Forecasting Research

Forecasting Research Division
Technical Report No. 106

A statistical correction method for Meteosat IR and WV products generated by Autosat-2

by

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17 August 1994

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1 Introduction

This technical note addresses a problem which has become apparent in the automatic analysis of calibrated Meteosat IR and WV imagery generated by Autosat-2. Raw data counts are calibrated and scaled by the Autosat-2 software so that the product pixel values represent points on a linear scale of brightness temperatures. It was discovered that a number of particular pixel values within the full range available (normally 0–254) were not being used, while neighbouring values occurred too frequently. The resulting "spiky" histograms caused problems with the analysis of features in IR-VIS and IR-WV space. A solution is described which makes randomised adjustments, so as to obtain a distribution of product values in their statistically correct proportions.

2 The problem

Each Autosat-2 Meteosat infra-red or water-vapour product is normally generated as an array of byte values which corresponds linearly to a range of brightness temperatures. These brightness temperatures are derived from the original raw counts transmitted from the satellite by first using calibration coefficients to convert to a radiance value, and then using a look-up table for the non-linear conversion from radiance to equivalent brightness temperature. In practice, these two steps are combined into a single non-linear 256-valued count-to-temperature look-up table, illustrated in fig 1a (which uses the IR calibration coefficients valid for Meteosat-5 in March 1994). Finally each temperature is converted to the appropriate number in the linear scale 0–254 (255 is reserved for missing data), as shown in fig 1b. For most IR products the pixel value 0 corresponds to 198K and the value 254 to 308K.

Because the conversion from radiance to brightness temperature is non-linear, the 256 separate possible temperature values do not correspond in a one-to-one way with the 255 available numbers that can be used in the product output array. Some of the values are over-represented and others not used at all. A typical example is shown by the solid line in fig. 2, which is the histogram of values in the IR product shown in fig. 3. Where successive temperature values in the count-to-temperature look-up table are closer together than $((308.0 - 198.0)/254) = 0.43$K (ie for raw counts above about 170, where the slope of the curve in fig 1a is less than the slope of the line in fig 1b), some values in the final product are over-represented, and others under-represented. Where successive temperature values in the count-to-temperature look-up table are further apart than 0.43K (ie where the slope of the curve in fig 1a is greater than the slope of the line in fig 1b, which is the case over most of the range of temperature

