

LPM 2002

Field performance summary

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V1 22/7/03

V1.1 22/2/04

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## **1. Introduction**

This report gives an analysis of the performance of the eleven LPMs operating on the Plateau in 2002.

Overall data coverage was 79.6% and noise is now better than +/- 2.3nT.

The site positions, names and deployment dates are given in appendix 1.

Recommendations and comments about future work are given in section 7

## **2.1 Performance summary**

Over the eleven systems, total operation was 3597 days out of a possible 4239 or 84.8%. One logger was faulty on deployment (M88/316), without this system the operational coverage would have been 88.9%.

Total data coverage is less, due to disks filling on two systems (discussed later), 3527 days out of possible 4239 or 83.2%.

On a system level, three of the eleven sites had faults that resulted in data loss.

In common with last year, systems that suffered restarts eventually failed.

## **2.2 Performance details**

M78/337 - Dr Leech

Operated from deployment 17/12/01 to 11/12/02 when data card ran out.  
359 days from 393 days possible.

No restarts.

No missed GPS fixes.

All data at 1s resolution apart from:

12/9/02 until 27/09/02 at 3s resolution.

M79/336 - Bob

Operated from deployment 13/12/01 to 09/12/02 when data card ran out.  
361/397 possible.

No restarts.

No missed GPS fixes.

Data at 1s apart from:

20/09/02 until 10/10/02 at 3s.

M81/338 - A80 - Edmund

Operated from deployment 15/01/02 until pickup 14/01/03.  
364/364 possible.

No restarts.

24 missed GPS fixes out of 8117 possible.

Data at 1s apart from:

27/07/02 until 13/09/02 at 3s.

M82/003 - A81 - Mrs Miggins

Operated from deployment 17/12/01 until unexplained stop on 05/09/02.  
262/393 possible.  
Restart 03/09/02.  
136 missed GPS fixes out of 5427 possible.  
Data at 1s apart from:  
27/03/02 until 30/06/02 at 3s.  
30/06/02 until 04/09/02 at 60s.

M83/348 - Baldrick

Operated from deployment 13/12/01 until pickup on 22/01/03  
405/405 possible.  
No restarts.  
1 missed GPS fix out of 8898 possible.  
Data at 1s apart from:  
09/04/02 until 24/07/02 at 3s.  
24/07/02 until 07/09/02 at 60s.  
07/09/02 until 12/09/02 at 3s.

M84/336 - Baron Richthoven

Operated from deployment 16/01/02 until pickup 17/01/03  
366/366 possible.  
No restarts.  
No missed GPS fixes.  
Data at 1s apart from:  
06/04/02 until 08/09/02 at 3s.  
08/09/02 until 12/09/02 at 60s.  
12/09/02 until 18/09/02 at 3s.

M85/002 - Lord Melchett

Operated from deployment 17/12/01 until explained stop at 27/03/02.  
100/396 possible.  
No restarts.  
11 missed GPS fixes out of 2011 possible.  
Data at 1s apart from:  
26/03/02 until 27/03/02 at 3s.

#### M85/096 - Baby Eating Bishop

Operated from deployment 21/01/02 until pickup 05/02/03.

380/380 possible.

No restarts.

71 missed GPS fixes out of 5354 possible.

Data at 1s apart from:

30/03/02 until 05/04/02 at 3s.

05/04/02 until 27/10/02 at 60s.

27/10/02 until 28/10/02 at 3s.

#### M87/028 - Flash Heart

Operated from deployment 19/01/02 until pickup 05/02/03.

382/382 possible.

No restarts.

3 missed GPS fixes out of 6829 possible.

Data at 1s apart from:

19/03/02 until 15/06/02 at 3s.

15/06/02 until 21/10/02 at 60s.

21/10/02 until 07/11/02 at 3s.

#### M87/069 - Speckled Jim

Operated from deployment 22/01/02 until pickup 06/02/03

380/380 possible.

No restarts.

37 missed GPS fixes out of 6106 possible.

Data at 1s apart from:

29/03/02 until 10/04/02 at 3s.

10/04/02 until 03/10/02 at 60s.

03/10/02 until 05/10/02 at 3s.

