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Long Term Monitoring of GOME Diffuser Reflectivity and Dark Signal Analysis

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1. Introduction

The Global Ozone Monitoring Experiment (GOME) was launched on ERS-2 in April 1995 and has been continuously operational since then. It is a scanning nadir-viewing spectrometer, with its primary scientific objective being to retrieve total column ozone globally. A more detailed description of the instrument can be found in *[1]*. In common with previous instruments to measure total column ozone from space such as TOMS and SBUV, it measures 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 at comparable intensity. These diffuser plates have been found to be subject to degradation (see *[2]* for example) particularly when subject to shorter wavelength ultra-violet light, and efforts have been made to characterize this degradation for instruments such as SBUV/2, where the diffuser plate was exposed for a total of around 750 hours between 1979 and 1986. 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, and characterisation of any degradation is possible by means of the on-board Pt/Cr/Ne calibration lamp. In order to investigate the GOME diffuser degradation, and to see if the measures taken have reduced the effect, a first analysis was done in January 1997. The results and detailed description are presented in technical note *[9]*. Updates on the analysis were done for the time periods June 1995 to December 1997, June 1995 to December 1998, June 1995 to September 1999, June 1995 to January 2000 and June 1995 until April 2000 (see technical notes *[10], [11], [12], [13]*). This document provides the update on the degradation analysis, using the monthly calibration data from June 1995 and August 2001 following the same algorithms as in *[9]*.

Remark: The GOME internal calibration lamp is used only for monthly calibration measurements since September 2001. Before it was also used for daily calibration measurements during one orbit each day for a duration of ~2.5 minutes. After frequently repeated occurrences of Lamp Failures since end of August 2001 the GOME daily calibration sequence was reduced to only solar measurements.

Please note, that during the monthly calibration sequences of July 2001 and August 2001also Lamp Failures occurred during orbits 32788 and 33234. Those measurements where not used for the analysis below.

2. Algorithm Descriptions

The detailed description of the algorithms used for the calculation of diffuser reflectivity and dark signal components can be found in *[9]*. Below a short description is given.

2.1 Dark Current Analysis algorithm

One orbit out of a monthly calibration data set is taken. These data are decomposed into the components from each different integration time.

Dark measurements performed during the daytime part of the orbit contained spectral features for integration times of channel 4 for 3s and 24 s. Further problems (crosstalk effects) were noticed in channel 2 for 1.5 s integration time, channel 3 for 0.375 s integration time and channel 4 for 0.09375 s. Therefore measurements with those integration times were excluded from the trend analysis.

From all measurements with valid integration times the gradient was calculated (Leakage Current). The Leakage Current is then used to extrapolate from the shortest integration time to get the offset as Fixed Pattern Readout (FPRN).

2.2 Diffuser Reflectivity Algorithm

For the diffuser reflectivity one orbit out of the monthly calibration sequence is taken. All lamp measurements against all lamp via diffuser measurements are ratioed (for individual lamp lines). A dark signal correction is applied for each lamp line. Where lines were so weak that they were less than the dark signal + 3SD, those data were neglected for the analysis. The results of all remaining individual lines are averaged and weighed (so that more weight is given to those lines with small error).

3. Results

3.1 Dark Current Analysis

The dark signal for GOME is defined as being comprised of two parts - a constant value of between 140 and 150 binary units (BU) which is the fixed pattern readout noise (FPRN) and a time dependent component of around 2 to 5 binary units per second which is the leakage current (LC). Trends were calculated for both the FPRN and the LC, and for the noise on these measurements. No significant change is seen in the fixed pattern readout noise. The increase of the Leakage current component is stable during lifetime and values 12-13% per channel per year. It is becoming much noisier with time though. The results are shown in Table 1 below and Figures 1 to 4.

Ch.	FPRN	Noise	LC	Noise
1	-0.02	-2.98	+11.9	+20
2	+0.16	+1.14	+13.0	+59
3	+0.03	+1.15	+12.7	+31
4	+0.05	-0.04	+ 13.0	+21

Table 1: GOME Dark Signal Trends;% per year

3.2 Diffuser Reflectivity

The diffuser reflectivity is calculated as the ratio of calibration lamp measurements and the lamp measurements via the diffuser. The result of the analysis for the diffuser reflectivity can be seen in Figure 5. The diffuser reflectivity remains stable for channels 3 and 4 during the whole analysed time set June 1995 - August 2001 at a value of ~$5.2 * 10^{-4}$ for both channels.

