# Long Term and Short Term Variations of NICMOS Foci

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**ABSTRACT**

We present the results of the NICMOS focus monitoring program and discuss long term focus variations due to ongoing deformation processes within NICMOS, short term variations due to HST "breathing" effects, and focus spatial variations across NICMOS fields of view.

## 1. Introduction

The NICMOS cameras were designed to share a common focus whose position can be adjusted using the Pupil Alignment Mechanism, or PAM. PAM's main part is an adjustable mirror which can be moved within +/- 10 mm about its zero position, thus allowing fine tuning of the actual location of the focus. It was hoped that, whatever changes to the HST optical path may happen, the focus can always be brought back to the position of the detectors. Unfortunately, the unforeseen deformation of the NICMOS dewar has caused large mechanical distortions within NICMOS, which resulted in loss of a common focus for the three cameras. Worst of all, the camera 3 detector was pushed way out of the range within which the PAM can adjust the focus position. Soon after the Servicing Mission, this detector required a PAM position of about -17 mm to be in focus, which was far beyond the reach of the PAM (see Burrows 1997 for more extensive discussion of the issue).

The ongoing deformation processes in NICMOS keep changing the location of the detectors with respect to the PAM zero position. This necessitates checking the NICMOS camera foci on a regular basis so as to ensure timely adjustments of PAM nominal settings if required. To this end a special focus monitoring program observers biweekly a stellar field of the open cluster NGC 3603, and the data are analyzed to retrieve the current focus position.

## 2. Long term focus variations

The results of long term focus monitoring as of January 3, 1998 are presented in Figure 1. The abscissa is the day of observation (day number starting January 1st, 1997). The ordinate gives the position that the PAM should have to get the focus at the location of the detector (implied PAM

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position, often referred to as focus position in the PAM space). It is obtained using three different techniques based on phase retrieval, encircled energy, and plate scale measurements, respectively. Phase retrieval provides absolute value for the focus position. The method was developed by Krist & Burrows (1995) and expanded lately by Krist & Hook (1997b) to incorporate the NICMOS cameras. Encircled energy and plate scale provide independent focus measurements, which allows double-checking phase retrieval results.

Inspection of Figure 1 suggests that NIC 3 focus gradually moved up over the last half a year and currently is about 2.5 mm from the reach of PAM. NIC 1 and NIC2 did not show any systematic change in focus position. The last two points of the focus curves of all three cameras suggest a dramatic focus change occurred after December 1. This is believed to be associated with the change in FOM (Field Offset Mirror) setting made prior to the last two focus measurements. The change was made for January '98 NICMOS 3 campaign.

## 3. Focus variations on the orbital time scale

Alongside with long term focus variations displayed in Figure 1 there are short term variations which potentially may impact photometry. They occur on the HST orbital time scale and are caused by changing HST thermal conditions as the spacecraft moves from night to day and back to night. The resulting effect is known as "breathing" (see Suchkov and Casertano 1997 for the details of this effect and its impact on photometry). The NICMOS focus monitoring data provide a unique data set to quantify focus breathing and assess its impact on photometry. In Figure 2 we display the correlation between the measured focus position for camera 1 and a "breathing" parameter derived from telescope temperature data. Large value of the correlation coefficient leaves no doubt that focus follows the telescope temperature variations. It is also obvious that the breathing model which converts temperature variations to focus change is not ideal: if it were, the slope of correlation would have been 1, which is not the case. This makes the application of breathing corrections to focus data a tricky task. Fortunately, the magnitude of breathing is typically less than $\pm 0.5$ mm in PAM space over the orbital period as measured from phase retrieval. It may probably be important only for high-precision small aperture photometry, especially in cases when the detector is out of the best focus position.

## 4. Focus variations across detectors' field of view

Along with temporal variations, the NICMOS foci have been found to vary spatially across detectors' field of view. The observers doing high-precision photometry may need to be aware of this effect to better assess the accuracy of their photometry and be able to correct for it. To quantify focus positional dependence in all three cameras, we used focus measurements from phase retrieval for all suitable stars in a set of different frames. Thus we were able to restore the two-dimensional geometry of focus field variations from different sets of independent data by fitting a two-dimensional polynomial to focus values across the detector field of view. Figure 3 illustrates such a fit. It was obtained for a particular data set using multiple quadratic regression in $x$ and $y$. In all panels, the fitting surface has been plotted in the same scale to allow straightforward comparison of the amount of focus deviations from the focal plane for all detectors. Focus position is measured in millimeters of PAM space, with an arbitrary zero chosen so as to ensure better viewing.

