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S Campbell

THE ERRORS IN RADIANCE MEASUREMENT ASSOCIATED WITH THE TIROS N SSU

Introduction

A study of the performance of a radiometer was undertaken. Various different sizes of fields of view, with different spacings between them were employed, and also the instrumental noise inherent in the radiometer was varied. See reference 1 for details of the relationship between the number of observations N, the viewing cone angle Θ and the spacing between, and the size of the fields of view.

It is proposed that the Tiros N satellite will adopt a circular, near-polar orbit with a mean height of 833 kilometres, and that the radiometer, the Stratospheric Sounder Unit or SSU, will make 8 observations of 10° viewing cone angle across the sub-satellite track during a scan lasting about 32 seconds. Also, it is expected that the instrument will have a root mean squared (rms) noise of 65 I units for a 1 second observation of 1° viewing cone angle. (Here R units or radiance units will denote erg sec^{-1} cm^{-1} sr^{-1} $(cm^{-1})^{-1}$ and I units or instrumental noise units will denote R units $sec^{\frac{1}{2}}$ deg^{2}).

The study determined the rms error in R units which would arise if a radiance field were measured using a given viewing configuration and a given instrumental noise in I units. (Viewing configuration will be used to denote a particular combination of number of observations per scan and the viewing cone angle of each observation.)

The different viewing configurations and the instrumental noise were both varied independently in order to examine their effects on the rms errors which arose when the underlying radiance field was "observed" under those circumstances. The following is a description of the results obtained with particular reference to the Tiros N.

Results

A computer programme simulating the action of the radiometer when observing a radiance field was run, where the parameters were varied, independently, as follows:

1. The number of observations per scan, N, was varied from 3 to 12.

2. The viewing cone angle, Θ, was varied from 2° to 30° in 2° increments.

3. The constant of instrumental noise $\sigma(n_I^*)$ in I units was varied from 0 to 130 I units in 10 I unit increments, with an additional run at 65 I units, the expected value of instrumental noise for the SSU.

The resultant rms errors $\sigma(\Delta R)$ in R units associated with "readings" using each different viewing configuration with the different instrumental noises were then examined.

A graph of $\sigma(\Delta R)_A$, the rms error for the particular viewing configuration of 8 observations of 10° viewing cone angle per scan, against $\sigma(n_I^*)$, the constant of instrumental noise showed a virtually linear increase in $\sigma(\Delta R)_A$ as $\sigma(n_I^*)$ increased over the range of $\sigma(n_I^*)$ considered. (See figure 1.) This increase was fairly rapid, with an rms error of 0.314 R units for an instrumental noise of 65 I units, (which is equivalent to an rms error in temperature of about $0.3^\circ K$

for a mean radiance field of about 70 R units), and an rms error of 0.634 R units for an instrumental noise of 130 I units, (corresponding to an rms error in temperature of about 0.6°K for a radiance field of about 70 R units).

Although this viewing configuration is by no means the worst according to the criterion of rms errors, there are viewing configurations which are considerably better, and this might become an important consideration if either the instrumental noise of 65 I units ceases to be attainable, or if the instrument were to deteriorate while in operation.

The optimum viewing configuration, ie the one which produced the minimum rms error $\sigma(\Delta R)_{opt}$ for a given value of instrumental noise, changes with instrumental noise, and so it is not possible to adopt a viewing configuration which is the optimum one under all circumstances. However, after the instrumental noise increases beyond about 70 I units, the optimum viewing configuration remains stable at 5 observations of 22° viewing cone angle with respect to changing instrumental noise. In fact the rms error $\sigma(\Delta R)_B$ for this viewing configuration only varies between 0.096 and 0.102 R units over the whole range of $\sigma(n_I^*)$ considered, and so the rms error $\sigma(\Delta R)_B$ for this configuration is, to all intents and purposes, independent of the instrumental noise $\sigma(n_I^*)$. This means that although this viewing configuration is the optimum one only for $\sigma(n_I^*)$ greater than 70 I units, it nevertheless performs very well over the whole range of $\sigma(n_I^*)$ examined, and very little would be gained by using the optimum configuration for $\sigma(n_I^*)$ less than 70 I units, especially since this configuration might perform fairly badly if $\sigma(n_I^*)$ were to increase above 70 I units.

