GOME Diffuser and Dark Signal Trends

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Abstract

The Global Ozone Monitoring Experiment (GOME) was launched on ERS-2 in April 1995 and has been functioning continuously since then. GOME is a scanning nadir-viewing spectrometer, with its primary scientific objective being to retrieve total column ozone globally. To achieve this it uses four Reticon array detectors to measure the back-scattered radiance from the Earth's atmosphere and surface, and the solar irradiance which is viewed via a diffuser plate to provide a reference spectrum of similar intensity. A more complete description of the instrument can be found in the GOME User's Manual. An analysis of the long term behaviour of the diffuser plate reflectivity and detector array dark signals since the geophysical validation phase commenced in July 1995 is presented here.

Keywords: GOME, diffuser, dark signal, trend.

Introduction

The long term behaviour of the diffuser plate in instruments which use one to view the sun has been of interest since it was realised in the 1980s that they are susceptible to degradation when subject to UV radiation (WMO, 1988). GOME has been designed with a cover for its diffuser plate in an attempt to minimise this degradation, with exposure usually being for a short time for one orbit each day to obtain a reference solar spectrum. Characterisation of any degradation is possible by means of an on-board Pt/Cr/Ne calibration lamp. It is also of some interest to monitor the degradation of the Reticon array detectors due to their exposure to the low Earth orbit radiation field, in order to have some indication of likely behaviour in future similar instruments.

The data presented here are the results of analysing the monthly calibration sequences from July 1995 until January 1997, mainly using the output provided by the Extended Rascals for GOME (ERGO) system developed under ESA contract by Dornier and SRON.

Dark Signal

The dark signal for GOME is defined as being composed of two parts - a constant value of around 140 binary units (BU) which is the fixed pattern readout noise (FPRN), and a time dependent component of around 2 binary units per second which is the leakage current (LC). ERGO calculates the dark signal using an algorithm specified in Slijkhuis, S. (1995), which in essence is:

Find all dark products for each monthly calibration file.
Get their corresponding integration times.
Fit the integration times and the dark signal taking note of the integration status of band 1A.
Return the offset as the FPRN, and the gradient as LC.

Results for January 1997 for two of the four channels are shown in Figure 1, using only those products where the integration is complete for all bands so as to avoid a known cross-talk problem. Immediately apparent in the FPRN is a superimposed spectral signature probably due to light reflected from a baffle when the mirror is pointing to deep space.

