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WFPC2 Flatfields with Reduced Noise

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ABSTRACT

We examine the noise contributed by the WFPC2 flatfields during normal calibration, and provide new low-noise flats for 41 filters. Highly exposed science images (>20,000 electrons per pixel) will show significant noise reduction if these new flats are used; this is especially true for images on the PC1 chip. For some ultraviolet filters a significant improvement occurs even for much lower exposure levels. Potential photometric issues are also discussed. The new flats are available in the HST data archive as "correction" images which observers can multiply into calibrated science data (i.e. data which have already calibrated with the normal flatfields) to obtain the noise reduction. These corrections may be incorporated in the normal pipeline flatfields at some future date for selected filters.

1. Introduction

The WFPC2 chips can detect more than 50,000 electrons/pixel before saturation occurs. This theoretically allows one to take images of signal-to-noise ratios near 220. When flatfielding images, the noise of the image and the noise of the flatfield are added (via the root of squares of noise). If the noise of the flatfield is much lower than the noise of the science image, flatfielding essentially preserves the signal-to-noise ratio of the image. However, if the noise of the flatfield is larger than the noise of the science image, the signal-to-noise ratio of the calibrated image is mostly limited by the flatfield. An investigation of the standard WFPC2 flatfield reference files in use at the end of the year 2000 (herein referred to as "2000-flatfields") found that a fair number of WF flatfields have less noise than the best achievable in an image, thus they are close to perfect with regard to noise. On the other hand, all PC1 flatfields and some WF flatfields (especially those in ultraviolet) are noisier than the best achievable image. Thus, improving those flatfields allows one to improve signal-to-noise ratios of calibrated images.

Improved flatfields were created by averaging flatfields of similar wavelength in such a manner that wavelength-dependent features were mostly preserved, yet the noise of the flatfield was significantly lowered. These improved flatfields are called 2001-flatfields.

The ratios of the 2001-flatfields / 2000-flatfields have been computed and are available to observers via the HST archive system. These correction flats can be multiplied into calibrated data for the purpose of reducing noise contributed by the flatfields.

As of this writing (July 2001) these corrections have not been incorporated in the automatic calibration pipeline (i.e. ‘‘On the Fly Reprocessing” system), though this may be done at some future date. Observers wishing these corrections will need to manually apply them to their data, at least for the time being.

The next section shows how flatfields can influence the quality of flatfielded images. The following section gives noise data which is important to judge if an archived image would significantly benefit from flatfielding with 2001-flatfields. Section 4 discusses application of the new correction files to science data; and Section 5 cautions that there may be a few cases where the 2001-flatfields are inferior to 2000-flatfields, or might cause photometric errors. The final section gives details on how the 2001-flatfields were created.

2. Example

Figure 1 shows images taken with the F336W filter which is one of the 10 WFPC2 filters used most often (Table 1 lists the original images, all taken on PC1). The left image column shows images before flatfielding, the middle column after flatfielding with 2000-flatfields, the right column after flatfielding with 2001-flatfields. While the middle column has some artificial features removed, the noise is still quite high. The decreased noise in the right column makes many features visible. Likewise, features in other archived WFPC2 images may have been hidden by the noise of the 2000-flatfield but may become visible by flatfielding with 2001-flatfields.

Table 1. Images used for Figure 1.

Filename	Target	Date	Program	PI
U2FI0706T	Jupiter	1994-07-15	5642	Storrs, A.
U2QE0308T	Saturn	1995-11-17	6030	Tomasko, M.
U43H0101M	Uranus	1997-07-29	7429	Tomasko, M.
U2J30301T	Neptune	1994-10-11	5329	Hammel, H.
U2IZ0101T	Titan	1994-10-04	5508	Smith, P. H