The above viewing configuration of 5 observations of 22° viewing angle is obviously preferable to the present adopted one of 8 observations of 10°, but at this stage in the development of the radiometer, such a change would not be feasible. There is, however, a change which might possibly still be feasible which would produce a considerable improvement in the performance of the radiometer from the point of view of rms errors. This would be to halve the number of observations per scan to 4, while leaving the viewing cone angle unaltered at 10°. Such a change would probably involve a modification to the stepping motor only, while the optics would remain unaltered.

With the viewing configuration of 4 observations of 10° per scan, the rms error $\sigma(\Delta R)_C$ again varies almost linearly with the instrumental noise $\sigma(n_I^*)$, although the increase in $\sigma(\Delta R)_C$ with $\sigma(n_I^*)$ is much less rapid that that of $\sigma(\Delta R)_A$, and $\sigma(\Delta R)_C$ is consistently less than $\sigma(\Delta R)_A$ for all $\sigma(n_I^*)$ greater than about 25 I units. For a $\sigma(n_I^*)$ of 65 I units, for instance, $\sigma(\Delta R)_C$ is 0.176 R units and for a $\sigma(n_I^*)$ of 130 I units $\sigma(\Delta R)_C$ is 0.273 R units.

Although these values of rms error, $\sigma(\Delta R)_C$ are not as low as $\sigma(\Delta R)_B$ they are nevertheless significantly better than those of the adopted viewing configuration $\sigma(\Delta R)_A$, and the differences become more important as $\sigma(n_I^*)$ is increased.

A plot of the contours of rms error for the different viewing configurations for a given value of instrumental noise showed that the optimum area of minimum rms error was relatively extensive with a rather ill-defined minimum, but outside this area, the gradient could become very steep indeed. (See figure 2.) If N_{opt} and Θ_{opt} denote the values of N and Θ which produced the minimum rms error

$\sigma(\Delta R)_{min}$ for a given value of $\sigma(n_I^*)$, then if Θ is much less than Θ_{opt} and N is much greater than N_{opt}, $\sigma(\Delta R)$ increases very rapidly although for Θ greater than Θ_{opt}, the gradients are much less steep, and the edge of the optimum region is less sharply defined. It is therefore important that the viewing configuration chosen should lie within this minimum region, although exactly where in the region is not particularly important. The rms error for the adopted viewing configuration lies outside this minimum region at the edge with the steep gradients for the probable values of $\sigma(n_I^*)$ to be encountered, whereas the rms error $\sigma(\Delta R)_c$ for the viewing configuration of 4 observations of 10^o lies just about on the edge of this area, although it too begins to move outside it for very large values of $\sigma(n_I^*)$.

Conclusions

The adopted viewing configuration of 8 observations of 10^o per scan is not a particularly suitable one from the point of view of the rms errors which arise when a radiance field is "read" using this configuration. These errors might be considered acceptable if an instrumental noise of 65 I units could be guaranteed, but if either this value became impossible to achieve, or if the instrument itself were to deteriorate during operational use, then the resultant rms error might well be considered unacceptable.

A change from 8 observations to 4 without altering the viewing cone angle from 10^o would represent a considerable improvement, possibly without a great deal of effort being required for its implementation. This would still not be the best possible viewing configuration for the expected values of $\sigma(n_I^*)$. However, the changes necessary to bring about the optimum viewing configuration for those values of $\sigma(n_I^*)$ would be formidable, and the actual improvement in rms error would not be great in absolute terms. Hence if the work involved were not prohibitive, it might be worth considering a change to 4 observations of 10^o thereby achieving a suitable compromise.

At first sight this conclusion seems rather surprising, as it might seem desirable to provide the extra spatial coverage which would be given by using 8 observations. In fact, the change to 4 observations effectively doubles the time available for each observation and this is responsible for reducing the noise in these observations, thereby providing a more accurate representation of the radiance field.

