

# Using 1D Sums to Find Fiducials

Jeren Suzuki

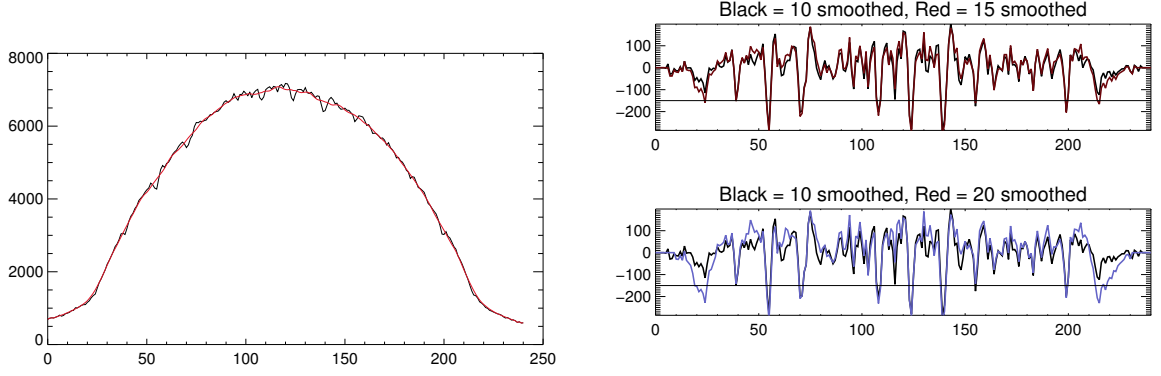
Last Edited June 10, 2013

## Contents

<b>1</b>	<b>Introduction</b>	<b>1</b>
<b>2</b>	<b>Finding Fiducials</b>	<b>1</b>
2.1	Using Gaussian Fits . . . . .	2
2.2	1D Sums . . . . .	2
2.3	Sub-Pixel Fitting . . . . .	2

# 1 Introduction

Instead of using convolution filters, we look at 1D sums to identify fiducials.



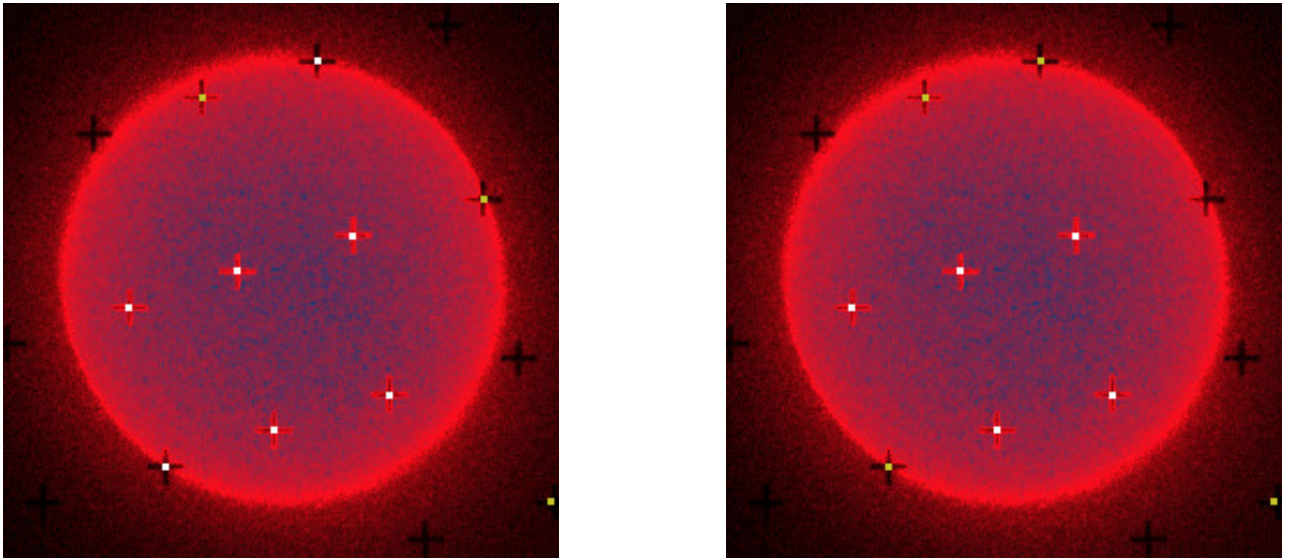
(a) This is the 1D sum of a solar image. Small dips are seen in the profile corresponding to fiducials. The line in red is the sum smoothed by 10 pixels.