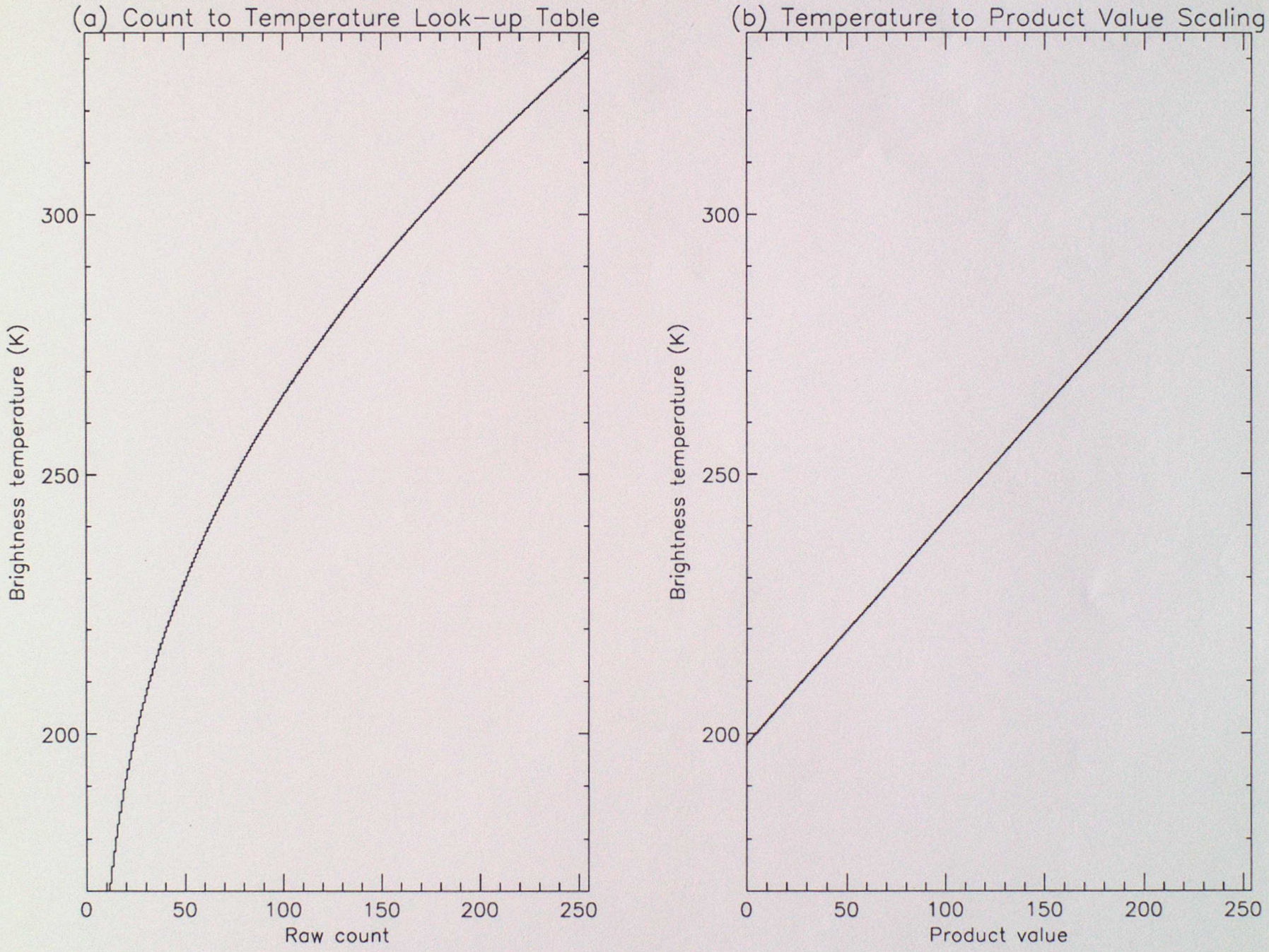

(a) Count to Temperature Look–up Table
Brightness temperature (K)
300
250
200
0
50
100
150
200
250
Raw count
(b) Temperature to Product Value Scaling
Brightness temperature (K)
300
250
200
0
50
100
150
200
250
Product value

Figure 1.