#### M88/316 - Lord Whiteadder

Operated from deployment 19/01/02 until unexplained stop 23/06/02

1 restart, operated from 20/1/03 to 2/2/03.

168/383 possible.

1 restart.

2 missed GPS fixes out of 979 possible.

All data at 60s resolution.

### 2.3 Observations on the performance coverage.

#### Sampling rate

The sampling rate is lowered to lessen power usage and is decided upon by a calculation of remaining battery capacity, in 2002 the possible sampling rates were 1s, 3s, 60s. In 2002, battery temperature was not considered in determining the remaining battery capacity.

In 2003, an allowance for battery temperature was added in to the rate determination function which should result in the systems staying at 1s for longer. In addition, in 2003, the sampling rates available have been changed to 1s,10s,60s, which should result in much less data recorded at 60s resolution. In addition the GPS and Housekeeping rate has been slowed from 1 every hour to one every 6 hours which will lower both the average power and the disk usage.

2002		2003	
Sample rate	Ave Power	Sample rate	Ave Power
1s	508mW	1s	424mW
3s	252mW	10s	79mW
60s	81mW	60s	47mW

Table 1. Ave Power usage in 2002 and 2003.

As an example; M83/348 in 2002 after sundown operated for 6 days at 1s sampling, 106 days at 3s sampling and then 45 days at 60s sampling. In 2003 it can be expected that after sundown M83/348 will stay at 1s sampling for approximately 50 days and then the rest of the winter at 10s sampling (if on solar power alone).

Small wind generators have been fitted to the 7 most southerly sites in the 2002/3 season which should result in more power at those sites and hence more fast sampling, although the performance increase is difficult to predict.

## Disk usage

Two factors resulted in higher disk space usage than expected this year. Firstly the GPS and HK sampling rate was erroneously left at 1 per hour rather than once every 6 hours, and the systems were serviced early last season and late this season, in the case of M83/348 going 405 days between servicing. This resulted in the two most northern systems (which ran longest at 1s sampling) running out of disk space; in the case of M79/336, 36 days before servicing.

In 2002 the 192MB disk would have lasted 352 days at 1s sampling, in 2003 we can expect the same disk to last 366 days. In 2004 256MB disks will be fitted which should last 487 days at 1s sampling.

The following should be used as the last date for servicing in the 2003/4 season in order to avoid data loss.

Site	Latest servicing date
M78/337	14/01/04
M79/336	15/01/04
M81/338	15/01/04
M82/003	14/01/04
M83/348	26/01/04
M84/336	15/01/04
M85/002	16/01/04
M85/096	05/02/04
M87/028	05/02/04
M87/069	06/02/04
M88/316	06/02/04

Table 2. Service dates in 2003/4 to avoid data loss

## Podule positions

Table 3 contains the podule serial number at each site. The podules were rotated in 2002 to help locate the fault that occurred at M84/336 in 2001. New podules have been fitted for 2003. The intention is to refurbish the 2002 set for redeployment in 2004.

Site	2001	2002	2003
M78/337	L01	L03	L39/02
M79/336	L02	L04	L40/02
M81/338	L04	L06	L37/02
M82/003	L06	L07	L38/02
M83/348	L07	L01	L41/02
M84/336	L03	L05	L36/02
M85/002	L05	L02	L35/02
M85/096	NA	L22	L32/02
M87/028	NA	L21	L31/02
M87/069	NA	L23	L33/02
M88/316	NA	L24	L34/02

Table 3: Podule locations.

Podule L03 failed at M84/336 in 2001, but performed fine at M78/337 in 2002, as did podule L05 at M84/336 in 2002. Hence neither podule or site seem to have a recurring fault.

Podule L07 had very poor GPS coverage at M83/348 in 2001. M83/348 (with podule L01) had good GPS coverage in 2002, podule L07 (at M82/003) had reasonable coverage in 2002 but remained as the worst performing GPS unit, hence the GPS unit in L07 will be replaced before its redeployed.

### 3. Magnetometer data.

#### 3.1 Absolute values.

Table 4a contains a comparison of a spot value from each system (the middle of the second data block) compared with the IGRF modelled value for January 1<sup>st</sup> 2001.

