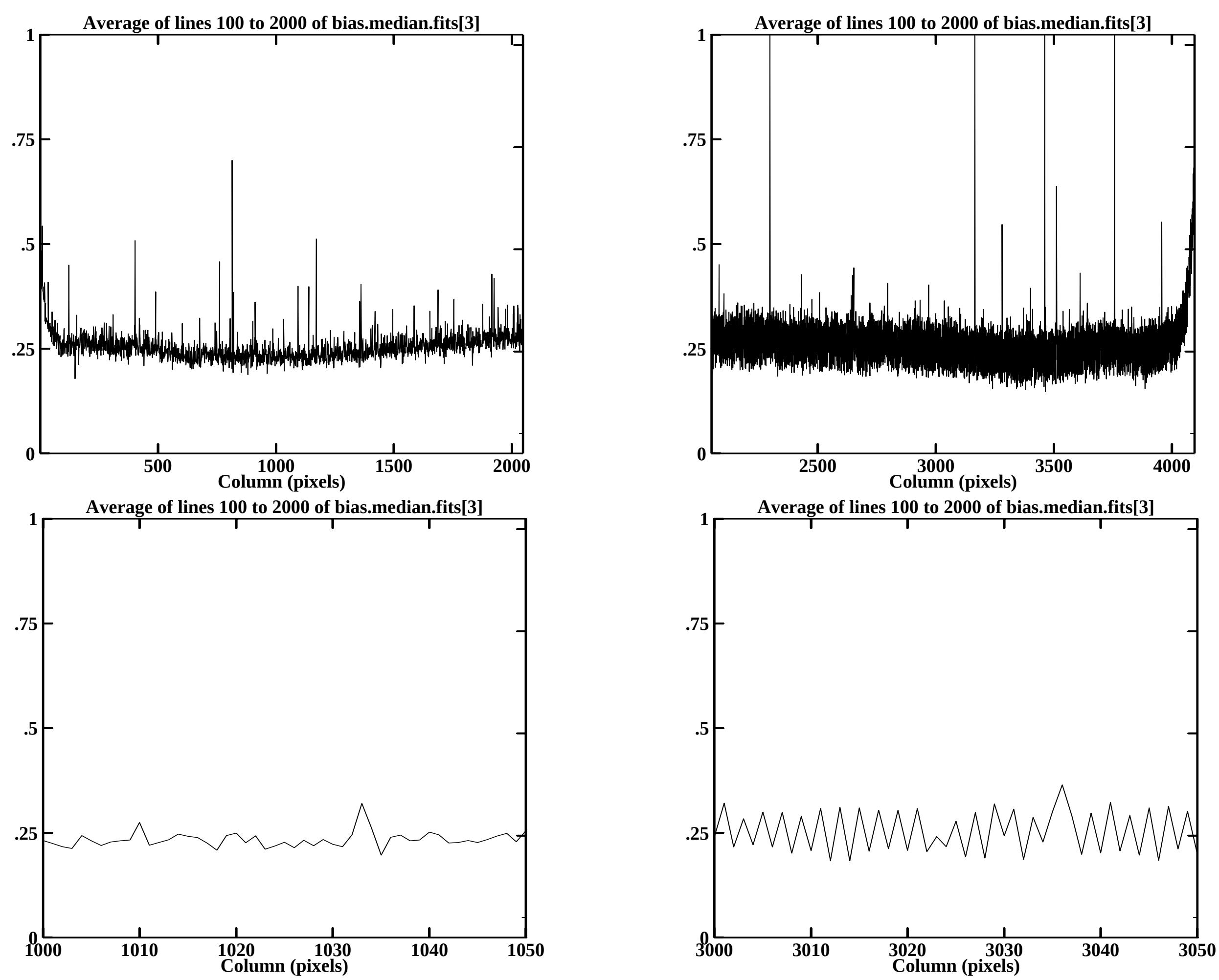
A superbias file was generated from a median of all available good, full-frame, four-amp readout, overscan-corrected biases (27 images); the result is shown in Figure 1. Quadrants A and B are relatively flat along the horizontal direction, though B shows slightly more noise than A (~0.2 e^- peak to peak in B vs <0.1 e^- in A, based upon an average of about 2000 lines). Along the vertical direction in quadrants A and B, based upon an average of ~2000 columns in each quadrant, the level at the bottom of the chip is ~0.6 e^- , dropping to ~0.2 e^- at the top. In C and D, there are two distinct 'ridges' which run parallel to, and about 300 pixels away from, the outer vertical edges. The ridges are about 500 pixels wide, with a level of 0.4-0.5 e^-, compared to the inner chip area which is at ~0.2-0.3 e^-.

Figure 1: Superbias file constructed from a stack of all good, full-frame, four-amp readout biases obtained during the April 2007, shown with inverted stretch (+2 to -1 DN).



In Figure 2, below, the higher noise in the B quadrant is illustrated via a horizontal slice (an average of ~2000 rows) taken across the image. The top plots present the count level, in DN, of the average slice as a function of column number across the entire quadrant (A on the left, B on the right) while the bottom plots presents the count level, in DN, of the average slice across just 50 columns of the A and B quadrants (left and right, respectively). The bias level in B is seen to be varying regularly, with odd-numbered columns slightly higher than the even-numbered columns (~0.2 e^- peak to peak). The low-level effect is not apparent in an image display but detectable when averaging a large number of rows. No such oscillation is visible in quadrants A, C, or D; in addition, no such variations are detectable in the vertical direction (average of a large number of columns) in any quadrant.

Figure 2: Slices through the superbias file from Figure 1. Shown is the count level in DN, based upon an average of ~2000 lines, as a function of column number across the entire A and B quadrants (top left and top right, respectively). The lower figures show a subsection of the upper figures, count level as a function of column number across 50 columns in A and B quadrants (left and right, respectively).



As mentioned earlier, the detector was operating at a relatively warm temperature (-54C) during all of ambient; once cooled to the nominal -84C, some of these bias features may be reduced or disappear. As long as any bias structures are stable over time (which was the case over the course of this short ambient test), the bias file calibration in the pipeline will be able to correct for them. If the bias level oscillations in quadrant B are found to vary over time, the calibration pipeline overscan correction algorithm could be modified to provide a correction as is done, for example, for WFPC2 images.

Conclusions

The readnoise levels in recent ambient (April 2007) data have been measured. In full-frame, four-amp bias frame readouts, the overscan pixels and science area pixels provide similar results, namely 3.1, 3.2, 2.8, and 3.2 e^- for amps A,B,C and D (errors <0.1e^-), assuming a gain of 1.5 e^-/DN. Applying the measured UVIS-2 gain values will increase these values by 3-10%, depending upon the amp. Subarray (200x200 pixel) readnoise levels were slightly different than the full frame results (0.01-0.15e^-, depending upon amp). A comparison of readnoise from the overscan region for a variety of image types showed that the results can be 1-6% (0.02 - 0.2 e^-) different - usually higher but not always - than those measured on bias frames. Finally, an evaluation of a superbias produced from a median of all good full-frame ambient biases is provided. Quadrant B is found to have slightly higher noise than the other quadrants, with the bias level systematically high for odd columns and low for even columns (~0.2 e^- peak to peak). If this effect persists in the upcoming thermal vacuum test data and is found to be time-variable, the overscan correction algorithms in the calibration pipeline could be updated to provide a column-dependent correction.

Acknowledgements

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References

Baggett, S., “WFC3 Ambient-2 Testing: UVIS Gain Results,” WFC3 Instrument Science Report WFC3-2007-11, April 2007.