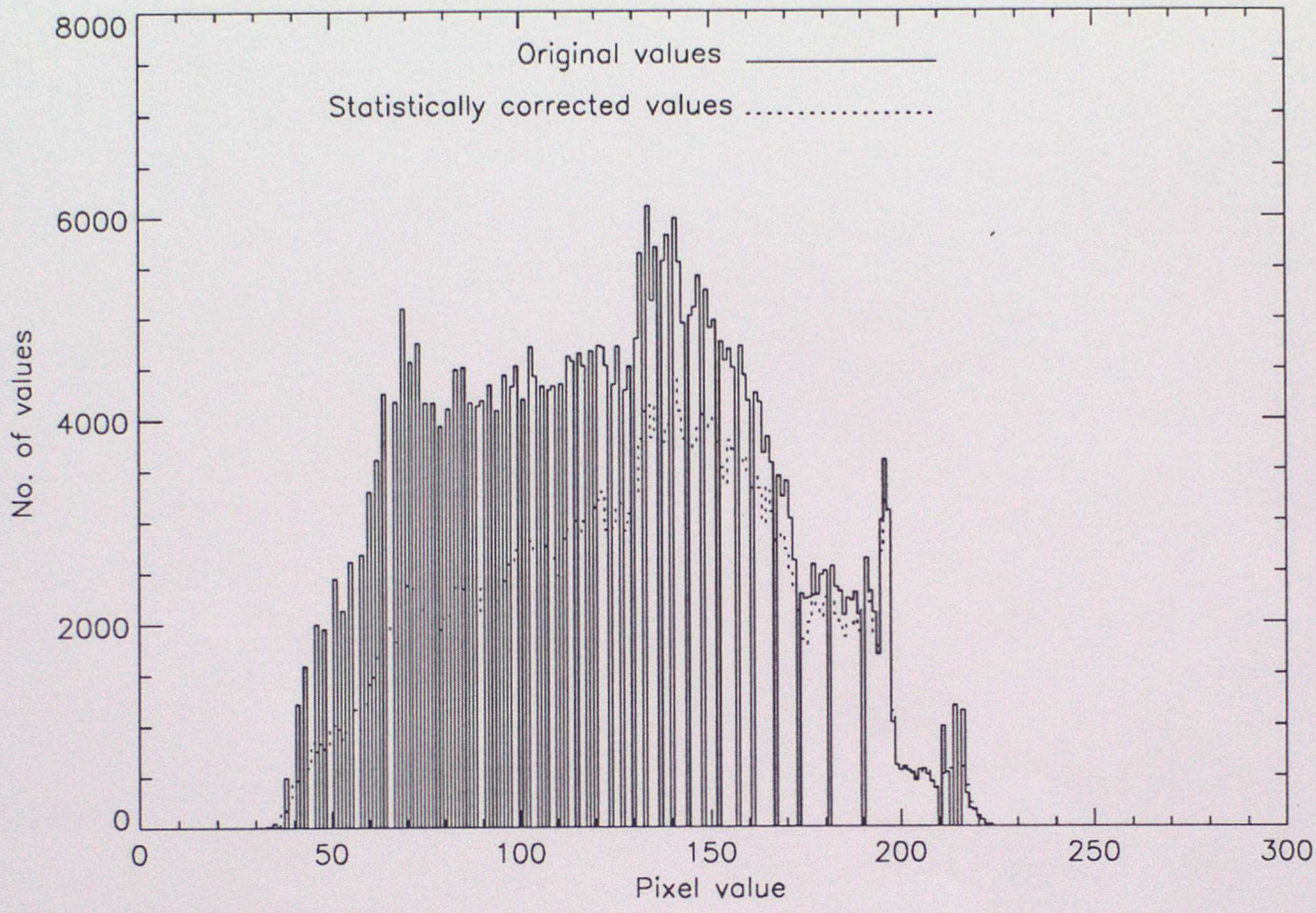
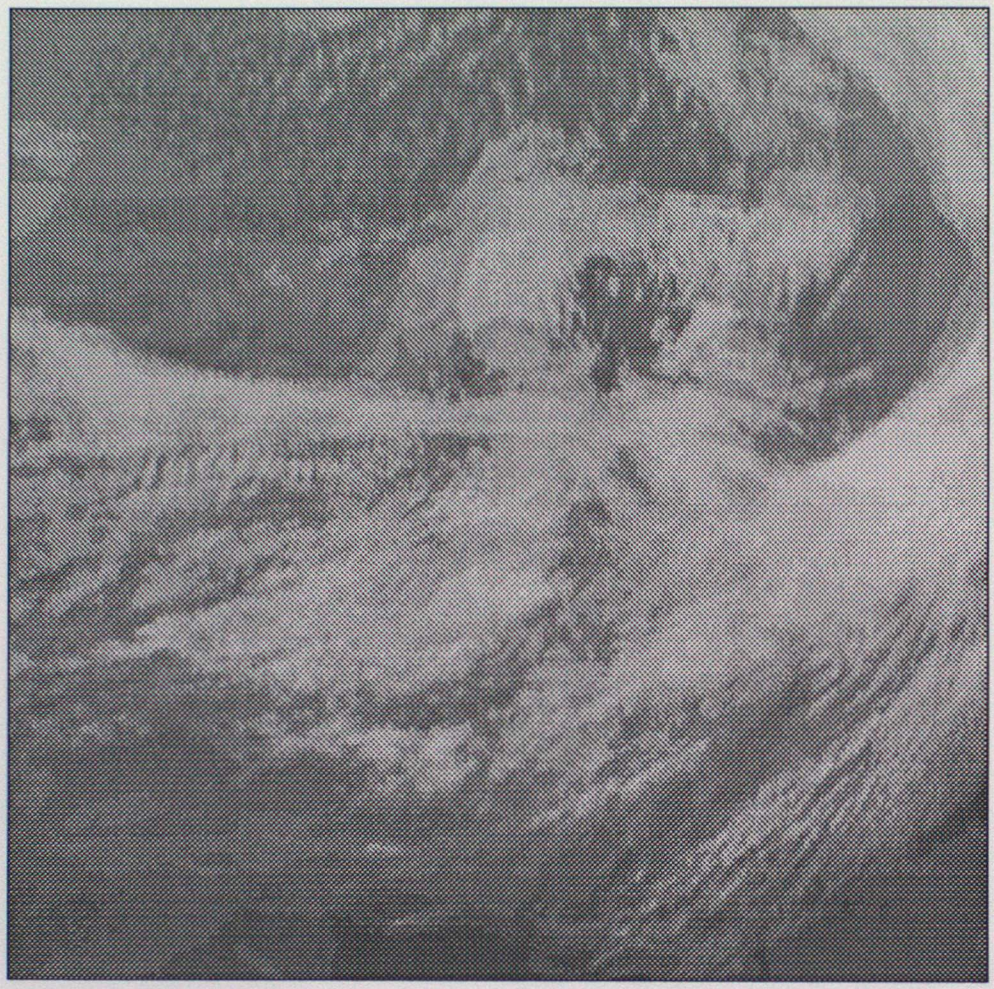

