

NICMOS SAA Contour Test: Results from SMOV data.

Doris Daou and Daniela Calzetti
December 31, 1997

ABSTRACT

This Instrument Science Report presents the results of the analysis of the South Atlantic Anomaly (SAA) contour test executed in June 1997 during SMOV. The goal of the test is to determine the optimal SAA limits for the NICMOS detectors operations, and the orbital radiation effects on the NICMOS dark current during passages and when coming out of the SAA. The data show that the most external SAA contour (Model 5) is the most appropriate for NICMOS science operations; inside the contour there is a steep increase in the number of pixels affected by cosmic rays (CRs), by factors in the range 5 to 40. CR counts go back to nominal within 4 minutes of leaving the contour defined by Model 5. If the NICMOS detectors are kept on and reading during SAA crossings, the average dark counts do not show variations before and after the crossing. However, in one SAA passage the detectors were switched off, and in this case the average dark counts measured after leaving the SAA show the post-SAA pedestal effect, namely the exponentially decreasing trend already observed in other NICMOS dark frames. These results suggest to: 1. keep the NICMOS detectors on as much as possible; 2. determine a new SAA contour intermediate between Model 5 and the inner Model 2, for the purpose of reducing the effects of the post-SAA pedestal. NICMOS science operations should still be performed only outside the current SAA Model 5.

1. Introduction

The Hubble Space Telescope traverses the South Atlantic Anomaly (SAA) every 8-9 orbits, implying 5-6 passages a day. During these passages, the NICMOS detectors have been found to be flooded with cosmic ray hits: a rate of about 10 cosmic rays per second, a factor of 5 or higher above the standard rate of 1.2-1.6 events/Camera/second, (ISR NICMOS-97-022, equivalent to a number of CR-affected pixels of 2-3 pixels/Camera/second).

During the early days of the instrument's on-orbit life, NICMOS has incurred a few SEUs (Single Event Upsets) while crossing the innermost regions of the SAA (Model 2, cf. <http://www.sesd.stsci.edu/et/seu/seu.html>), which have led to the suspend of the instrument. In order to avoid the repeat of such suspends, the current operational procedure (called SAA-OPER) requires to turn OFF the NICMOS detectors during the SAA passages.

However, recent studies in the NICMOS group have uncovered a link between the NICMOS DC pedestal and the "switching off/on" of the instrument in connection with SAA crossings. In particular, one of the two components of the DC Pedestal is a function of the time since the detector was switched on following a SAA-OPER mode. This component shows up as elevated dark counts, has large amplitude (up to ~100 DN), a long decaying time (~ 20-30 minutes). For comparison, the other component is a transient with short timescale (decaying time of ~ 2 minutes), small amplitude (~ 3-10 DN), and which shows up at the beginning of each orbit (C.J. Skinner and L.E. Bergeron 1997). The physical cause of the long timescale transient is still under investigation, the two possibilities being thermal instability induced by the SAA-OPER switch-off, or persistence from CRs due to the flooding the switched-off detectors receive while in the SAA. Whichever the physical interpretation, we will see below that switching off the detectors is the main culprit of the post-SAA pedestal.

Thus, the full characterization of the radiation effects on the NICMOS detectors during SAA crossings has become a pressing issue. For this purpose, data from the SMOV program 7036, which were obtained during SAA crossings, are here analyzed to understand the impact of CRs on the NICMOS dark current and science operations. The objective of this study is to investigate the possibility to maximize the "detector-on" status for NICMOS to mitigate the post-SAA pedestal effect.

2. Analysis

The data

This test (prop-id 7036) was executed in June 1997, as part of the Servicing Mission Orbital Verification (SMOV). The data are multiple, contiguous dark frames of 2 minutes each, taken in 3 stages during 3 independent passes through the SAA at different contour positions (Figures 1 and 2).