For Channel 1 and 2 the values for the diffuser reflectivity are constant within the error bars from June 1995 - December 2000, since February 2001 an offset is noticed from a value of ~$6*10^{-4}$ to a value of ~$7*10^{-4}$.

4. Conclusions

Over a period of about 6 years, 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 ~12-13% per year in leakage current for all detectors
- No significant change is seen in the diffuser reflectivity for channels 3 and 4.
- The diffuser reflectivity in channels 1 and 2 increased since February 2001
- To be considered should be a degradation of the Scan Mirror which is wavelength dependent and especially found in shorter wavelengths as pointed out by Snel (see *[14]*). Moon and sun observations were analysed as sources of stable radiation. The analysis showed that for both - lunar and solar measurements - a degradation of the same order of magnitude was resulting. However the lunar derived degradation was observed to be faster at several wavelengths after some years than the solar one. This could be explained with a scan-angle dependent degradation, as the main difference between sun and moon optical paths is the angle of incidence on the scan mirror. Further in that study a physical model was presented of a degrading scan mirror that is consistent with the degradation of the measurements.

  Note that the diffuser degradation algorithm ratios two signals obtained with different positions of the scan mirror, hence the results presented here also suffer from these scan mirror angular dependent degradation effects.

- Another study was performed on GOME irradiance measurements compared with ground-based measurements by Richter and Wagner (see *[15]*). NO_2 and BrO lv 2 values were determined in a longer time series using a single solar irradiance measurement and in comparison the daily solar irradiances. As a result GOME irradiance measurements were found to contain spectral artefacts, and it was concluded that there is an angle dependence of the spectral reflectivity of the diffuser plate and the variation in the incident of solar radiation on the diffuser during one year.

This analysis is performed within the PCS about every half year to monitor GOME in orbit instrument performance.

5. References

[1]: GOME User's Manual SP-1182
ESA Publications Division September 1995.

[2]: Report of the International Ozone Trends Panel
WMO Report No. 18 Vol. 1, §2.3.6 1988.

[3]: ERGO Software User's Manual
DOR-GO-QA-SUM Issue 1.0 12/12/1995

[4]: ERGO Design Document
DOR-GO-QA-DD Issue 2.0 12/12/1995

[5]: GOME Data QA - Specification of Instrument Parameters - S. Slijkhuis
SRON-GOME-QA-TN01 Issue 2/A 30/06/1995.

[6]: ERGO Test Report of Final S/W Delivery Dec-1995 - S. Slijkhuis
SRON-GOME-QA-TN04 Issue 1 09/02/1996.

[7]: Remote Sounding of Atmospheres by J.T. Houghton, F.W. Taylor and C.D. Rodgers
Cambridge University Press 1st Edition 1986.

[8]: Functional / Performance Test on GOME BBM - Olij, C. & Zoutman, A. E.
TPD-ERS-GO-MIR-11 Issue 2 1993

[9]: GOME Diffuser Reflectivity and Dark Signal Analysis - D. Pemberton
ERS2-GO-DDS-TN-001 Issue 1.0 1997

[10]: Long Term Monitoring of GOME Diffuser Reflectivity and Dark Signal Analysis- A. Dehn
ERS2-GO-DDS-TN-002 Issue 1.0 1998

[11]: Long Term Monitoring of GOME Diffuser Reflectivity and Dark Signal Analysis- A. Dehn
ERS2-GO-DDS-TN-003 Issue 1.0 22/03/1999

[12]: Long Term Monitoring of GOME Diffuser Reflectivity and Dark Signal Analysis- A. Dehn
ERS2-GO-DDS-TN-004 Issue 1.0 09/11/1999

[13]: Long Term Monitoring of GOME Diffuser Reflectivity and Dark Signal Analysis- A. Dehn
ERS2-GO-DDS-TN-005 Issue 1.0 April 2000

[14]: In-Orbit Optical Path Degradation: GOME Experience and SCIAMACHY prediction-
Ralph Snel ERS-ENVISAT Symposium Gothenburg October 2000

[15]: IDiffuser plate spectral structures and their influence on GOME slant columns- A.Richter and T.Wagner, technical note January 2001