It was found that camera 2 has the largest range of focus variation, of about 1.5 mm. Comparable focus abberations were found for camera 3. Less dramatic field variations are present in camera 1. These results are consistent with earlier results obtained by Krist 1997 from different data sets.

The results from phase retrieval have been found to be also consistent with independent focus measurements from encircled energy. Figure 4 gives grey scale representation of focus variation across the NIC2 field of view which has been obtained from encircled energy measurements for 630 stellar images in the focus monitoring data. One can see that both Figure 3 and Figure 4 are suggestive of the same mainly top-to-bottom geometry of focus variation across the NIC2 detector field of view, with peak-to-peak focus difference of about 1.5 mm (in PAM space).

In an independent study, Krist & Hook (1997a) have estimated the impact of spatial focus variations on aperture photometry for all three cameras. They have incorporated the focus positional dependence into the *Tiny Tim* software, so the observers can now use *Tiny Tim* to simulate the corresponding NICMOS PSFs variations across detectors' field of view.

## REFERENCES

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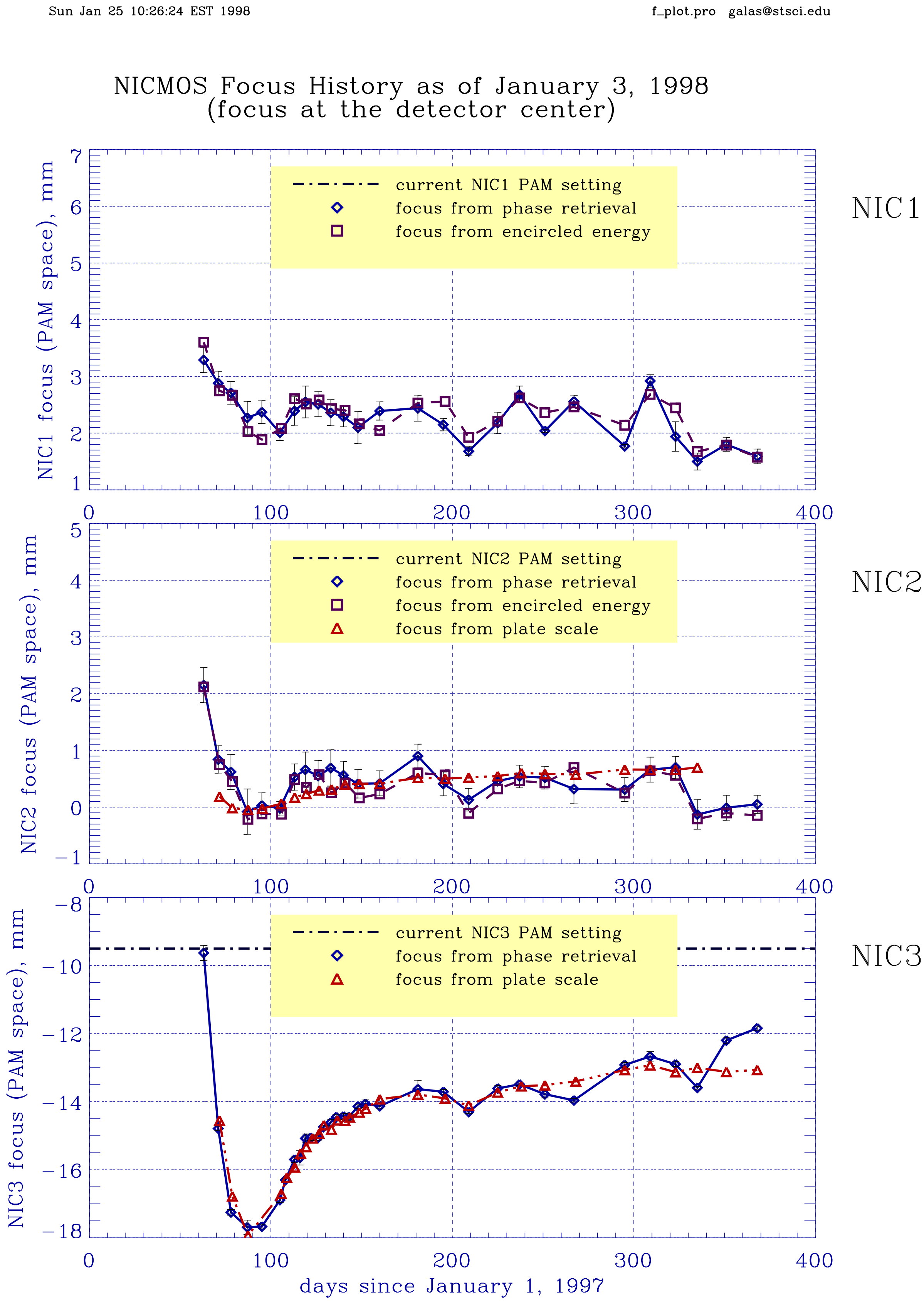