(b) We subtract the smoothed profile from the raw data to emphasize dips. Comparisons of the smooth amount change the width and number of the dips, although not really the depth.

Figure 1

## 2 Finding Fiducials

For each position below a certain threshold (see Figure 1b) a row/column is returned. Once we have an array of possible fiducial row and column positions, they are matched against each other using a method that iteratively checks to see if a pair of coordinates is a fiducial. For Figure 2, the white squares are pairs where both X and Y coordinates were returned from thresholding, the yellow squares are pairs where one of the coordinates had to be guessed since it was not found.



(a) 10 pixel smoothed sum

(b) 20 pixel smoothed sum

Figure 2

There is a problem with the row/columns returned from thresholding the sum - smoothed sum; sometimes the number of indices don't match up. i.e., we "see" 7 fiducials in one axis but only 5 in another.

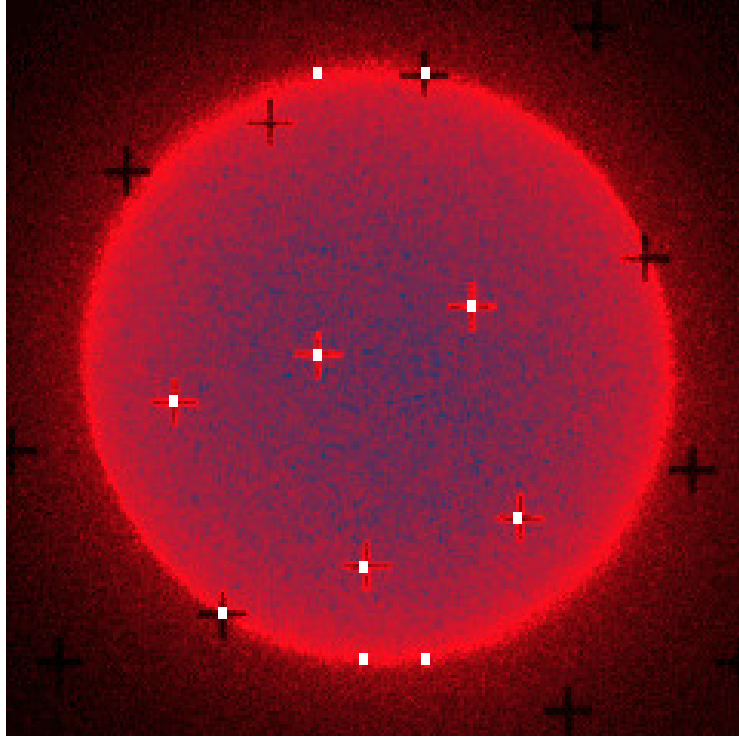


Figure 3 Gaussian fits with a  $\chi^2/N > 20$

How do we correctly rule out extra fiducials in one axis but not the other?

Also, this summing implementation aims to simplify and speed up the fiducial finding process, but once we have an array of X and Y positions of fiducials, verifying they actually lie on fiducials requires methods we tried to move away from.