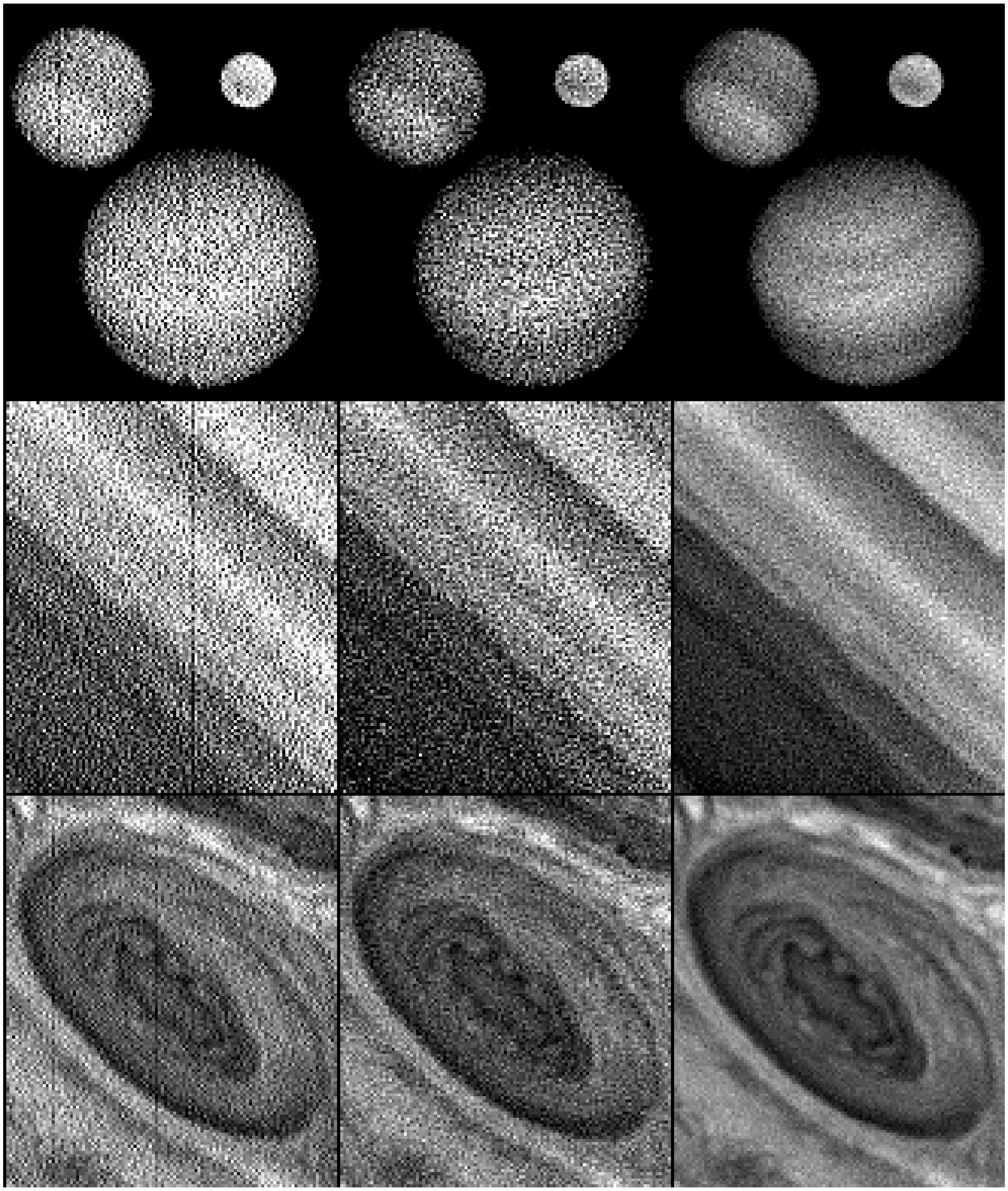

Figure 1: Sample raw images on PC1 with filter F336W (left column), flatfielded with the standard calibration pipeline (2000-flatfield, middle column), and flatfielded with 2001-flatfields (right column). All images were processed with the same high-pass filter in order to enhance small-scale features.

3. Noise Data

The noise of flatfields was estimated with a method described in Section 6.b. Figure 2 shows the estimated noise of all investigated flatfields. These data are also listed in Table 2. Images with the highest exposure levels (50,000 electrons per pixel) have a photon noise of 0.45 percent of the signal (signal-to-noise ratio 220). In order to preserve this noise in flatfielded images, the noise of the flatfield needs to be lower than 0.45 percent. For detector PC1, none of the 2000-flatfields conform with this condition but many of the 2001-flatfields have a noise less than or at least similar to 0.45 percent. The WF flatfields fare somewhat better.

In the example of Section 2, typical exposure levels were 30,000 electrons yielding a noise about 0.6 percent of the signal. The 2000-flatfield has a noise of 1.8 percent. Thus, the flatfielded images have a noise of 1.9 percent (the noise adds via the square-root of the squares), completely dominated by the noise of the flatfield. The 2001-flatfield has a noise of 0.4 percent which leads to a noise of the flatfielded images of 0.7 percent, an improvement of almost a factor of three. Even a perfect noiseless flatfield would not do much better.