Original values
Statistically corrected values
No. of values
Pixel value
8000
6000
4000
2000
0
0
50
100
150
200
250
300

Figure 2.



Autosat-2 Meteosat IR product, 22 March 1994, 1530UT

Figure 3.

values), some product values are not used.

This feature of the mapping between raw counts and product values makes no difference to the visual quality of the images, and there is no effect on those applications which make use of temperature values of individual pixels. However, there can be a serious distorting effect for any application which uses some measure of the variation in brightness temperature over limited sub-areas, such as the local standard deviation, or for the cross-correlation of successive images. Also, cloud classification methods which make use of the 2- or 3-dimensional distribution of IR, VIS and WV product values require histograms with the correct shape.

3 A solution

One solution to the problem is to recognise that each original count in the raw data does not correspond to a precise radiance value, but to a value which is somewhere in the range from half-way back towards the previous value to half-way on towards the next. Or in terms of brightness temperatures (assuming local linearity), instead of T_i, the temperature is equally likely to be any value in the range $\frac{1}{2}(T_{i-1}+T_i)$ to $\frac{1}{2}(T_i+T_{i+1})$. By taking real values randomly from this range for each T_i, before converting to discrete product values in the range 0–254, the product values are used in their statistically correct proportions as defined by the distribution of raw counts.

Each T_i is replaced by

$$\begin{aligned} & \tfrac{1}{2}(T_{i-1}+T_i) + R[0:1]\{\tfrac{1}{2}(T_i+T_{i+1}) - \tfrac{1}{2}(T_{i-1}+T_i)\} \\ = \; & \tfrac{1}{2}\{(1-R[0:1])T_{i-1} + T_i + R[0:1]T_{i+1}\} \end{aligned}$$

where $R[0:1]$ represents a random number in the range 0 to 1 (see fig 4).