Figures

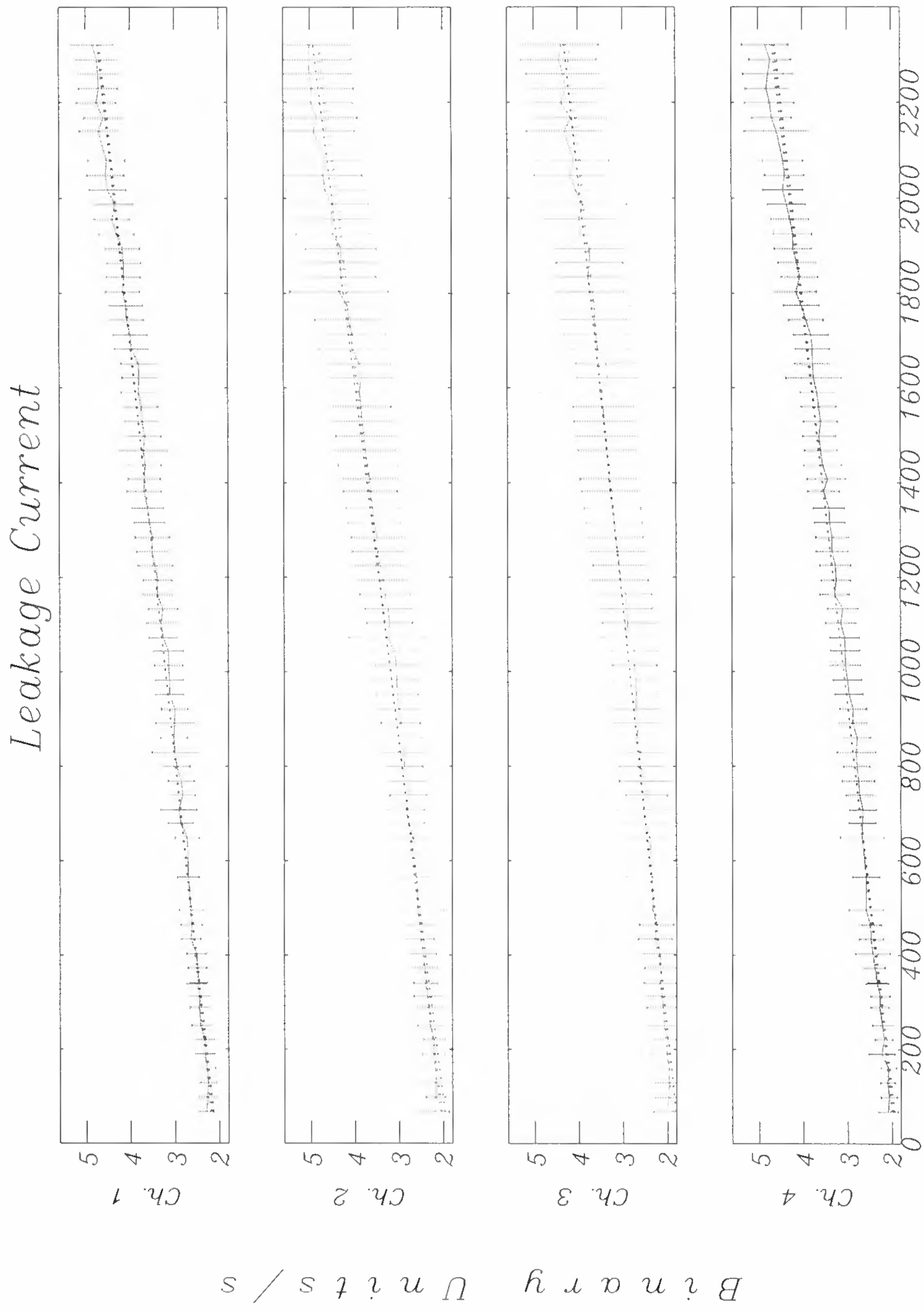

Figure 1: Leakage Current

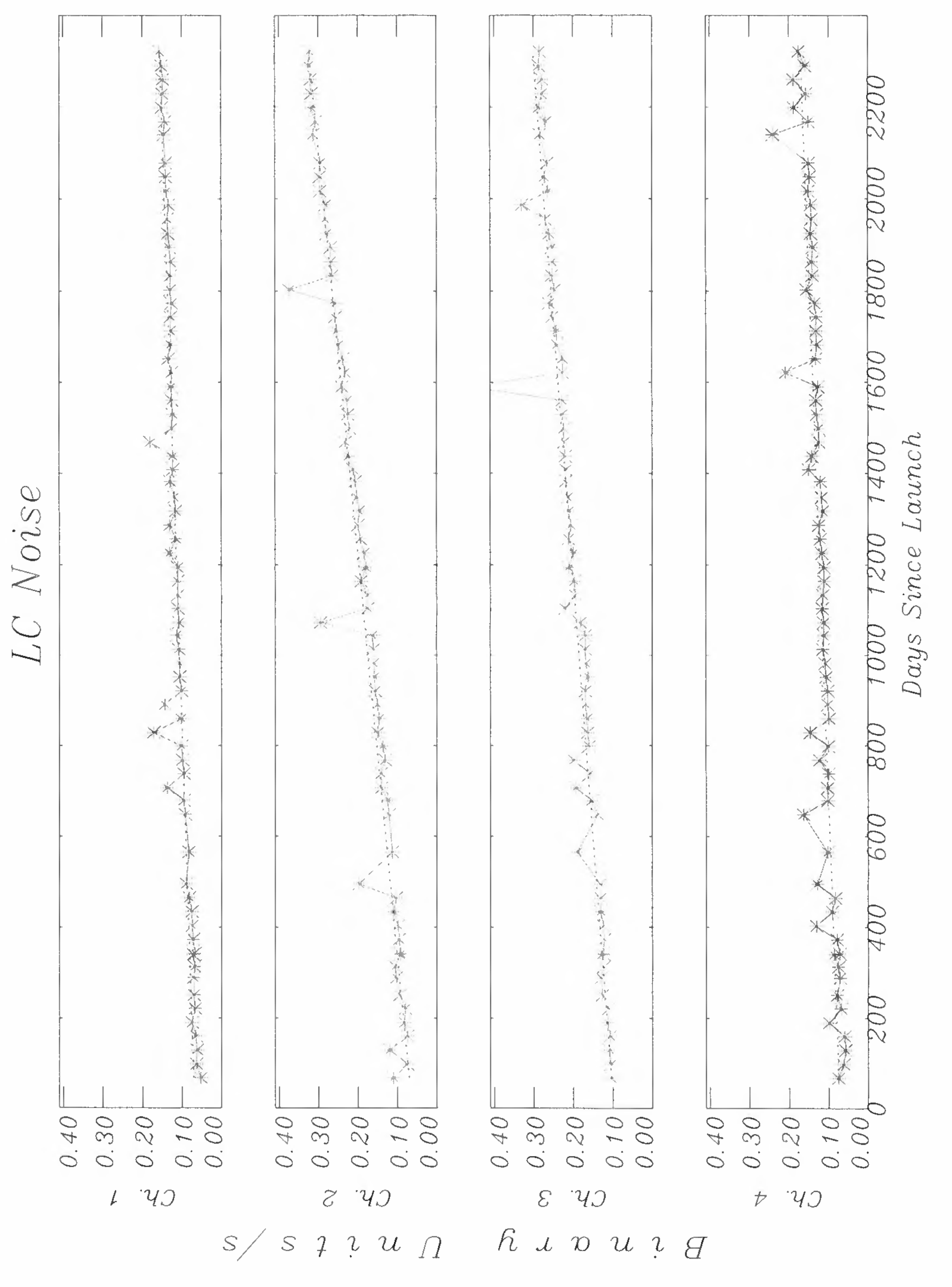

Figure 2: Leakage Current Noise

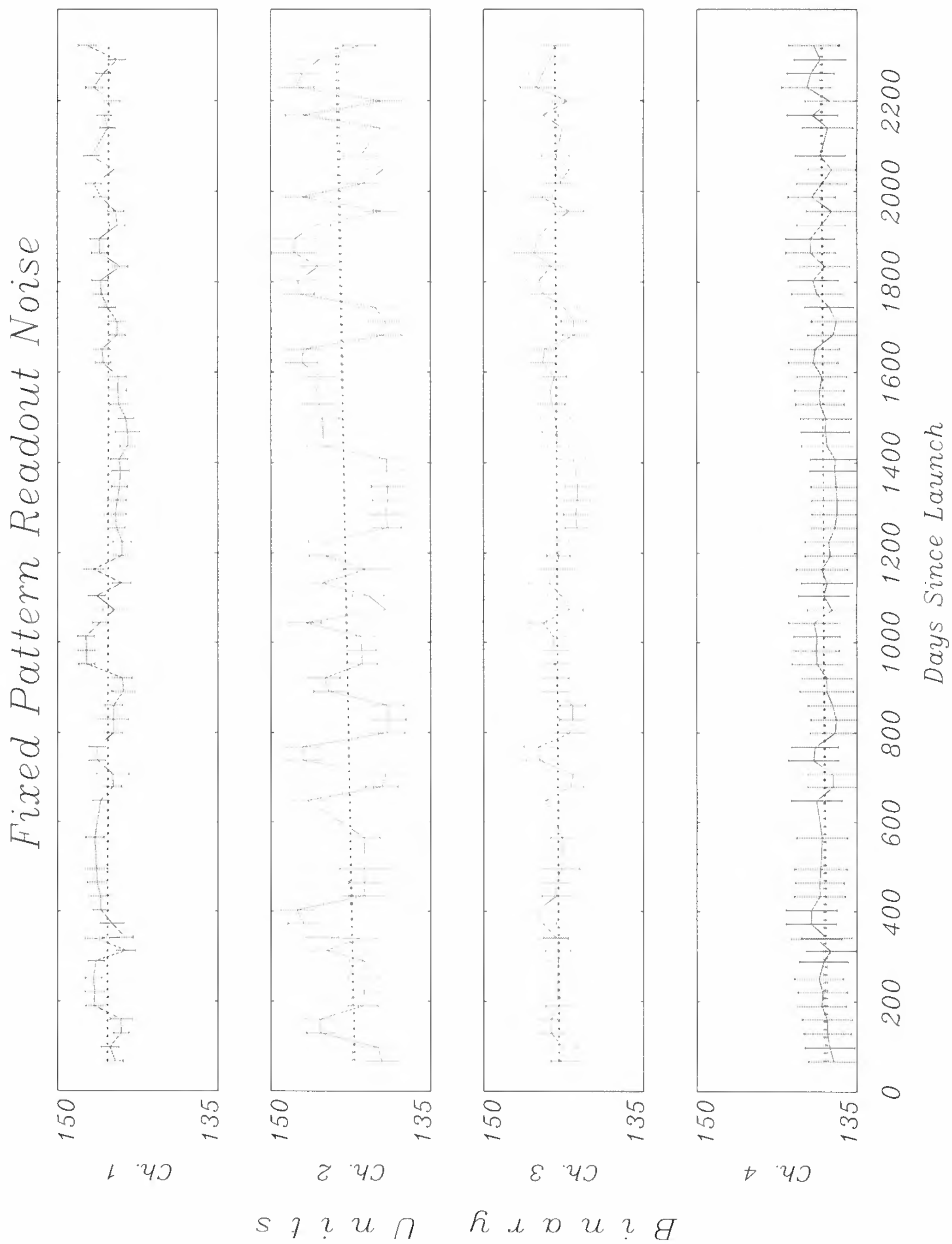

Figure 3: Fixed Pattern Readout Noise

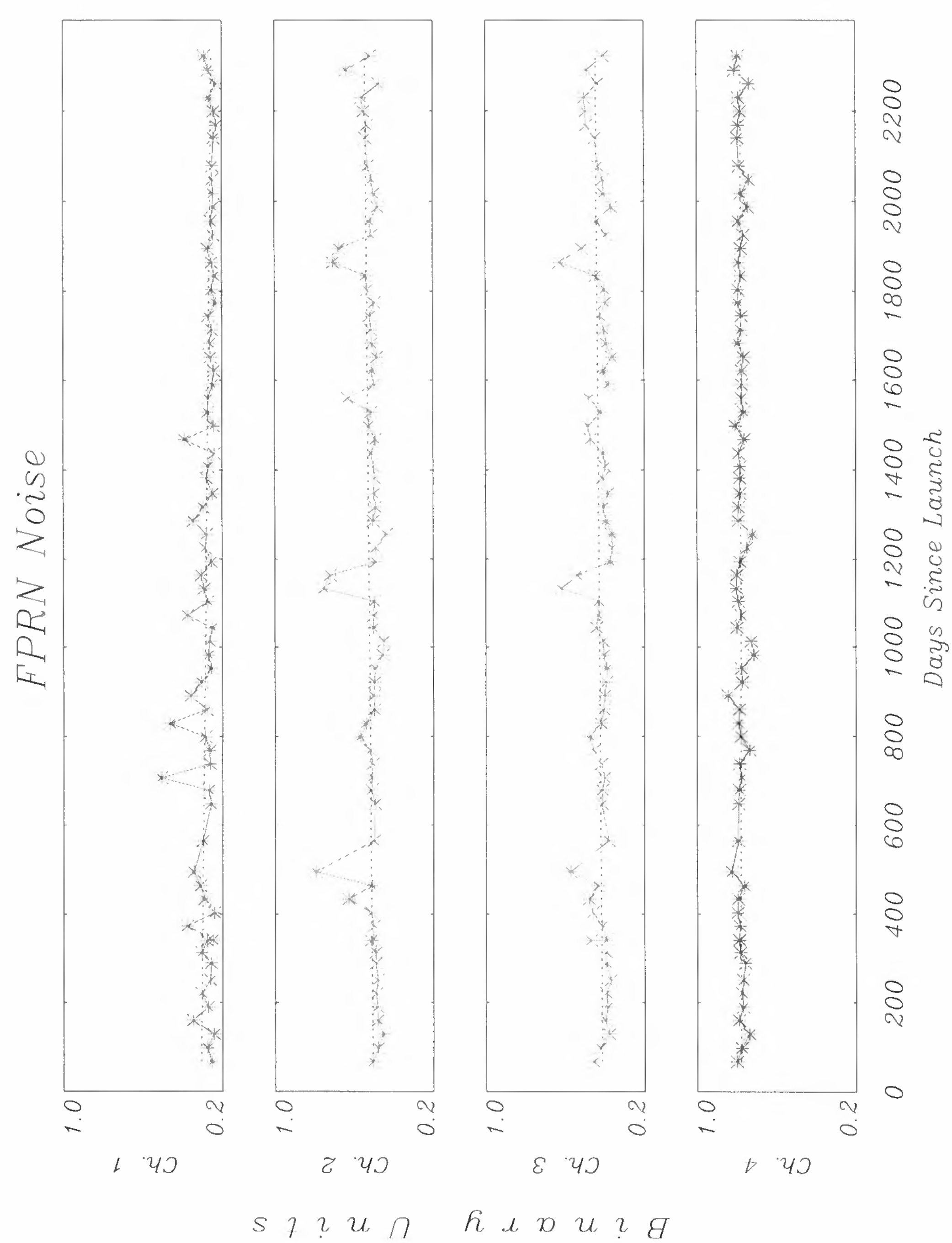

Figure 4: FPRN Noise