## 2.1 Using Gaussian Fits

It turns out that using Gaussian fits to find fiducials is faster than expected. After finding all possible row/column combinations of fiducials, each candidate's 1D sum is fitted with a Gaussian, regardless of being a fiducial or not. We look at the  $\chi^2/N$  statistic to order out fits by how 'fiducial' they are. Since we only need, say,  $M$  fiducials, we can sort the fiducials by their  $\chi^2/N$  and pick the top 5.

We're walking a fine line here; instead of minimizing our  $\chi^2/N$ , we're maximizing it.

## 2.2 1D Sums

1D Gaussians provide a robust method to identify fiducials but they take quite a long time to run. An alternative is to use another 1D sum to identify fiducial shapes in cropped areas defined by running a larger 1D filter. Figures 6 and 7 illustrate the relationship between the region we look at versus what the 1D sums look like. In Figure 5, 7 fiducials are found using the 1D sum method.

## 2.3 Sub-Pixel Fitting

Once I know where the peaks are in the arrays of Figure 7, I perform a quick parabolic fit to the 3 pixels encompassing the peak maximum. This method is on the order of 1 magnitude faster to find the sub-pixel peak than the gaussian peak-fitting method. However, there is a problem when trying to fit sub-pixel positions of the 1D sums. Some of the arrays in Figure 7 reveal that some fiducials on the edge of the sun have defined peaks corresponding to fiducials but the peaks are not considered the maxima of