Fig. 1.— NICMOS focus history

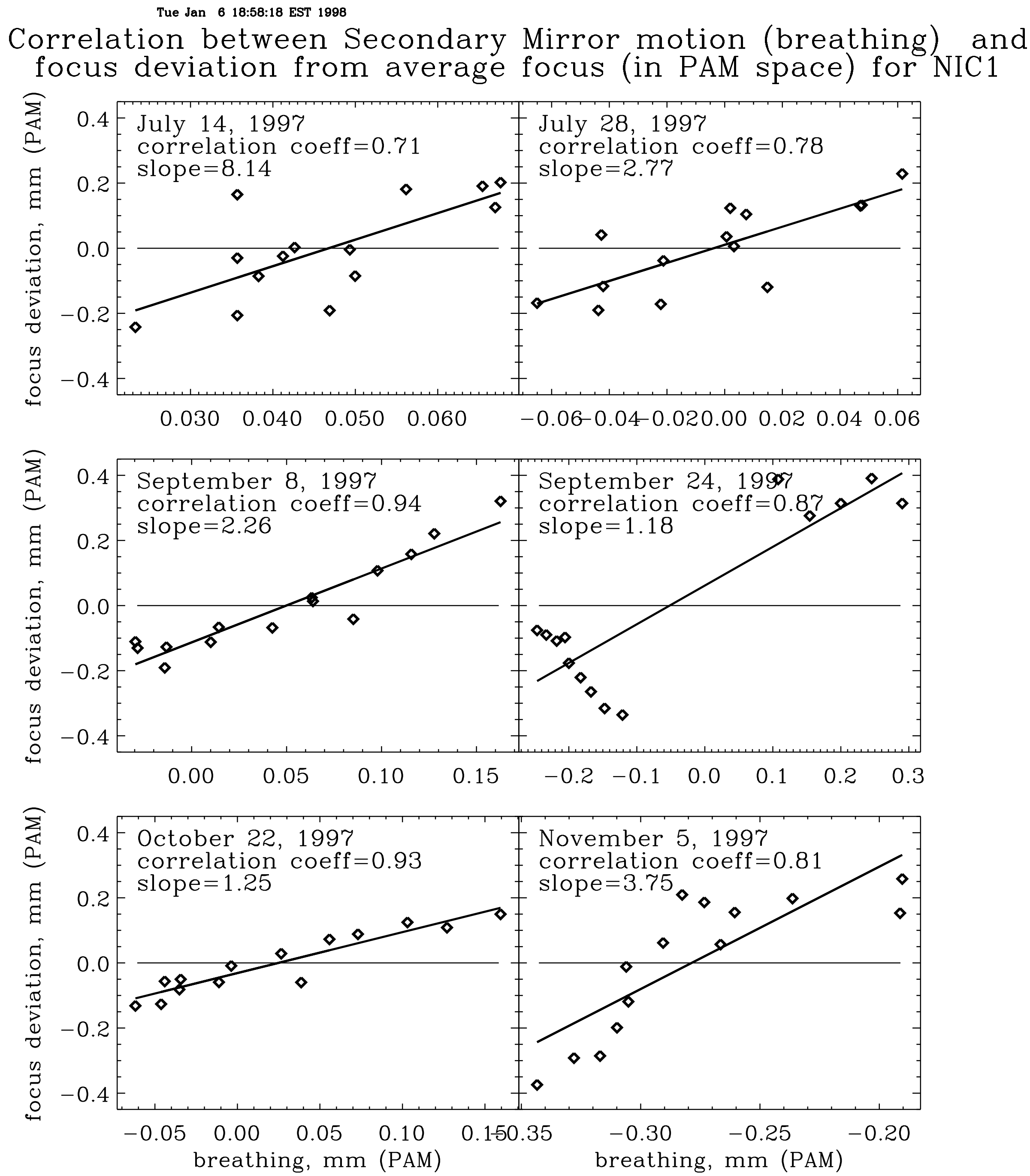


Fig. 2.— Correlation between focus position and breathing for NICMOS 3 data. The focus is measured relative to the mean value determined by each of the data sets.