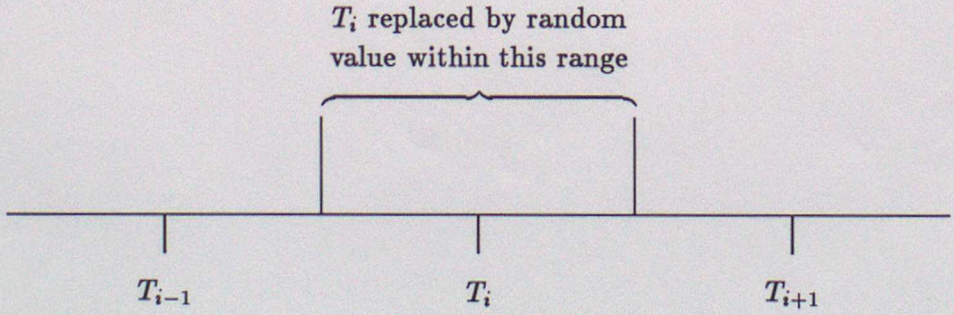
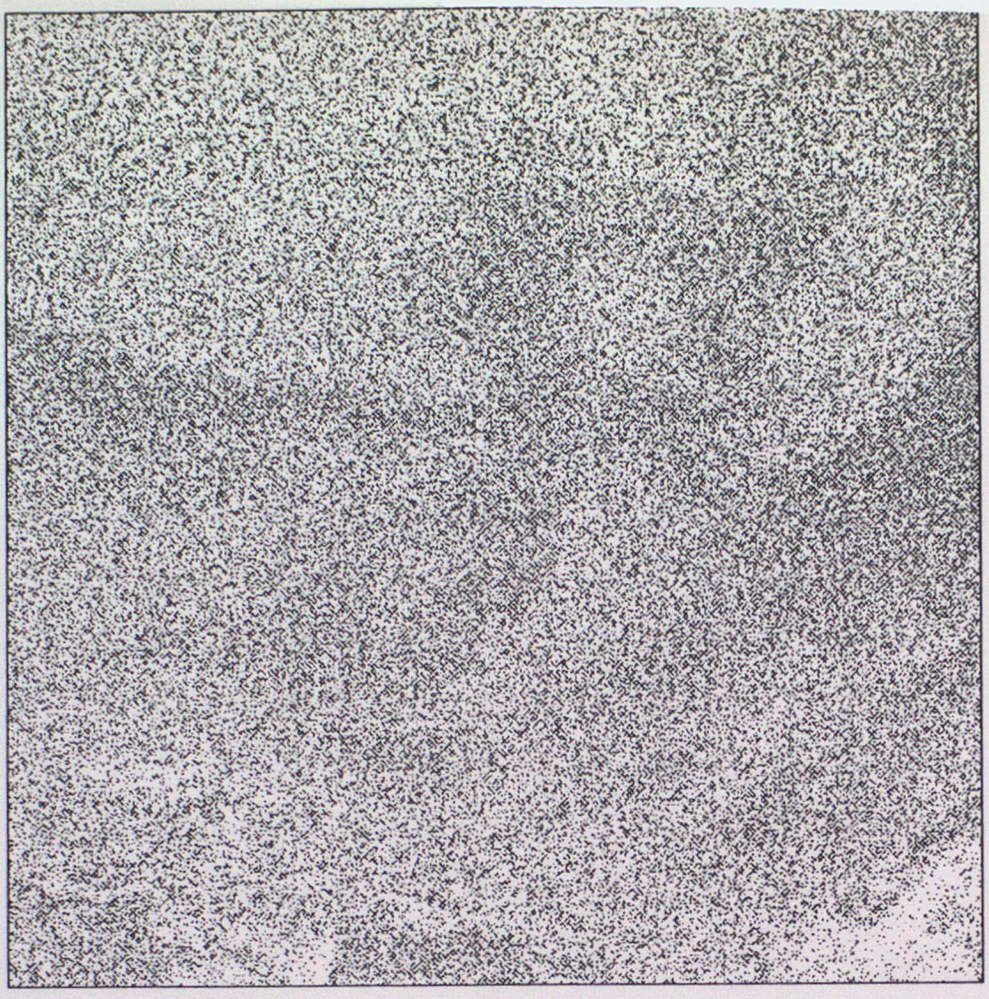


Figure 4.

A product generated by this method is visually indistinguishable, even on a high-resolution display, from a product with the same specification and for the same time, but generated in the conventional way. For the image shown in fig. 3, 252562 (61.7%) of the 409600 pixel values are unchanged, 84965 (20.7%) increased by one, 71802 (17.5%) decreased by one, 144 (0.04%) increased by two and 127 (0.03%) decreased by two. The positions of the pixels whose values are changed are shown in fig. 5a and fig. 5b. It can be seen that there are more values changed in the areas of the image containing colder cloud, which correspond to temperatures for which the slope of the curve in fig 1a is much greater than the slope of the line in fig. 1b. The histogram of values is shown in fig. 6 and by the dotted line in fig. 2, and demonstrates much smoother changes between successive values, with unrealistic peaks and troughs removed.

4 Discussion

The technique outlined in the previous section has been implemented on Autosat-2 since 27 April 1994. Its benefits are that, without affecting the visual appearance of the products, more accurate product values are obtained (at least on average, if not necessarily at particular pixels). Analysis methods which make use of, say, the variation of brightness temperature over an area or sub-area, or the maximum or minimum value within an area, or pattern recognition within IR-VIS or IR-WV space, in utilising more realistic distributions of product values, will generate more accurate and reliable results.