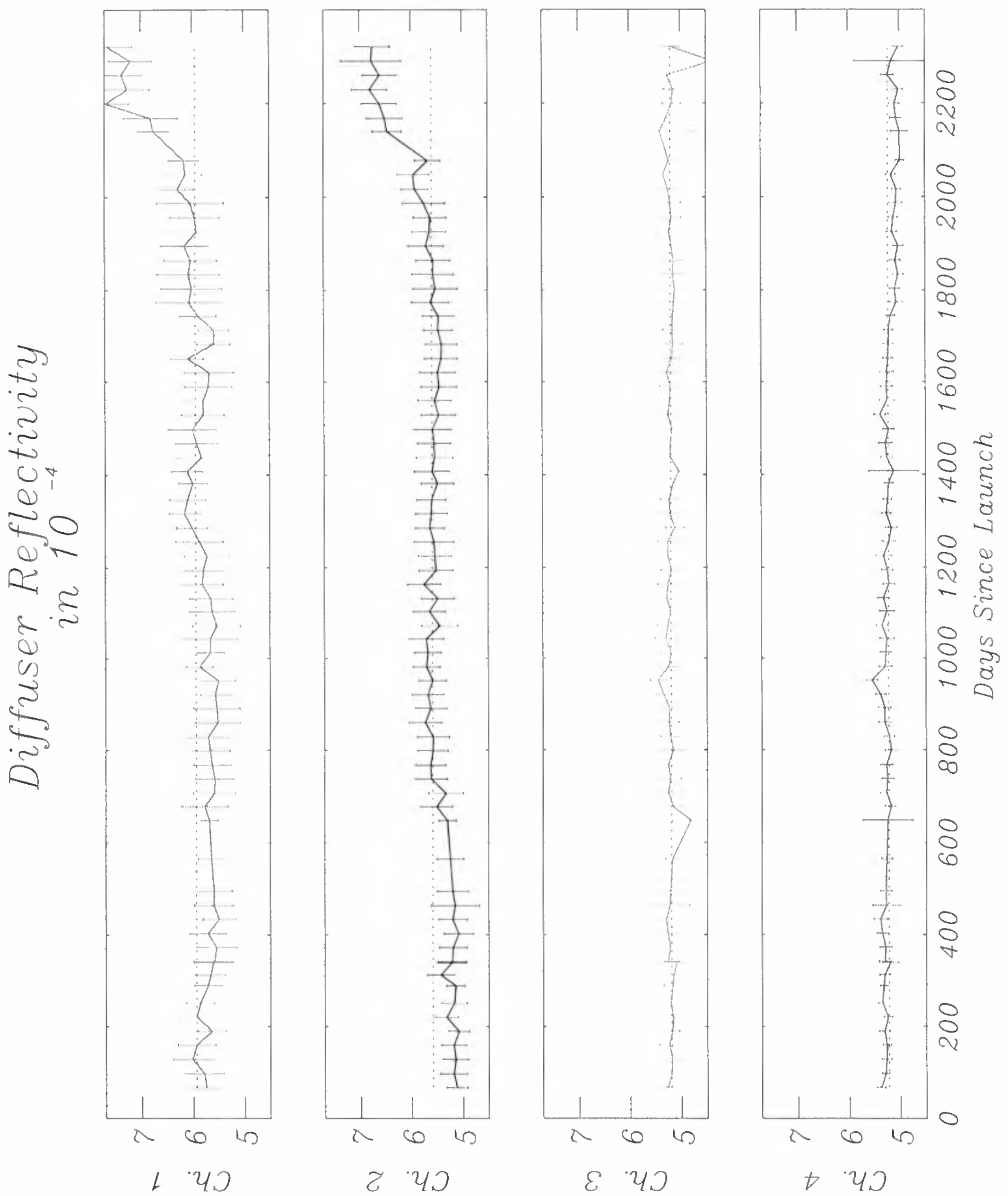

Figure 5: Diffuser Reflectivity (to be multiplied by 10^{-4})

Appendix A

Monthly Calibration Data Sets

Calibration Sequence	Date	Days From Launch	Orbits (No.)
1	27 June 1995	67	965 - 967; 969 (4)
2	28 July 1995	98	1410 - 1413 (4)
3	28 August 1995	129	1854 - 1857 (4)