The first two passes were inside the SAA outer contour Model 5, but outside the inner contour Model 2 ("diamonds" and "plus" symbols in Figures 1 and 2). The two contours identify roughly two levels of CR intensity, with Models 2 having the highest level. 19 contiguous dark frames were obtained with NICMOS Camera 3 during each of the two passages. Each exposure was performed with the MULTIACCUM mode, the sample sequence set to STEP8, NSAMP=20 and an exposure time of about 2 minutes. Each SAA

passage lasted about 20 minutes, and an additional 20 minutes (10 before and 10 after the SAA contour 5) was accounted for reference exposures outside contour Model 5.

The third pass was designed to have NICMOS coming out of Model 2 and out of SAA-OPER. The dark frames were obtained as soon as the detector was back on again, which happened when the telescope was already outside Model 5 (“square” symbols in Figures 1 and 2). 12 contiguous dark frames of 2 minutes each were taken with MULTIACCUM, STEP8 and NSAMP=20.

The Method

The detection of CR events was performed with the NICMOS data reduction software CALNICA. The rejection threshold for counting CR-affected pixels was set to two different values: $T_{\sigma}=5\sigma$ and $T_{\sigma}=8\sigma$. The first frame of each set was discarded from the computation of the mean dark counts, because it is affected by the “short time scale” pedestal effect, which implies an increased dark rate of about 15-20% relative to the average. Results for both thresholds are analyzed and compared in the following section.

CALNICA implements a very straightforward CR rejection routine. First, a mean countrate for each pixel is calculated by fitting a straight line to a list of counts vs exposure time data pairs using a simple linear regression. Data pairs are comprised of a list of exposure times corresponding to each readout and the number of counts (DN) recorded at each of those exposure times. The error estimates for each count value is used in the linear regression routine to apply relative weights for each point, and to estimate an uncertainty in the computed countrate. It is worth mentioning that bad pixels (e.g. hot/cold pixels, saturated) are not used in the fit. Once the initial fit is performed, the distance (sigma) of each input count value from the fit is computed. These sigmas are analyzed to identify cosmic ray hits. This process is then iterated until no new samples are rejected.

Figure 3 shows examples of two dark frames: one obtained outside Model 5 and the other inside Model 5. The difference in the number of CR-affected pixels is striking.

Figure 1: (Below) The positions of the dark frames with respect to the SAA contour Model 5 are shown. For each passage, the frames are ordered from West to East. DIAMONDS represents the first pass, PLUS symbols the second and SQUARES the third. All exposures were obtained with NICMOS Camera 3, MULTIACCUM mode, STEP8 samp sequence and NSAMP=20. The exposure time of each is 120 seconds. All exposures were consecutive with no break in continuity.