(a) Pixels where product values are changed (by 1 or 2).

(b) Pixels where product values are changed by 2.

Figure 5.

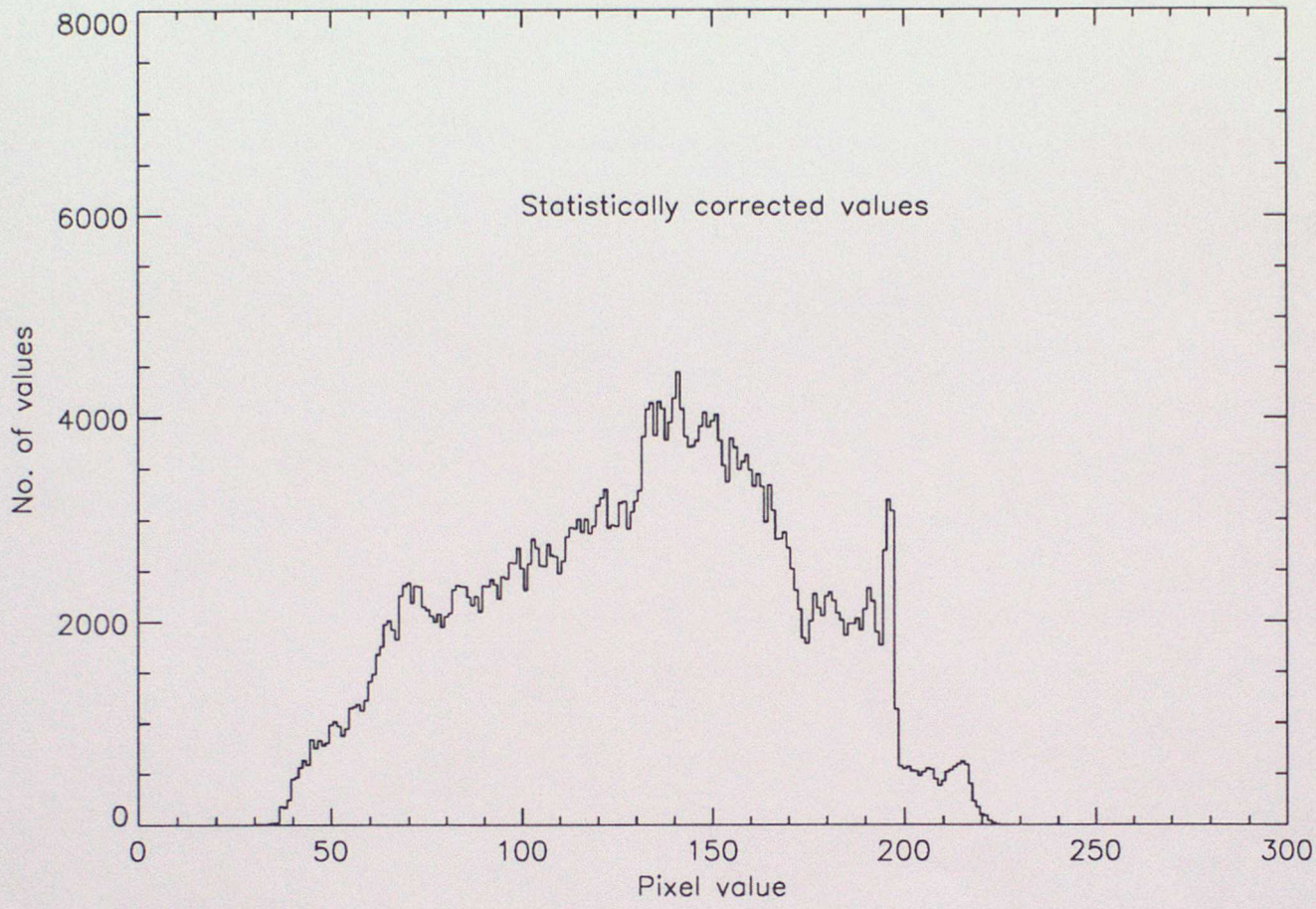

Statistically corrected values
No. of values
Pixel value
8000
6000
4000
2000
0
0
50
100
150
200
250
300

Figure 6.