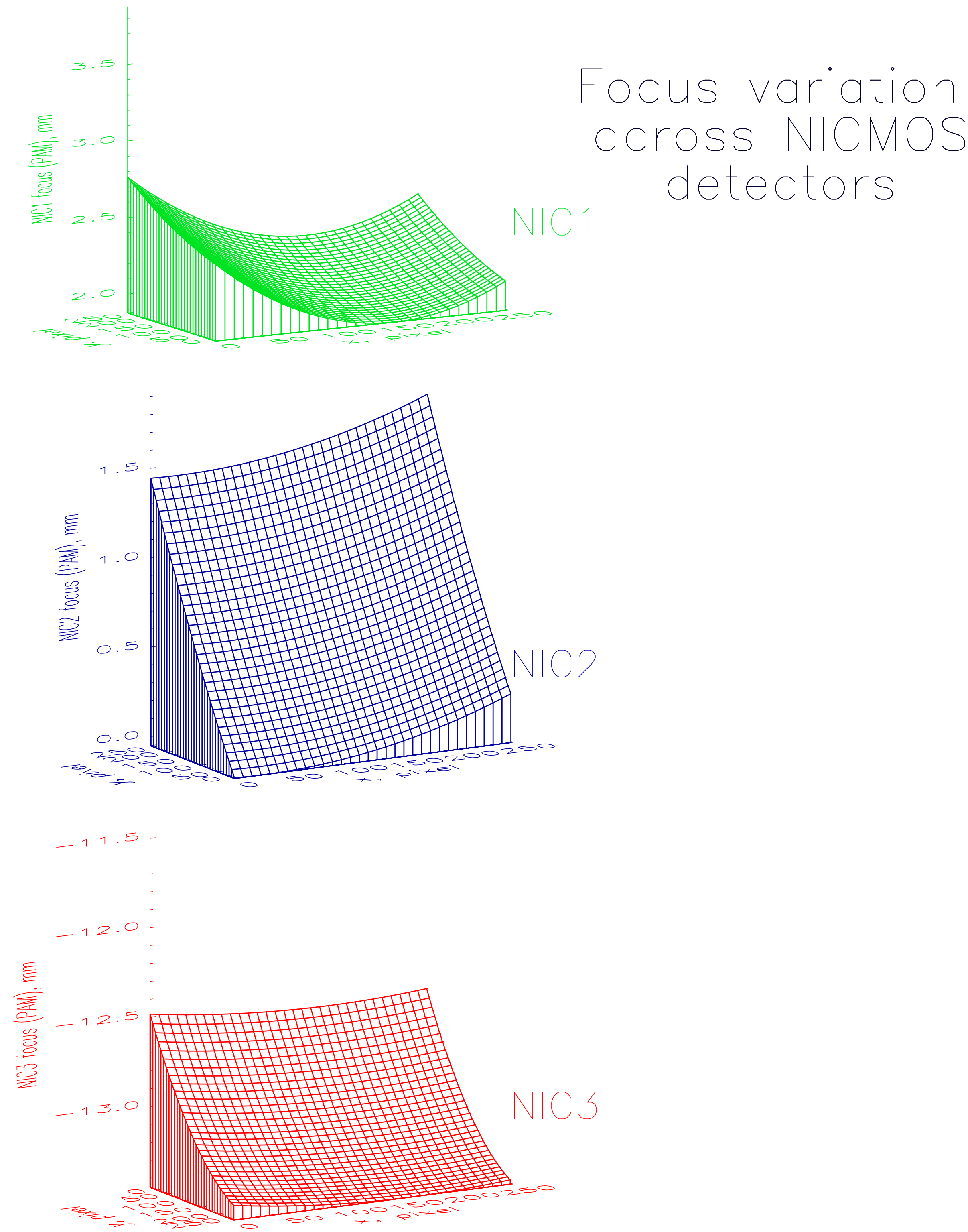


Fig. 3.— Focus variations across the field of view of NIC1 (top), NIC2 (middle), and NIC3 (bottom)