We note that dithering will also tend to reduce the pattern noise contributed by flatfields in WFPC2 images, and should also be considered when deciding whether the 2001-flatfields will be beneficial.

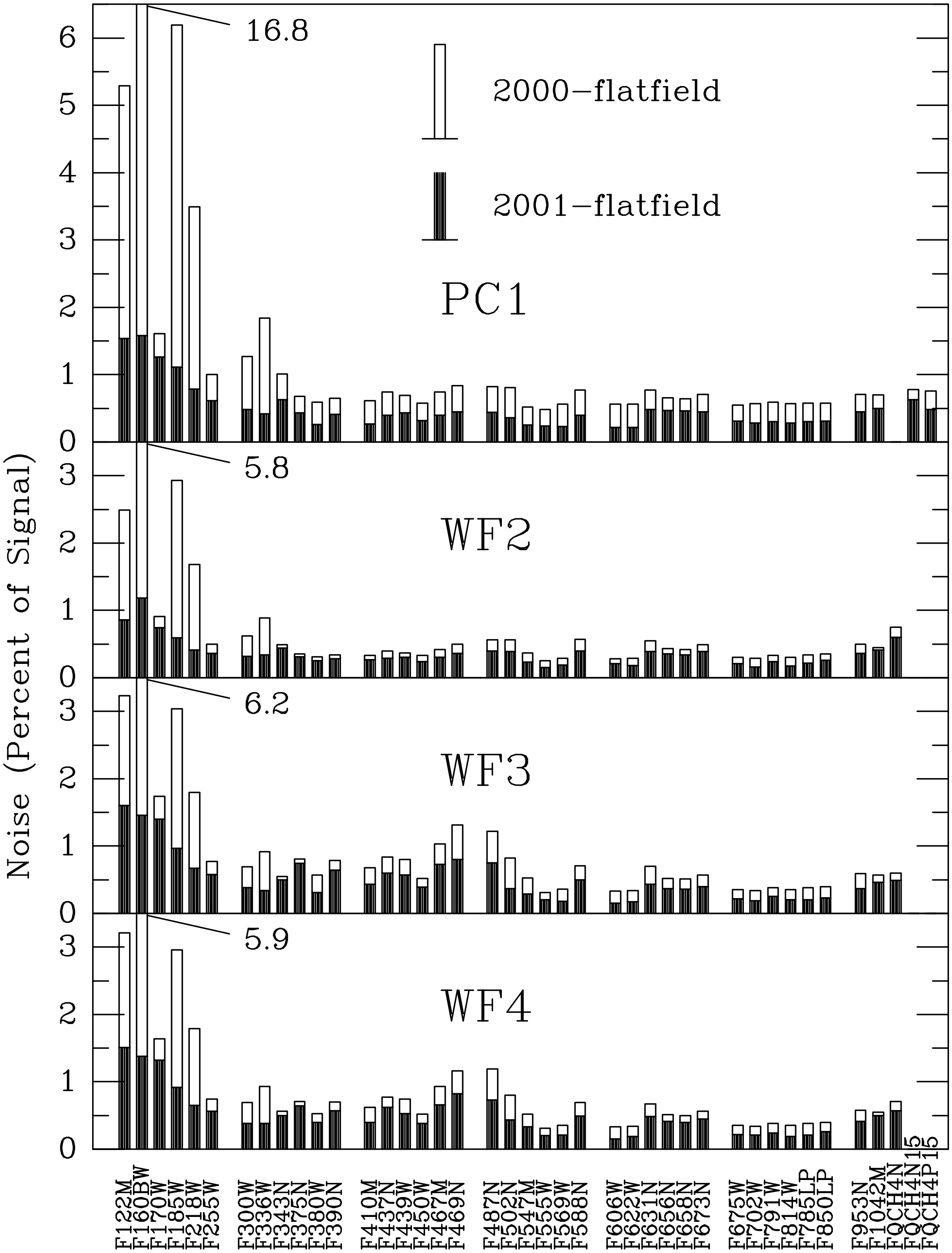

Figure 2: Noise in percent of the signal for each investigated filter and each CCD for the 2000- and 2001-flatfields.

Table 2. Noise (in percent) of flatfields for each filter and CCD.