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Reference 1 - HA/IG/10

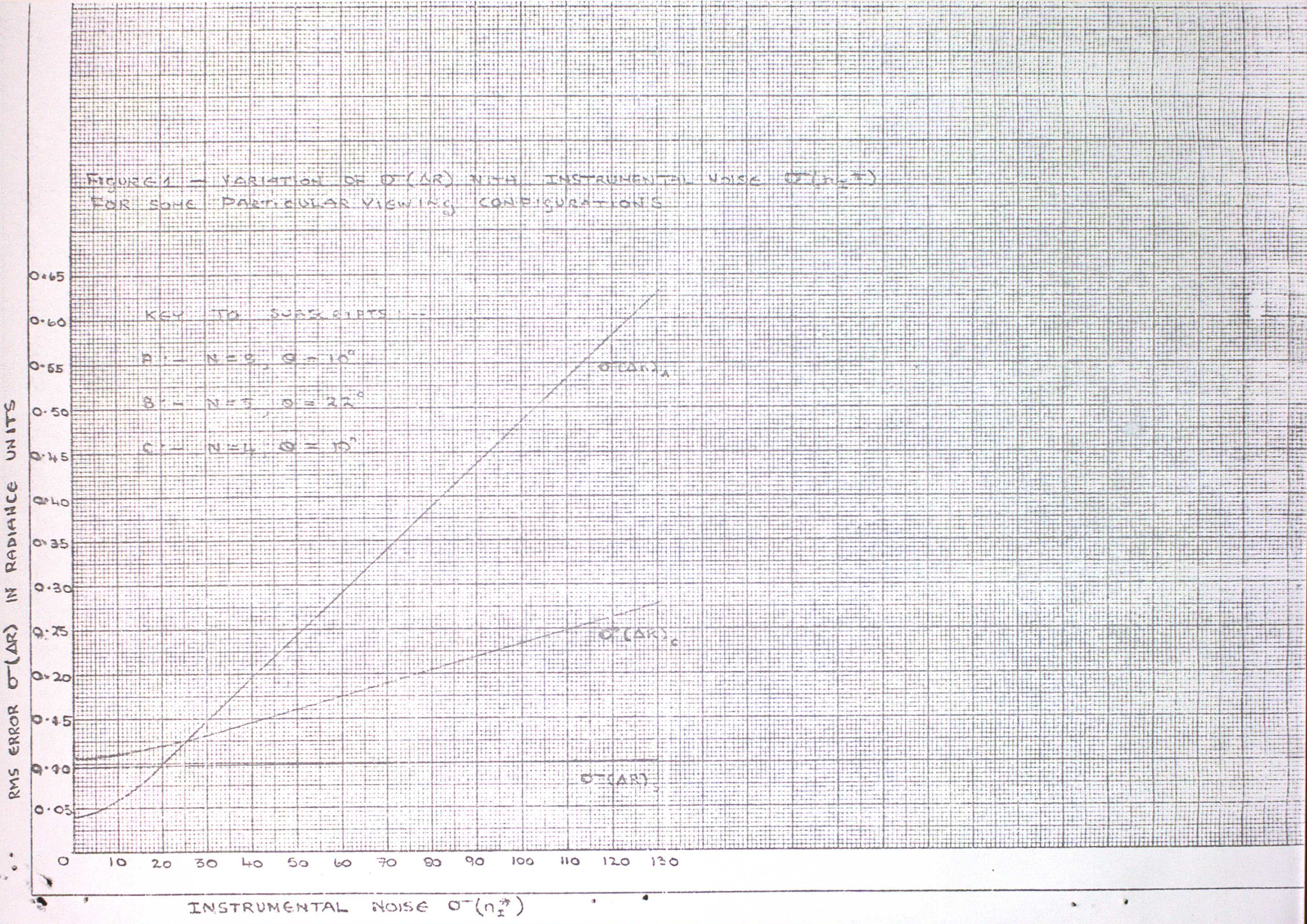

FIGURE 1 — VARIATION OF σ(ΔR) WITH INSTRUMENTAL NOISE