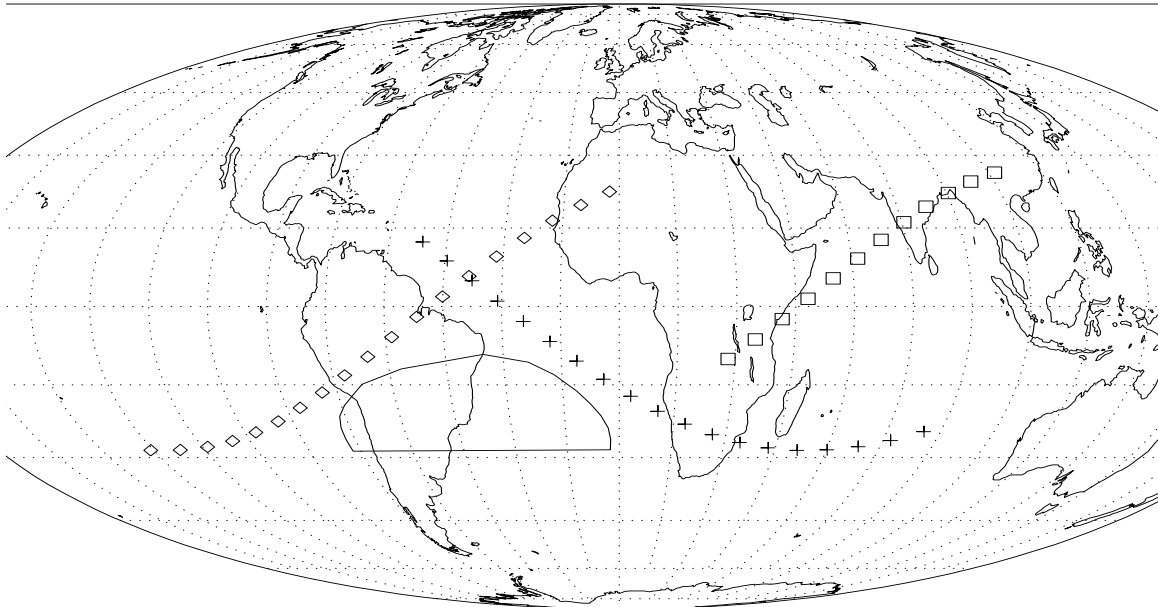
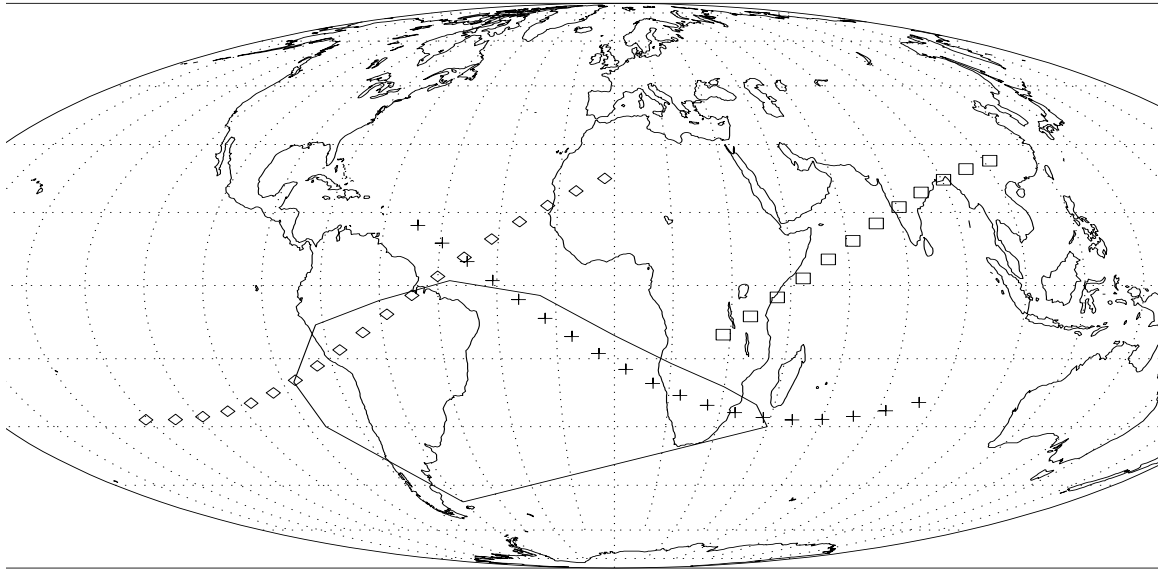


Figure 2: (Above) The same as figure 1, showing the dark frame positions with respect to the SAA contour Model 2.