The values from the magnetometer have not been adjusted for temperature (which would add in the order of 0.1% to the readings), or the analog card calibration (typically +/- 0.5%).

Site	IGRF H in nT 2001	IGRF Z in nT 2001	2001 H in nt	2001 Z in nt	2002 H in nT	2002 Z in nT
M78/337	19590	40978	19045	40835	19093	40970
M79/336	19490	42566	19787	41951	19759	41947
M81/338	19251	44348	19332	44281	19412	44148
M82/003	18974	45079	19674	44511	19634	44755
M83/348	18837	46274	18873	46217	18450	46274
M84/336	18519	47860	17850	47511	17874	47564
M85/002	18139	48909	17757	48669	17596	48728
M85/096	15752	54672			16735	54454
M87/028	17495	50792			17178	50866
M87/069	16678	52773			17728	52503
M88/316	17276	51644			17369	51025

Table 4a. Absolute field strengths compared to IGRF model.

It is worth noting that the Z axis alignment error is probably in the region of +/- 0.5° (field alignment error of the magnetometer tube) and the orthogonality error between the axes is also specified by the manufacturer to be +/-0.5°

The measurements are in very good agreement with the IGRF model, indicating that the sensors have been installed correctly and are working, and that the analog card is working as expected in the DC field.

The values from the systems are broadly in good agreement with the IGRF model. Where differences do exist, the difference seems stable from year to year indicating that the 'error' is either in the model, the alignment of the sensor, or the calibration of the sensor, rather than in the podule electronics.

Table 4b contains spot raw x,y,z values from the magnetometer, these are primarily of use to show that the sign of the readings is consistent and to give a rough estimation of how much the data needs to be rotated in order to put it in the H,D,Z coordinate system.

<b>Site</b>	<b>2001 X nT</b>	<b>2001 Y nT</b>	<b>2001 Z nT</b>	<b>2002 X nT</b>	<b>2002 Y nT</b>	<b>2002 Z nT</b>
M78/337	+13800	-13100	-40900	+13900	-13050	-40850
M79/336	+19700	-900	-41950	+19750	-850	-41950
M81/338	-4700	-18850	-44150	-4600	-18800	-44300
M82/003	+19550	-2500	-44750	+19500	-2450	-44500
M83/348	+18450	+350	-46250	+18850	+550	-46250
M84/336	-17820	-1700	-47550	-17750	-1700	-47500
M85/002	+5550	+16750	-48700	+5600	+16850	-48700
M85/096				+15140	-7050	-54500
M87/028				-17150	+110	-50850
M87/069				+13900	-10250	-52550
M88/316				-17350	-150	-51100

Table 4b. Raw x,y,z values to the nearest 50nT

### 3.2 Magnetometer samples.

The following pages contain graphs of the raw X, Y and Z nT readings from the 2<sup>nd</sup> datablock from each site. Note the Y scale can change from graph to graph.