Filter Name	Wave-length (nm)	Noise (%) for Each CCD and Flatfield Version (2000 or 2001)							
		PC1		WF2		WF3		WF4	
		2000	2001	2000	2001	2000	2001	2000	2001
F122M	170	5.29	1.54	2.49	0.86	3.23	1.60	3.21	1.51
F160BW	157	16.81	1.58	5.79	1.18	6.25	1.46	5.91	1.38
F170W	194	1.61	1.26	0.91	0.74	1.74	1.40	1.64	1.32
F185W	199	6.19	1.11	2.93	0.59	3.04	0.97	2.96	0.92
F218W	222	3.49	0.79	1.68	0.41	1.80	0.67	1.79	0.65
F255W	261	1.00	0.61	0.50	0.36	0.77	0.58	0.74	0.56
F300W	302	1.27	0.48	0.62	0.32	0.69	0.38	0.69	0.38
F336W	337	1.84	0.42	0.89	0.34	0.92	0.34	0.93	0.38
F343N	343	1.01	0.63	0.49	0.44	0.55	0.50	0.56	0.50
F375N	374	0.68	0.43	0.35	0.31	0.81	0.74	0.71	0.64
F380W	399	0.59	0.26	0.31	0.25	0.57	0.31	0.53	0.40
F390N	389	0.65	0.41	0.34	0.28	0.79	0.64	0.70	0.57
F410M	409	0.61	0.27	0.33	0.27	0.68	0.43	0.62	0.40
F437N	437	0.74	0.40	0.40	0.29	0.84	0.60	0.77	0.62
F439W	432	0.69	0.43	0.37	0.30	0.80	0.57	0.74	0.53
F450W	458	0.58	0.32	0.33	0.24	0.52	0.39	0.52	0.38
F467M	467	0.74	0.40	0.42	0.30	1.03	0.73	0.93	0.66
F469N	469	0.84	0.45	0.50	0.36	1.31	0.80	1.16	0.82
F487N	487	0.82	0.44	0.56	0.40	1.22	0.75	1.19	0.73
F502N	501	0.81	0.36	0.56	0.39	0.82	0.37	0.80	0.43
F547M	549	0.52	0.25	0.37	0.23	0.53	0.29	0.52	0.33
F555W	547	0.48	0.24	0.25	0.15	0.31	0.20	0.31	0.20
F569W	566	0.56	0.23	0.29	0.19	0.36	0.18	0.35	0.21
F588N	589	0.77	0.40	0.57	0.40	0.71	0.50	0.69	0.49
F606W	604	0.56	0.22	0.28	0.21	0.33	0.15	0.33	0.15
F622W	620	0.56	0.22	0.29	0.18	0.34	0.17	0.34	0.19
F631N	631	0.77	0.48	0.55	0.39	0.70	0.43	0.67	0.48
F656N	656	0.66	0.47	0.43	0.35	0.52	0.37	0.51	0.41
F658N	659	0.64	0.46	0.42	0.34	0.51	0.36	0.50	0.40

Filter Name	**Wave-length (nm)**	**Noise (%) for Each CCD and Flatfield Version (2000 or 2001)**							
		PC1		**WF2**		**WF3**		**WF4**	
		2000	**2001**	**2000**	**2001**	**2000**	**2001**	**2000**	**2001**
F673N	673	0.71	0.45	0.49	0.39	0.57	0.40	0.56	0.45
F675W	673	0.55	0.31	0.30	0.21	0.35	0.22	0.35	0.22
F702W	694	0.57	0.28	0.29	0.16	0.34	0.19	0.34	0.21
F791W	789	0.59	0.30	0.33	0.24	0.38	0.25	0.38	0.24
F814W	802	0.57	0.28	0.30	0.17	0.35	0.20	0.35	0.19
F785LP	871	0.58	0.30	0.34	0.22	0.38	0.20	0.38	0.21
F850LP	912	0.58	0.31	0.35	0.26	0.40	0.23	0.40	0.26
F953N	955	0.71	0.45	0.50	0.36	0.59	0.37	0.58	0.41
F1042M	1023	0.70	0.50	0.45	0.41	0.57	0.46	0.55	0.50
FQCH4N	(a)	-	-	0.75	0.60	0.60	0.49	0.71	0.57
FQCH4N15	620	0.78	0.63	-	-	-	-	-	-
FQCH4P15	892	0.76	0.48	-	-	-	-	-	-

(a) 544nm for WF2, 892nm for WF3, and 728nm for WF4

4. Correcting Science Data

The correction flats are available through the usual HST data archive interface (e.g. StarView). In the current version of StarView (v. 6.2), the correction flats may be accessed as follows:

- On **View** menu select **Retrieval**. This will create a new window in the lower panel.
- In the new window select **Add DataSets**.
- On the new pop-up menu select **By Hand**.
- Type (e.g. for F555W) **L6E1501BU** in the box and click **OK**.
- It should then display information about the file in the **StarView Retrieval / HST** window. Now click on **Submit** and proceed in the normal manner for archive requests.