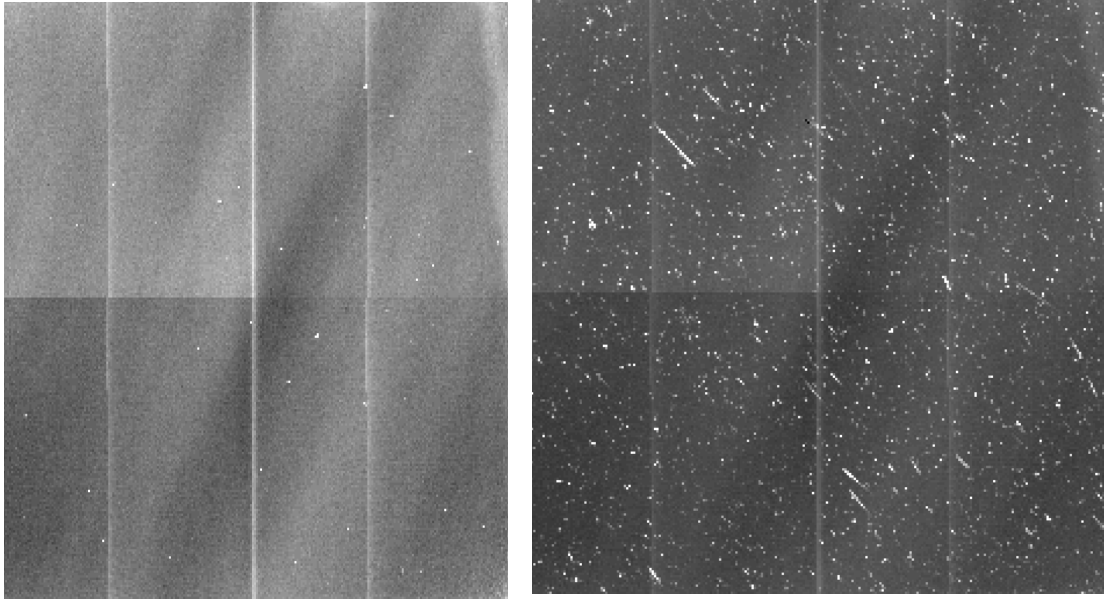


Figure 3: A NIC3 dark frame exposed for 120 seconds is shown for an exposure outside (left) contour 5 and inside (right) contour 5. There are about 10000 CR affected pixels in the right panel. In the dark outside (left panel), there are about a 100 CR affected pixels.

3. Results and Discussion

Cosmic Rays inside the SAA

Figures 4 and 5 plot of the number of pixels affected by CR hits as a function of the exposure number, for the two different thresholds, 5σ and 8σ . For each of the three SAA passes, the exposures are ordered from West to East (cf. Figure 1). The symbols used in Figures 4 and 5 and the same as Figure 1, where “diamond” and “plus” symbols identify the crossings through Model 5 and the “square” symbols identify the passage out of Model 2.

The two rejection thresholds exhibit similar patterns and the number of CR-affected pixels does not show a major increase by lowering the threshold from 8σ to 5σ . The maximum increase in the number of CR-affected pixels as a function of threshold is about 10%.

The two passes inside Model 5 show the expected increase in the number of CR affected pixels relative to nominal values. More in detail: for each passage, the number of CR-affected pixels is nominal for the first 5-6 frames (while the telescope is still outside Model 5), increases by a factor 5 to 40, depending on the orbital position, for the subse-

quent 8-10 frames (when the telescope is inside Model 5), and decreases again in the final 4-5 frames (when the telescope exits Model 5). In the worst case, i.e. the middle of the passage over South America, where the telescope is well inside Model 5 and the closest to Model 2 (see the “diamond” symbols in figures 4 and 5), about 1/6 of the chip is covered with hits. In both passes the number of CR-affected pixels goes down back to nominal values (about 300 pixels, equivalent to a rate of 2.5 pixels/second) WITHIN 4 minutes of leaving Model 5. The two passes, while qualitatively similar, are quantitatively different in their behavior inside the SAA; we attribute this difference to the temporal variations of the position of the SAA contour Model 5.

The third orbit, the one which lies totally outside the SAA, shows a relatively small number of pixels affected by cosmic ray hits (about 2-3 pixels/second), well within the standards already established, and with no measurable variations as a function of orbital position.