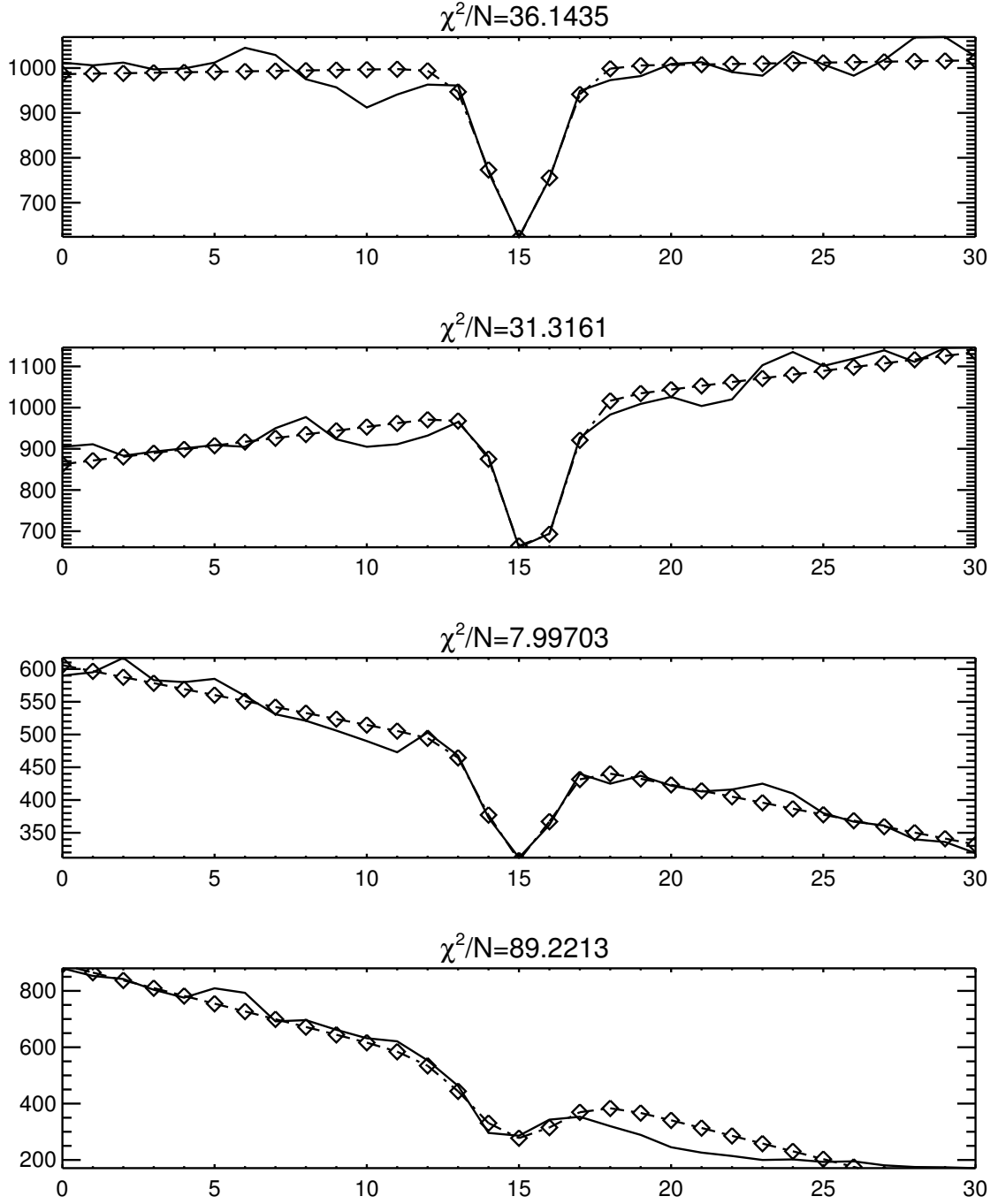


Figure 4 These are all real fiducials, ranging from looking nice (first two) to being on the solar limb (last 2).

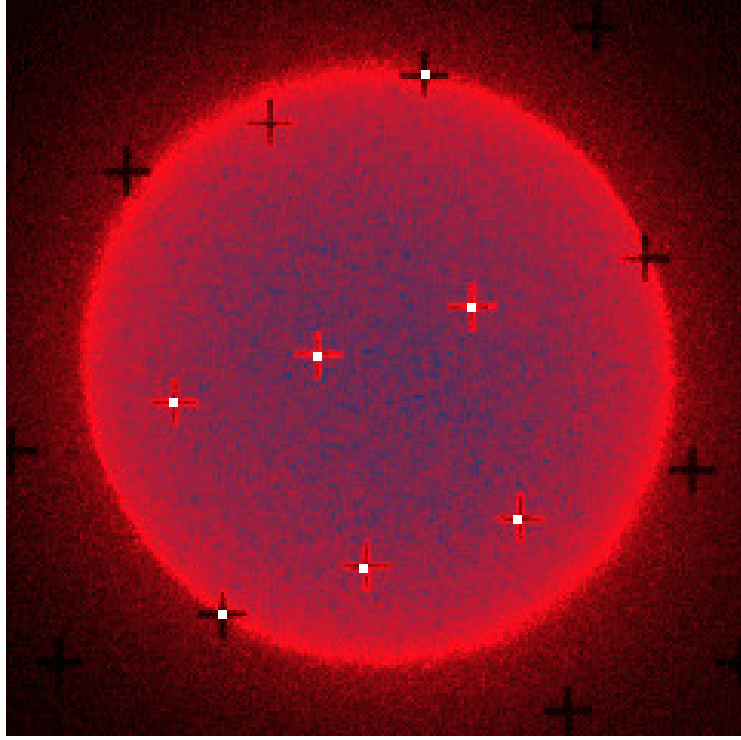


Figure 5 Fiducials found using a 1D summing method on the entire image followed by another 1D summing method on a cropped region based on fiducial candidates. Using a threshold of 100 on an `smooth(array,10) - array` identifies the white squares.

the array. The problem is not fitting a parabola to the peak, but identifying the peak in the first place. Gaussian fitting excels in this scenario because it robustly identifies the fiducial peak regardless of what shape the array is.