The correction flats are effectively computed as the ratio 2001-flatfield / 2000-flatfield, and hence need to be multiplied into the calibrated (flatfielded) science data. The archive file root names are given in Table 3; the files have suffixes of .r6h and .r6d. These files should be multiplied into the calibrated science data (i.e. flat fielded science data) on a group-by-group (chip-by-chip) basis. For example, in IRAF the commands would be:

```
imarith data_f555.c0h[1] * l6e1501bu.r6h[1] data_f555_out.hhh[1/4]
imarith data_f555.c0h[2] * l6e1501bu.r6h[2] data_f555_out.hhh[2]
imarith data_f555.c0h[3] * l6e1501bu.r6h[3] data_f555_out.hhh[3]
imarith data_f555.c0h[4] * l6e1501bu.r6h[4] data_f555_out.hhh[4]
```

This can also be accomplished somewhat more elegantly in the STSDAS package with the command:

```
imcalc data_f555.c0h,l6e1501bu.r6h data_f555_out.hhh “im1*im2”
```

It would be advisable to first check that the flat field reference file listed in the science data header keyword FLATFILE agrees with the 2000-flatfield listed in Table 3. At some future date new flat field reference files may be delivered incorporating these corrections, and this check will help avoid the potential problem of applying the corrections twice.

Table 3. HST archive file names for new correction flats.

Filter	Old Flat (2000-flatfield)	New Correction Flat (2001-flatfield / 2000-flatfield)
F1042M	G7C1403PU	L6E1500HU
F122M	I5515213U	L6E1500IU
F160BW	I5515214U	L6E1500JU
F170W	I5515215U	L6E1500KU
F185W	I5515216U	L6E1500LU
F218W	I5515217U	L6E1500NU
F255W	I5515218U	L6E1500OU
F300W	G6409256U	L6E1500PU
F336W	G6I1148HU	L6E1500QU
F343N	G6I1148LU	L6E1500RU
F375N	G640925BU	L6E1500SU
F380W	G6I1148NU	L6E1500TU
F390N	G7C14030U	L6E15010U
F410M	G7C14034U	L6E15011U
F437N	G6I1148QU	L6E15012U
F439W	G6I1148TU	L6E15014U
F450W	G640925GU	L6E15015U
F467M	G7C14037U	L6E15016U
F469N	G6I11492U	L6E15017U
F487N	G6I11494U	L6E15018U
F502N	G640925KU	L6E15019U
F547M	G7C1403BU	L6E1501AU
F555W	G640925NU	L6E1501BU
F569W	G6H0944PU	L6E1501CU
F588N	G6H0944TU	L6E1501DU
F606W	G640925RU	L6E1501FU
F622W	G6H09453U	L6E1501GU
F631N	G6H09457U	L6E1501HU
F656N	G6H0945CU	L6E1501IU
F658N	G6H0945FU	L6E1501JU
F673N	G6H0945IU	L6E1501KU
F675W	G6H0945LU	L6E1501LU
F702W	G6Q1912HU	L6E1501MU
F785LP	G7C1403EU	L6E1501NU
F791W	G6Q1912JU	L6E1501OU
F814W	G6409260U	L6E1501QU

Filter	**Old Flat (2000-flatfield)**	**New Correction Flat (2001-flatfield / 2000-flatfield)**
`F850LP`	`G7C1403IU`	`L6E1501RU`
`F953N`	`G7C1403LU`	`L6E1501SU`
`FCH4N`	`DCE14595U`	`L6E1501TU`
`FCN15`(a)	`I5515219U`	`L6E15020U`
`FCP15`(a)	`I551521BU`	`L6E15021U`

(a) FCN15 and FCP15 correspond to FQCH4N15 and FQCH4P15, respectively.