Effects on the Dark Counts

Figure 6 shows the average dark counts of each frame as a function of exposure number. The first frame has been removed from each set, because of the elevated counts due to the short timescale pedestal.

Again, the two passes inside Model 5 exhibit similar behavior. Variations in the average dark counts are observed only while the instrument is well inside the SAA; no variations are observed before and after the SAA crossing. Normal (pre-crossing) dark count levels are recovered upon exiting the contour Model 5. Thus, passages inside the SAA Model 5 do not leave CR persistence (in the form of elevated dark counts) on the NICMOS detectors if the latter are ON and reading.

The third pass, out of Model 2, exhibits the typical behavior of the post-SAA pedestal, with elevated average dark counts which are undergoing exponential decrease. It should be remembered that this pass was the only one of the three where the NICMOS detectors had been switched OFF during the SAA crossing. This was also the only pass through Model 2.

4. Conclusions

The passages into the SAA are clearly registered as an increase by many factors (many tens) of the CR-affected pixels. This implies that:

science operations can be performed only when NICMOS is outside the SAA Model 5.

CR hits during SAA (Model 5) crossings do not leave residuals in the NICMOS dark counts and the number of CR-affected pixels goes back to nominal within 4-5 minutes of

Figure 4: This figure shows the number of pixels affected by CR hits with rejection threshold set to 5σ . Symbols are as in Figure 1: DIAMONDS represents the first pass, PLUS symbols the second and SQUARES the third.

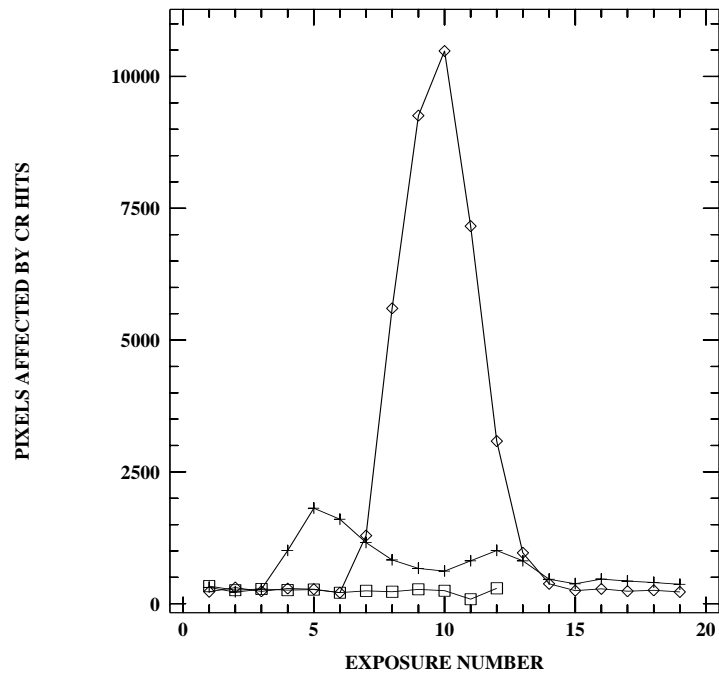


Figure 5: This figure shows the number of pixels affected by CR hits with rejection threshold set to 8σ . Symbols are as in Figure 4.