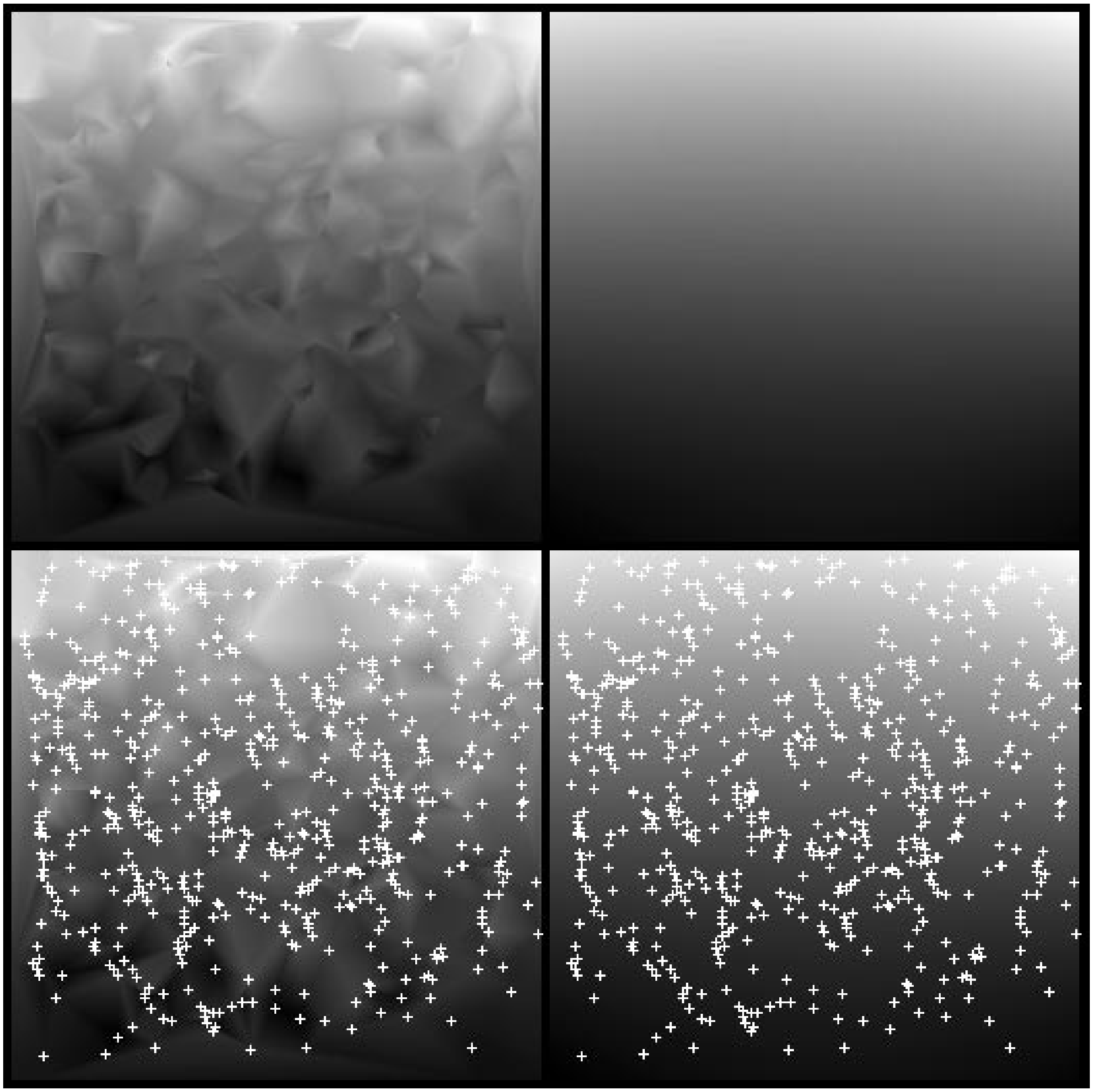

Fig. 4.— Grey scale presentation of focus variation across the NIC2 detector field of view obtained from encircled energy measurements. Upper left is triangle interpolation between all 630 encircled energy points in NIC2 through day 251, all normalized to 0 PAM at the center and included in the fit. The upper right is a smooth surface fit to the interpolated data. The lower 2 images are the same as above, but with the 630 measurement points overplotted as crosses.