5. Caution and Photometric Concerns

These low-noise flats were generated by averaging 2000-flatfields at nearby wavelengths. Since flatfields are wavelength dependent, averaging of flatfields of various wavelengths introduces systematic features. These features are mostly between 0.05 and 0.1 percent RMS on scales of ~10 pixels across the field of view, and thus completely negligible for most purposes. Table 4 gives the RMS dispersion of the ratio 2001-flatfield / 2000-flatfield after averaging in 10x10 pixel blocks for a few representative filters.

On smaller scales, most features are due to noise and thus improved in the 2001-flatfields. Nonetheless, most of the flats have a few 1% or 2% features with scales of a few pixels. Many of these are coincident with known features in the flats (Table 4), and hence are likely to be real, and caused by differing diffraction effects at wavelengths. Thus there may be a few localized spots where the 2001-flatfield is worse than the 2000-flatfield. These could be important if some astronomical object happened to land on one, though in general the spots are small and the risk is low. Observers are advised to examine the 2000-flatfields and correction files themselves, and consider the impact of any low-level artifacts which may be present.

On larger scales, the artifacts have even less amplitude. A few flatfields seem to have intensity slopes on the order of 1 percent from corner to corner which are reduced in the averaging process. These slopes may or may not be real, and hence the modified flatfields may be slightly better or worse on large scales.

Table 4. Peak amplitude of potential photometric artifacts for a few sample cases.

Correction Flat (2001-flatfield/ 2000-flatfield)	**Filter**	**RMS error**[(a)]	**Maximum error**[(b)]	**Notes**
L6E1500JU	F160BW	2%	40%	Spot on WF4; large errors beyond edge of circular filter.
L6E1500KU	F170W	0.07%	7%	Few pixels PC1; 2%-3% spots other CCDs.
L6E1500QU	F336W	0.3%	22%	A few scattered spots with large amplitude.
L6E15014U	F439W	0.15%	2%	Feature (2%) on WF4; others present.
L6E15019U	F502N	0.1%	2%	Many 2% features.
L6E1501BU	F555W	0.06%	2%	Feature (2%) on PC1.
L6E1501FU	F606W	0.1%	2%	Few 2% pixels on PC1.
L6E1501IU	F656N	0.1%	1.3%	Feature 1.3% on WF2.
L6E1501MU	F702W	0.05%	1.4%	Few ~1% spots on WF4.
L6E1501QU	F814W	0.06%	2%	Features (2%) on WF4.

(a) RMS dispersion in 10x10 pixel block-averaged image.
(b) Maximum amplitude of coherent feature in image (without averaging).

6. The Method

We now discuss details of creation of the new 2001-flatfield reference files.

a. Selection of filters

More than 100 unique WFPC2 filters or filter combinations have been used in archival WFPC2 images, yet the filter usage is very unequal. The 22 filters used most often make up 91 percent of the images. These 22 filters were all included in this investigation. Additionally, 19 filters were included which have been used with moderate frequency (and which also have a 2000-flatfield available). This covers 96 percent of the archival WFPC2 images. Many of the remaining filters or filter combinations do not have flatfields available (no 2000-flatfield, e.g. linear ramp filter data), and are not supported in the present work.

b. Estimation of the noise in current flatfields

A first estimation was made the following way. The seven filters closest in mean wavelength to the mean wavelength of the investigated filter were selected. Their 2000-flatfields were averaged. The 2000-flatfield of the investigated filter was divided by the mean flatfield. Then, each data number was subtracted by the mean of the data numbers of the four adjacent pixels. The mean (rms) subtracted data number divided by SQRT(1.25) (to account for the noise for the neighboring pixels) is a first estimate of the noise. Aside from the root-mean-square, the noise was also estimated with the average absolute deviation. Both techniques gave the same number within a percent or two for Gaussian noise.

This estimation is an under-estimation of the real noise because the average image is partially based on the investigated image. On the other hand, this estimation is an over-estimation of the real noise since flatfields change slightly within the wavelength range of the seven filters used. To account for both minor flaws, the noise vectors were compared. Noise vectors are vectors in a space of 640,000 dimensions (the number of pixels per frame) where the coordinate in each dimension is the deviation in data number due to noise. Because noise is uncorrelated, for any pair of noise vectors the vectors are perpendicular to each other. The noise vectors calculated with the first estimation were not quite perpendicular to each other. Thus, they were modified by the minimal amount to make them perpendicular. This changes their lengths slightly which gives improved estimations of noise. This resulting noise is expected to be accurate to about 20 percent which is sufficient for most purposes.