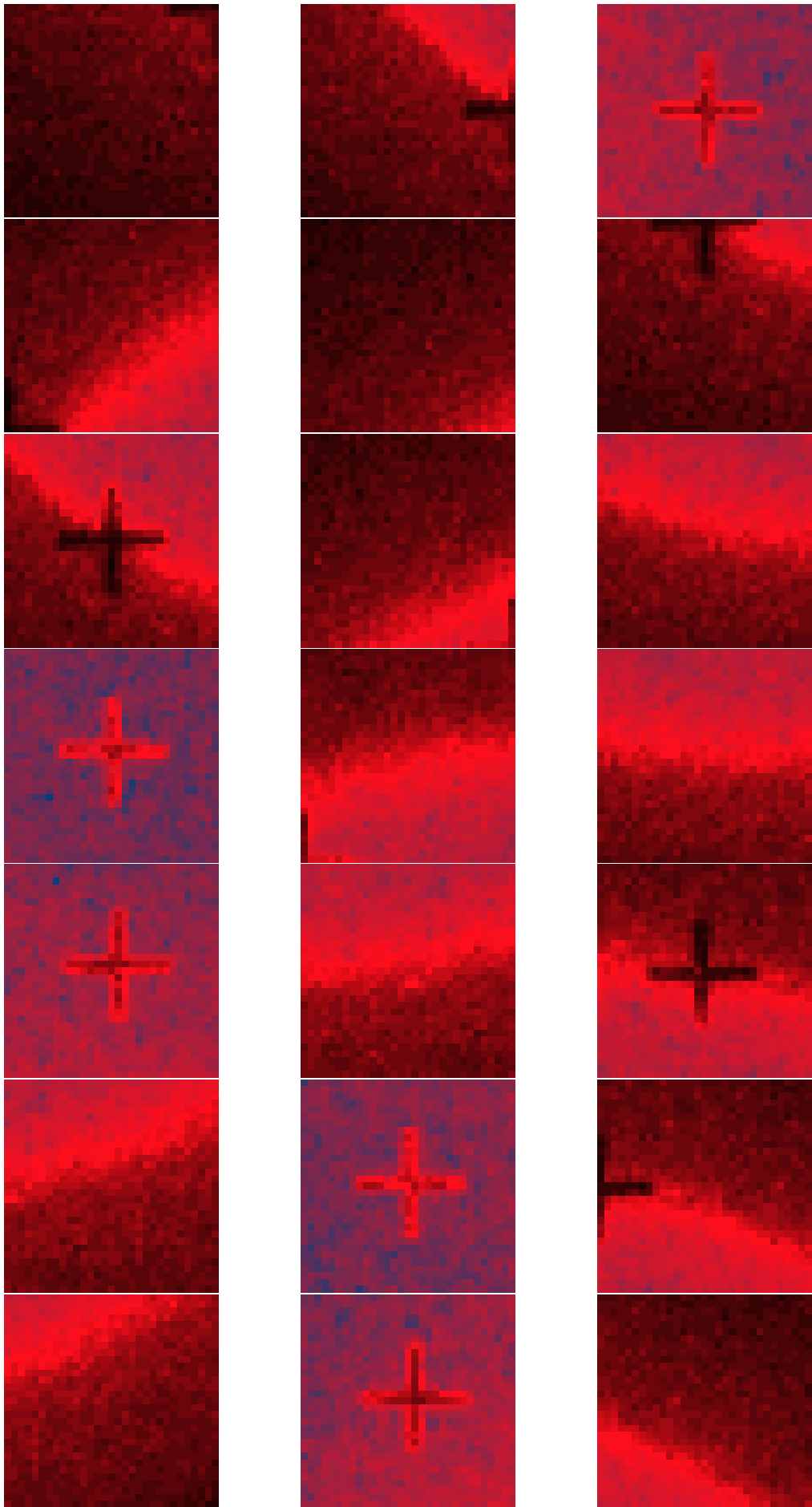


Figure 6

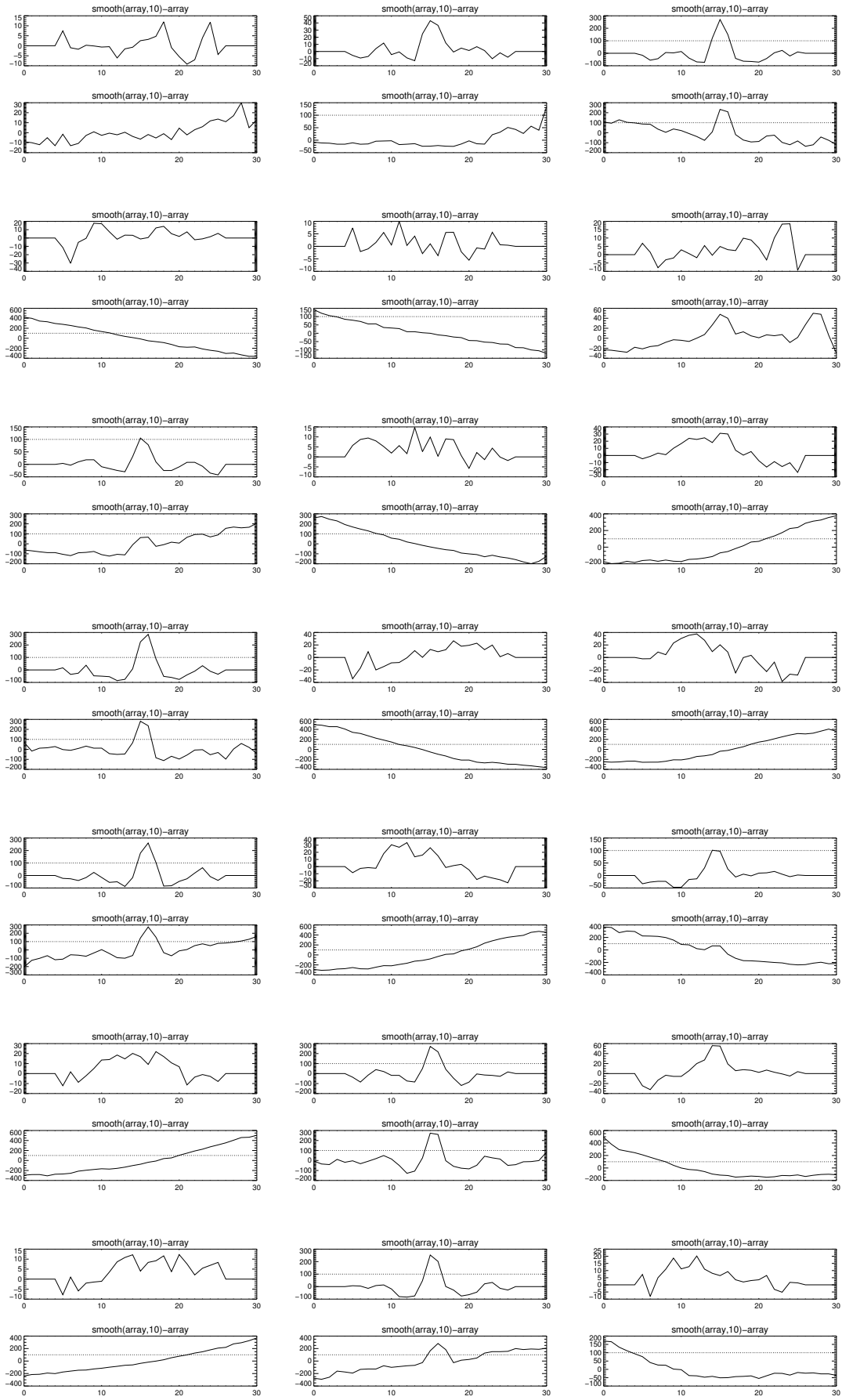


Figure 7 The horizontal line is at 100; if there are any elements of the array above 100 for both a column 1D sum and a row 1D sum, then the cropped area is identified to have a fiducial in it.