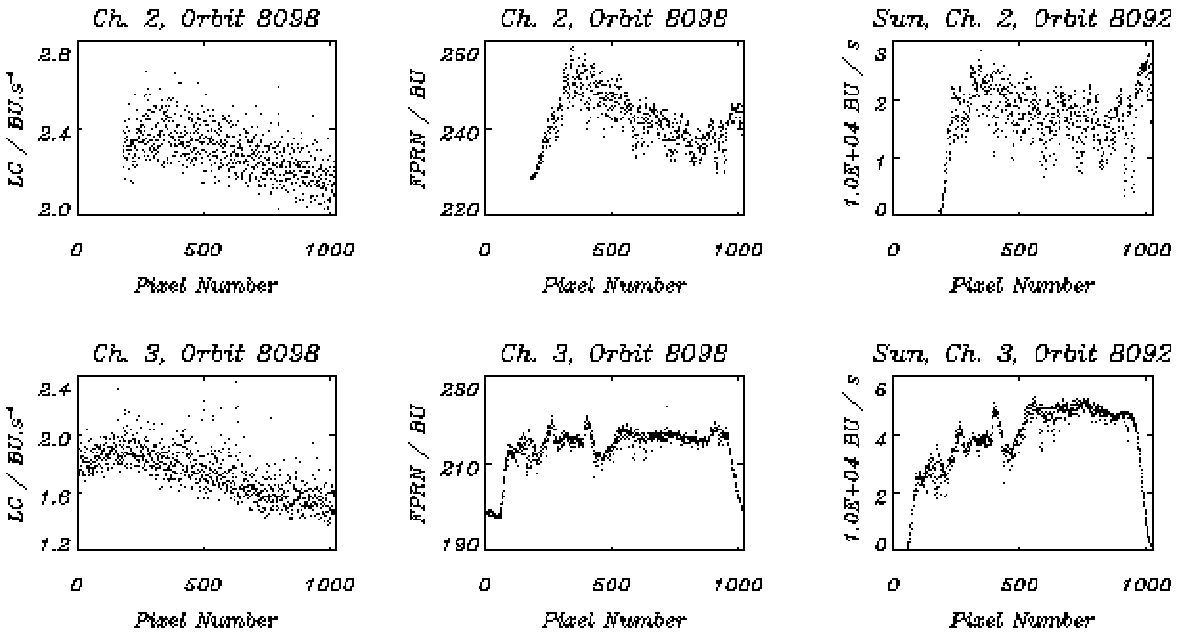

Figure 1: ERGO Dark Signal and Solar Spectrum, January 1997

To investigate this further, the data were decomposed into the components from each different integration time. An example of this is shown from June 1996 for channel 4 in Figure 2. Looking at all the data, it became clear that this spectral signature is only present for integration times of 3s and 24s, where the monthly calibration sequence performs dark signal measurements in the daytime part of the orbit.

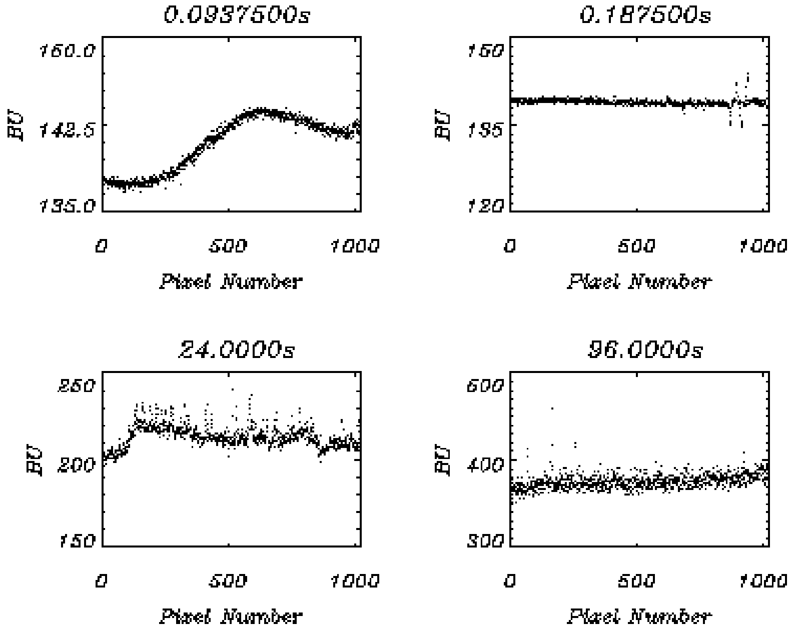

Figure 2: Dark Signal Measurements for Channel 4, June 1996

A further problem was also seen with the measurements in channel 2 at 1.5s, channel 3 at 0.375s and channel 4 at 0.09375s where a slow change in the dark signal across the detector elements is seen. The problem of some dark signal readouts being dependent on the integration status of other channels was noted in the functional performance tests performed at TPD on the BBM (Olij, C. and Zoutman, A.E., 1993). However, the monthly calibration timeline does not vary, and so it was sufficient to identify where these effects occurred. They are shown for the example case of June 1996 in Figure 3. Consequently measurements at these problematic integration times were excluded from further trend analysis. Note that discarding the daytime measurements removes any potential problems from South Atlantic anomaly effects, since the nighttime monthly calibration measurements occur well away from this area.