4	28 September 1995	160	2298 - 2301 (4)
5	28 October 1995	190	2726 - 2730 (5)
6	28 November 1995	221	3171 - 3174 (4)
7	28 December 1995	251	3600 - 3604 (5)
8	04 February 1996	289	4144 - 4148 (5)
9	28 Februrary 1996	313	4488 - 4491 (4)
10	13 March 1996	327	4684; 4687 (2)
11	26 March 1996	340	4874 - 4878 (5)
12	28 March 1996	342	4902; 4904 - 4906 (4)
13	28 April 1996	373	5347 - 5350 (4)
14	28 May 1996	403	5776 - 5780 (5)
15	28 June 1996	434	6220; 6221; 6223 (3)
16	28 July 1996	464	6649; 6650 (2)
17	28 August 1996	495	7092 - 7096 (5)
18	28 September 1996	526	7536 - 7540 (5)
19	06 November 1996	565	8094 - 8098 (5)
20	28 January 1997	648	9282 - 9286 (5)
21	28 Februrary 1997	679	9726 - 9730 (5)
22	28 March 1997	707	10129 - 10132 (4)
23	28 April 1997	738	10570 - 10574 (5)
24	28 May 1997	768	11000 - 11004 (5)
25	28 June 1997	799	11444 - 11448 (5)
26	28 July 1997	829	11874 - 11877 (4)
27	28 August 1997	860	12318 - 12322 (5)