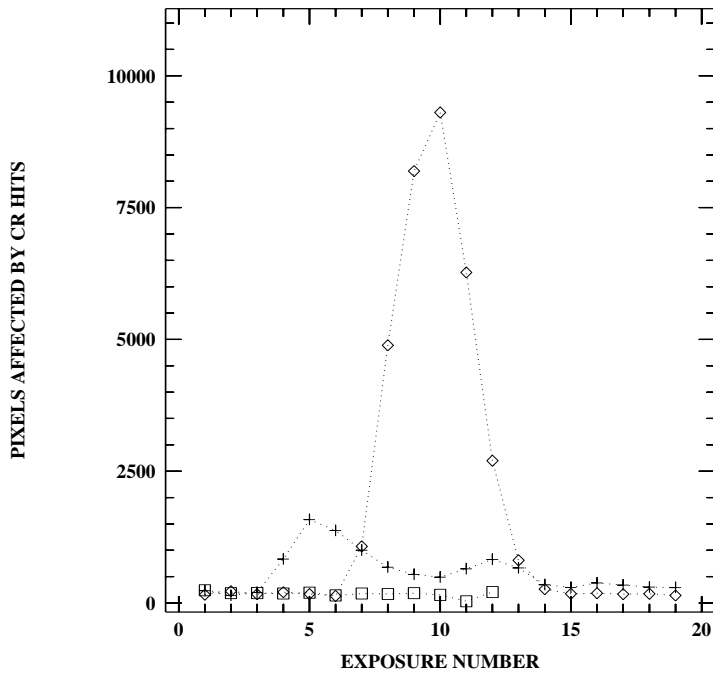
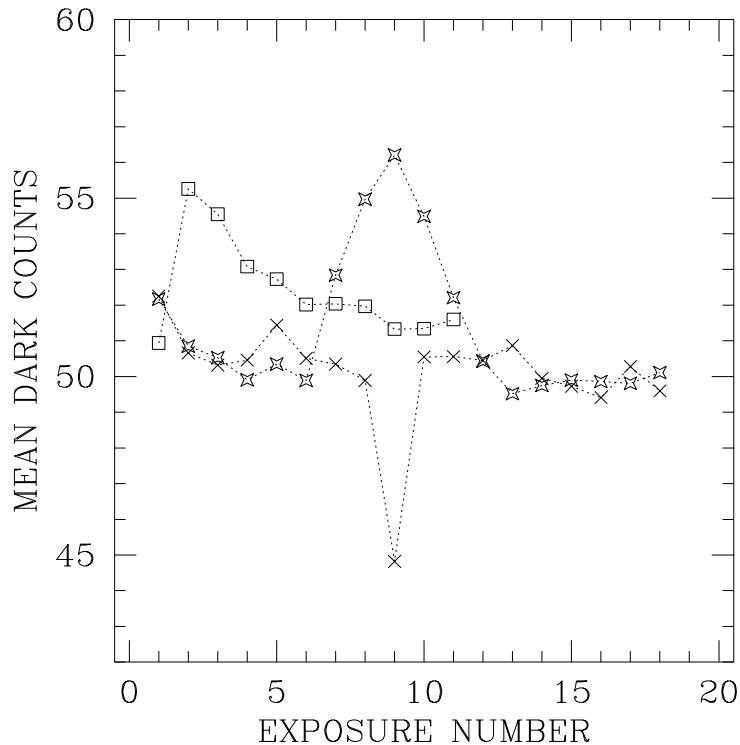


Figure 6: Behavior of the mean dark counts as a function of exposure number for the three SAA passages. Again, the open SQUARES indicate the exposures obtained out of Model 2.



exiting the SAA Model 5, if the detectors are kept ON and reading. Switching off the detectors during the SAA passage (or, possibly, a combination of the switch-off and the deep SAA crossing into Model 2) leaves an exponentially decreasing residual, namely the post-SAA pedestal. These results suggest to:

keep the NICMOS detectors on as much as possible, to reduce the post-SAA pedestal;

this could be achieved by having a SAA-triggered (rather than observation-triggered) SAA-OPER mode. In addition, since the NICMOS detectors do not appear susceptible to dark current variations during passages into Model 5, and since all the SEUs happened inside Model 2, the determination of a new SAA contour intermediate between Model 5 and the inner Model 2 deserves further investigation. In those cases where the detectors need to be switched off (e.g., deep passages into the SAA), a stabilizing period of about 15-20 minutes after switch-on is advisable before resuming science operations.

5. Acknowledgments

Daniela Calzetti gratefully acknowledges George Chapman for his invaluable help in crafting and scheduling the observations of the SMOV program 7036.