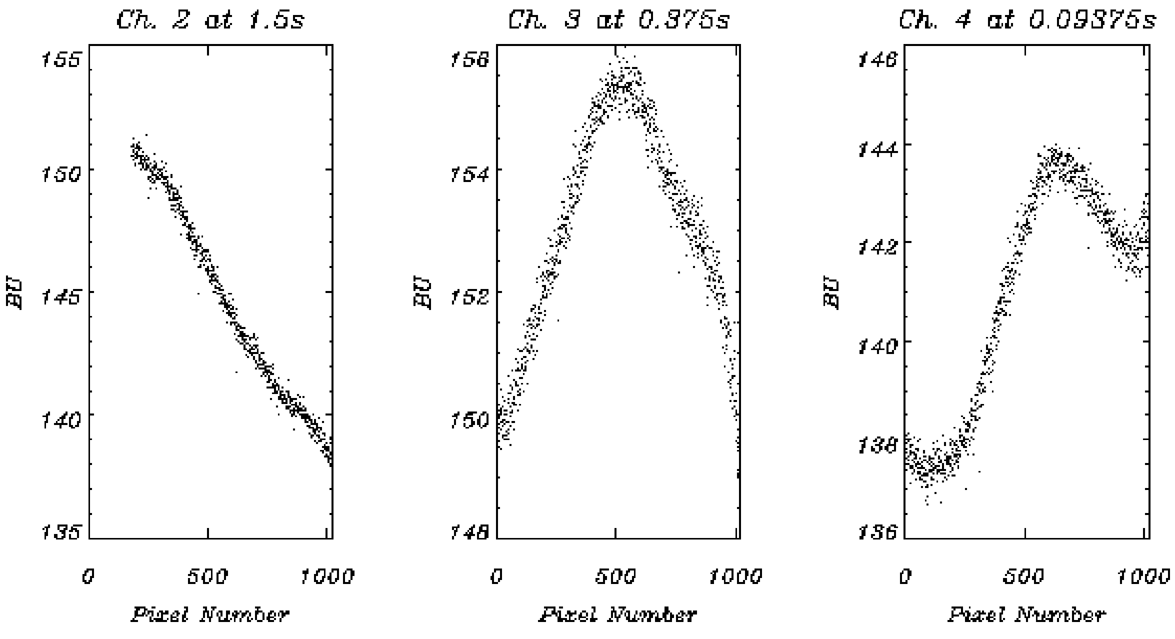

Figure 3: Integration Times and Channels where Variation of Dark Signal Across Detector Elements is Seen

The analysis of the remaining data was performed by taking the middle file of each monthly calibration sequence, calculating the gradient (LC) first from all valid integration times, and then using this to extrapolate from the shortest integration time to get the offset (FPRN). Trends were calculated for both the FPRN and the LC, and for the noise on these measurements. The results are shown in Table 1 below.

Channel	FPRN	FPRN Noise	LC	LC Noise
1	+0.6	+5.4	+13.3	+34
2	+1.2	+14.9	+14.9	+35
3	+0.3	+8.6	+13.5	+33
4	+0.6	+2.3	+17.8	+88

Table 1: GOME Dark Signal Trends; % per year change

From this one can conclude that there is no significant change in the fixed pattern readout noise, but that a linear increase in the leakage current is seen, which is also becoming noisier with time.

Diffuser Reflectivity

The algorithm used by ERGO to calculate diffuser reflectivity is specified in Slijkhuis, S. (1995) and updated in Slijkhuis, S. (1996). It can be broken down into the following components:

> Find all diffuser products for an orbit
> Find all lamp products after the last diffuser product
> Ignore the first lamp products with minimum integration times
> Locate the centre of each line
> Sum five pixels around this line centre
> Average the minima of ten pixels either side of the line centre
> Subtract this baseline
> Normalize according to integration time
> Ratio all diffuser measurements with all lamp measurements
> Store the line reflectivity and its associated error
> Get the channel reflectivity from a weighted average of line reflectivities

Some account of lamp power stability is taken by not using measurements for the first 130s after it has been switched on, thereby avoiding its power-up phase. There is however a problem with this algorithm (C. Caspar, private communication), in that the baseline subtraction which should remove the dark signal contribution to the measurement, does not remove the average value but the minimum. This leads to an erroneously high value for the line strength which is particularly noticeable at the long integration times used for diffuser characterisation where the dark signal contribution can be many times greater than that coming from the lamp line itself. Consequently the diffuser reflectivity is overestimated particularly when the lamp lines are weak, as is the case in channel 1. Another particularly insidious effect is that any trend in the difference between the mean and minimum values will manifest itself as a false trend in diffuser reflectivity.

The data set produced by ERGO is quite noisy, with occasional spikes. Two measures were taken in an attempt to identify spurious data points. The first of these was to discard points lying more than three standard deviations from the mean, and the second was to examine the spread for each monthly calibration cluster (typically five orbits), and discard those which were more than three SD greater than the others. A check on the remaining data showed that there was no noticeable effect from the South Atlantic anomaly.