Calibration Sequence	Date	Days From Launch	Orbits (No.)
28	28 September 1997	891	12760 - 12764 (5)
29	28 October 1997	921	13190 - 13194 (5)
30	28 November 1997	952	13634 - 13638 (5)
31	28 December 1997	982	14064 - 14068 (5)
32	28 January 1998	1013	14508 - 14512 (5)
33	28 Februrary 1998	1044	14950 - 14954 (5)
34	28 March 1998	1072	15352 - 15356 (5)
35	28 April 1998	1103	15796 - 15800 (5)
36	28 May 1998	1133	16224 - 16228 (5)
37	28 June 1998	1164	16668 - 16672 (5)
38	28 July 1998	1194	17098 - 17102 (5)
39	28 August 1998	1225	17542 - 17546 (5)
40	28 September 1998	1256	17986 - 17990 (5)
41	28 October 1998	1286	18416 - 18420 (5)
42	28 November 1998	1317	18858 - 18862 (5)
43	28 December 1998	1337	19288 - 19292 (5)
44	02 February 1999	1382	19804 - 19808 (5)
45	28 February 1999	1408	20176 - 20180 (5)
46	28 March 1999	1437	20576 - 20580 (5)
47	28 April 1999	1468	21020 - 21024 (5)
48	28 May 1999	1498	21450 - 21454 (5)
49	28 June 1999	1529	21894 - 21898 (5)
50	28 July 1999	1560	22322 - 22336 (5)
51	28 August 1999	1590	22768 - 22770 (3)
52	28 September 1999	1621	23210 - 23214 (5)
53	28 October 1999	1651	23640 - 23644 (5)
54	29 November 1999	1682	24098 - 24102 (5)
55	28 December 1999	1712	24512 - 24516 (5)
56	28 January 2000	1743	24956 - 24960 (5)
57	28 February 2000	1774	25400 - 25404 (5)

Calibration Sequence	Date	Days From Launch	Orbits (No.)
58	28 March 2000	1803	25816 - 25820 (5)
59	28 April 2000	1834	26260 - 26264 (5)
60	28 May 2000	1864	26688 - 26692 (5)
61	28 June 2000	1895	27132 - 27136 (5)
62	28 July 2000	1925	27562 - 27566 (5)
63	28 August 2000	1956	28006 - 28010 (5)
64	28 September 2000	1987	28450 - 28454 (5)
65	28 October 2000	2017	28878 - 28882 (5)
66	28 November 2000	2048	29322 - 29326 (5)
67	28 December 2000	2078	29752 - 29756 (5)
68	28 February 2001	2140	30641 - 30644 (4)
69	28 March 2001	2168	31040 - 31044 (5)
70	28 April 2001	2199	31484 - 31488 (5)
71	28 May 2001	2229	31914 - 31918 (5)
72	28 June 2001	2260	32358 - 32362 (5)
73	28 July 2001	2290	32786 - 32790 (5)
74	28 August 2001	2321	33230 - 33233 (5)

Appendix B

Lamp Lines Used For Diffuser Calibration

Channel 1				Channel 2		
Line Number	Wavelength / nm	Pixel Number		Line Number	Wavelength / nm	Pixel Number
1	244.08	313.79		1	321.91	275.71
2	248.79	353.41		2	332.47	368.00
3	262.88	475.23		3	337.92	415.96
4	266.02	503.16		4	352.15	542.43
5	273.48	569.93		5	369.53	698.64
6	281.03	638.76		6	372.82	728.42
7	283.11	657.69		7	390.99	893.48
8	293.06	749.28		8	392.03	903.05
9	299.88	812.66				
10	304.35	854.03				
11	306.56	874.64				

Channel 3				Channel 4		
Line Number	Wavelength / nm	Pixel Number		Line Number	Wavelength / nm	Pixel Number
1	425.55	145.6		1	588.35	44.42
2	427.60	155.2		2	594.65	72.22
3	429.09	162.2		3	597.72	85.92
4	437.25	200.6		4	603.17	109.43
5	460.20	309.8		5	607.60	130.53
6	492.36	464.5		6	609.79	140.45
7	503.92	520.3		7	613.01	155.21
8	540.21	694.7		8	616.53	171.30

Channel 3				Channel 4		
Line Number	Wavelength / nm	Pixel Number		Line Number	Wavelength / nm	Pixel Number
9	556.43	772.0		9	621.90	196.02
10	574.99	859.4		10	626.82	218.84
11	576.60	866.8		11	630.65	236.66
12	580.61	885.5		12	638.47	273.25
13	582.18	892.7		13	653.47	344.13
14	588.35	921.3		14	660.08	375.64
15	594.65	950.4		15	668.01	413.61
16	597.72	964.1		16	693.14	534.83
17	603.17	988.6		17	717.59	653.62
18	607.60	1008.5		18	724.72	688.28
				19	744.09	782.40
				20	749.09	806.62
				21	753.79	829.28