σ(n_I*) FOR SOME PARTICULAR VIEWING CONFIGURATIONS

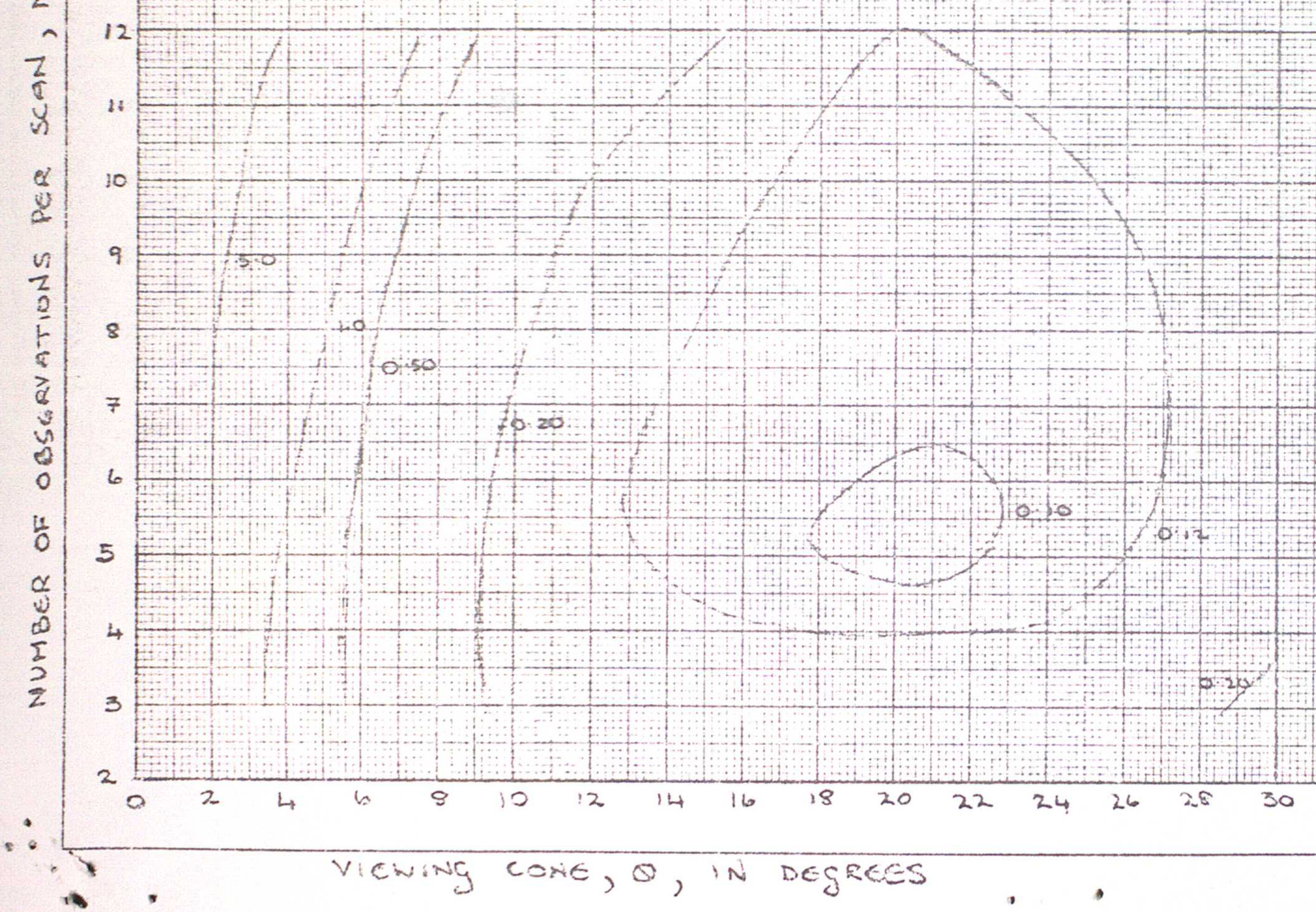

FIGURE 2 — VARIATION OF σ(ΔT) WITH N AND θ

$\sigma(n_{\nu}^{2}) = 65$ I UNITS