c. Creation of new flatfields

New flatfields were calculated by adding 10 (not necessarily different) 2000-flatfields and dividing the result by 10. Typically, five or more of the summed flatfields were the flatfield of the same filter, while the other contributions came from flatfields of filters of similar wavelengths. This produces a flatfield similar to the original one but with reduced noise. The noise of the resulting flatfield follows straight forward from the previous noise data via the sum of variances since different flatfields have uncorrelated noise. The contributions are listed in Table 5. The count level in the resulting 2001-flatfield was normalized to the original count level by averaging the whole frame with pixels near the center weighted most. The weight of each pixel was set proportional to the product of the four distances to the edges of the CCD or aperture edges. The magnitude of the change in data numbers was reduced near the edges of the illuminated field of view since the actual edges vary slightly from filter to filter.

Example: "ACCCCCCCCC" for F122M and PC1 in Table 5 means that the 2001-flatfield for the F122M filter on PC1 was calculated by adding 1/10 of the 2000-flatfield of F122M (ID=A) and 9/10 of the 2000-flatfield of F170W (ID=C). Rootnames refer to the 2000-flatfields.

A few flatfields required extra modifications:

1) F160BW: Because of the high noise of 2000-flatfields, they were first passed through a low pass filter averaging the nine pixels of the 3x3 pixels centered on each pixel. Furthermore, the resulting flatfield for the PC1 had a slightly different data number slope than the original one. Thus, the resulting flatfield was modified so the slope would not be changed. The WF flatfields display a radial intensity slope due to the reduced physical size of the filter. This slope was estimated so that the resulting flatfield has very similar radial intensity distribution. Flatfields WF2 and WF3 contain a feature of about 4 percent intensity which seems to be due to a red leak. The new flatfields show this feature at half of its original intensity.

Note that it was previously recommended to use the flatfield of F255W for the PC1 portion of the F160BW flatfield. It may still be useful to do this and compare the results against those obtained with the F160BW flat and its correction image given herein. The original F160BW flat contains a few hundred pixels with very large or small values (>factor 5 deviation) which are caused by hotpixels and charge traps in the original images used to produce the flat. The correction image given herein (while making a significant improvement) has been clipped to avoid excessive corrections, hence it may not fully correct the most discrepant pixels, and may leave a few errant or pixels scattered across the image.

2) FQCH4N: This is a quad filter comprised of four narrow band filter glasses with different central wavelengths. Three of the four filter quads cover part of the three WF CCDs. The flatfield was only improved in the fully illuminated area. This filter seems to have spatial transmission variations. Thus, intensity slopes were applied to the resulting flatfields so that the general intensity distribution would be very similar to the original flatfield. [This filter will be further investigated as part of the Cycle 10 calibration program.]

3) FQCH4N15 and FQCH4P15: 2001-flatfields were created only for the PC1 detector (which is the aperture location for these filters). The resulting flatfields needed a slight adjustment of the intensity slope to closely match the general intensity distribution of the original 2000-flatfields.

Table 5. Contributions for Averaging Flatfields.