In an effort to overcome the problems due to the baseline subtraction, the previous set of dark signal measurements were analysed at the positions of all the lamp lines used for diffuser characterisation, and the values of the mean - minimum difference calculated for each monthly calibration sequence. These values were then used to adjust the lamp measurements via the diffuser, and the reflectivity values recalculated, neglecting data from lines so weak that they were less than the dark signal + three standard deviations. The results from the analysis both before and after performing this correction are shown in Table 2 below, in which the ESTEC results (June 1995 until September 1996) are also shown for comparison.

Channel	Old Mean	Old Trend	ESTEC Mean	ESTEC Trend	New Mean	New Trend
1	6.2	+9.0	5.9	+1.0	5.7	-3.0
2	5.6	+1.5	5.0	+2.9	5.2	+1.1
3	5.4	-1.5	4.8	+0.1	5.2	-0.2
4	5.4	-1.0	5.4	+2.4	5.3	+0.2

Table 2: GOME Diffuser Reflectivity and Trends (% per year)

The results and the zero change lines are shown in Figure 4. On these plots are also shown the errors associated with each point, and it can be seen that the small values of the trends, which are linear best fits weighted by the measurement precision, are well within the bounds of zero change.

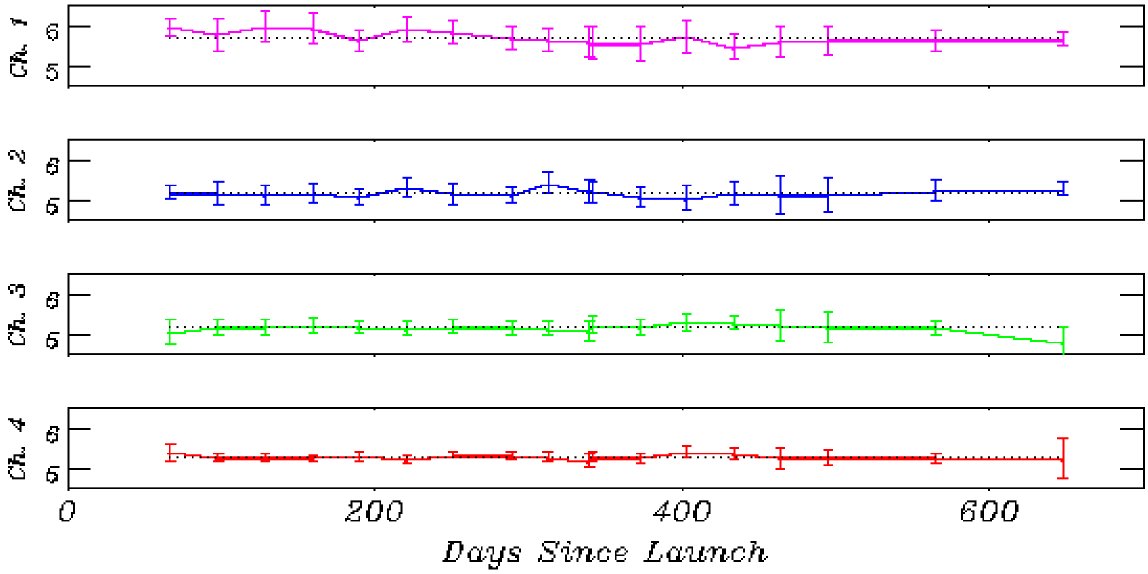

Figure 4: Diffuser Reflectivity (x 10,000) for all Channels

Conclusions

Over a period of more than eighteen months, the following conclusions regarding trends in the GOME dark signal and diffuser reflectivity have been reached.

No significant change is seen in the fixed pattern readout noise
There is an increase of ~15% per year in leakage current for all detectors
Leakage current measurements are becoming much noisier with time
No significant change is seen in the diffuser reflectivity

These results, from in-flight measurements, can be utilised to predict the likely degradation which will be encountered in missions with similar components, such as SCIAMACHY. One can further conclude that the measures taken to protect GOME's diffuser plate from degradation have been successful so far, with no significant reflectivity change having occurred.

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