Filter	2000-Flatfield	ID	PC1	WF2	WF3	WF4
F122M	I5515213U	A	ACCCCCCCCC	ACCCCCCCCC	ACCCCCCCCC	ACCCCCCCCC
F160BW	I5515214U	B	BCCCCCCCCC	BBBBBCCCCC	BBBBBCCCCC	BBBBBCCCCC
F170W	I5515215U	C	ACCCCCCCFF	CCCCCCCCFF	CCCCCCCCFF	CCCCCCCCFF
F185W	I5515216U	D	CCCCCDEFFF	CCCCCDEFFF	CCCCCDEFFF	CCCCCDEFFF
F218W	I5515217U	E	CCCEFFFFFG	CCCEFFFFFG	CCCEFFFFFG	CCCEFFFFFG
F255W	I5515218U	F	CCFFFFFGKM	CCFFFFFFGK	CCFFFFFFGK	CCFFFFFFGK
F300W	G6409256U	G	CFFFGGHKMO	FFGGGGHHMO	CFFGGGHHMO	FFGGGGHHMO
F336W	G6I1148HU	H	FFFGHKKMMO	FGGGHHHMMO	FFGGGHHKMO	FGGGHHHMMO
F343N	G6I1148LU	I	FGIIIIIIJK	IIIIIIIIIK	IIIIIIIIIK	IIIIIIIIIK
F375N	G640925BU	J	IJJJJJJKLM	JJJJJJJJJK	JJJJJJJJJK	JJJJJJJJJK
F380W	G6I1148NU	K	JKKKLMMOPQ	KKKKKKKKMP	KKKKLMMOPQ	KKKKKKKMMO
F390N	G7C14030U	L	JKLLLLLLMO	KLLLLLLLLO	KLLLLLLLLO	KLLLLLLLLM
F410M	G7C14034U	M	KKLMMMNOPQ	MMMMMMMMOP	KMMMMMMOPQ	KKMMMMMMOP
F437N	G6I1148QU	N	KMNNNNNOPQ	KNNNNNNNPQ	KNNNNNNNPQ	NNNNNNNNPQ
F439W	G6I1148TU	O	KMOOOOOOPV	MOOOOOOOOP	MOOOOOOOPV	MOOOOOOOPV
F450W	G640925GU	P	KMPPPPPQVW	MPPPPPPPQV	MPPPPPPPQV	MPPPPPPPQV
F467M	G7C14037U	Q	MPPQQQQQVW	MPQQQQQQQV	PQQQQQQQVW	PQQQQQQQVW
F469N	G6I11492U	R	PPQRRRRRVW	PQRRRRRRRV	PQRRRRRRVW	PQRRRRRRRV
F487N	G6I11494U	S	PPQSSSSSVW	PQSSSSSSSV	PPQSSSSSSV	PPQSSSSSSV
F502N	G640925KU	T	PPQTTTTUVW	PQTTTTTTTV	PPQTTTTUVW	PPQTTTTTUV
F547M	G7C1403BU	U	PQUUUUVWYZ	QUUUUUUVWY	QUUUUUVWYZ	QUUUUUUVWY
F555W	G640925NU	V	PQUVVVVWYZ	QUVVVVVWYZ	QUVVVVVWYZ	QUVVVVVWYZ
F569W	G6H0944PU	W	PUVVWWYYZZ	QVWWWWWWYZ	UVVWWWWYYZ	QVWWWWWYYZ
F588N	G6H0944TU	X	UVWXXXXXYZ	UWXXXXXXXY	VWXXXXXXXY	VWXXXXXXXY
F606W	G640925RU	Y	UVWWYYZZef	WYYYYYYYZe	VWWYYYZZef	VWWYYYZZef
F622W	G6H09453U	Z	UVWYZZeeff	WYZZZZZZef	VWYZZZZeef	VWYZZZZZef
F631N	G6H09457U	a	YZaaaaaaef	YZaaaaaaae	YZaaaaaaef	YZaaaaaaae
F656N	G6H0945CU	b	Zbbbbbbbef	Zbbbbbbbbe	Zbbbbbbbef	Zbbbbbbbbe
F658N	G6H0945FU	c	Zcccccccef	Zcccccccce	Zcccccccef	Zcccccccce
F673N	G6H0945IU	d	Zddddddeef	Zdddddddde	Zdddddddef	Zdddddddde
F675W	G6H0945LU	e	YZeeeeeffg	YZeeeeeeef	YZeeeeeefg	YZeeeeeefg
F702W	G6Q1912HU	f	YZeeffffgh	YZefffffgh	YZefffffgh	Zeffffffgh
F791W	G6Q1912JU	g	efgggghhii	fggggggghi	fgggggghhi	fgggggghhi
F814W	G6409260U	h	efghhhhiij	efghhhhhij	efghhhhhij	efghhhhhij
F785LP	G7C1403EU	i	gghhiiijjj	ghhiiiiiij	gghhiiijjj	ghhiiiijjj
F850LP	G7C1403IU	j	ghiiijjjjl	hiijjjjjjj	ghiijjjjjl	hiijjjjjjl
F953N	G7C1403LU	k	ijjkkkkkkl	ijjkkkkkkk	ijjkkkkkkl	ijjkkkkkkk
F1042M	G7C1403PU	l	ijklllllll	jlllllllll	ijllllllll	jlllllllll
FQCH4N	DCE14595U	m	mmmmmmmmmm	ijmmmmmmmm	ijmmmmmmmm	ijmmmmmmmm
FQCH4N15	I5515219U	n	YZnnnnnnnn	nnnnnnnnnn	nnnnnnnnnn	nnnnnnnnnn
FQCH4P15	I551521BU	o	iijjoooooo	oooooooooo	oooooooooo	oooooooooo

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8. References

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