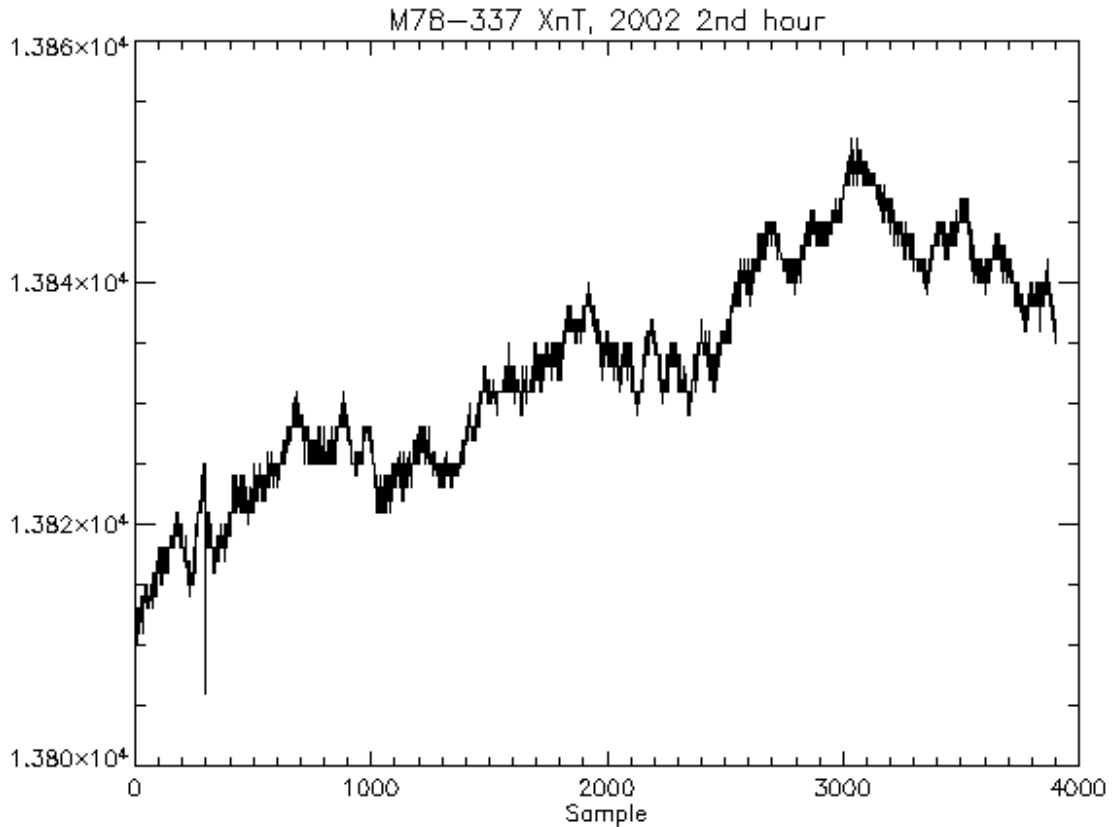


Figure 1. The X readings for the 3900s of the second datablock for M78-337. The minor tick of the Y axis is 5nT.

Overall the graph shows much improved noise from those in 2001 (where the noise was approx +/- 25nT). The single point which is 15nT lower which occurred at sample 300 happened when the GPS unit was switched off.

Figure 2 shows a 5 minute period within the same datablock. The minor Y tick is 1nT. A 20s smoothed version of the same data is shown for comparison (offset by 10nT for clarity).

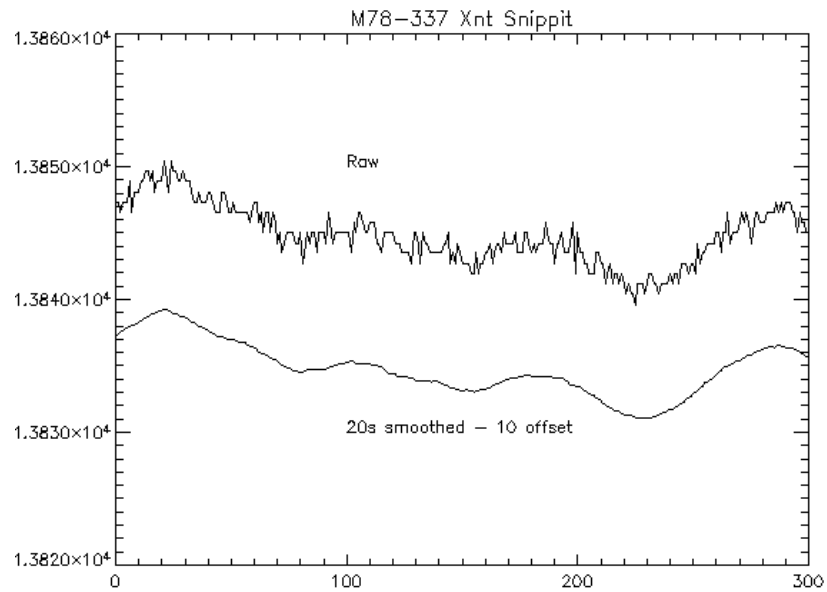


Figure 2 – M78-337, 5 minute period, raw and smoothed.

Figure 3 shows the residual of the raw data minus the 20s smoothed data. This shows that the noise is generally better than  $\pm 3$  counts, or 2.3nT. The 15nT 'blip' as the GPS turns off is apparent.

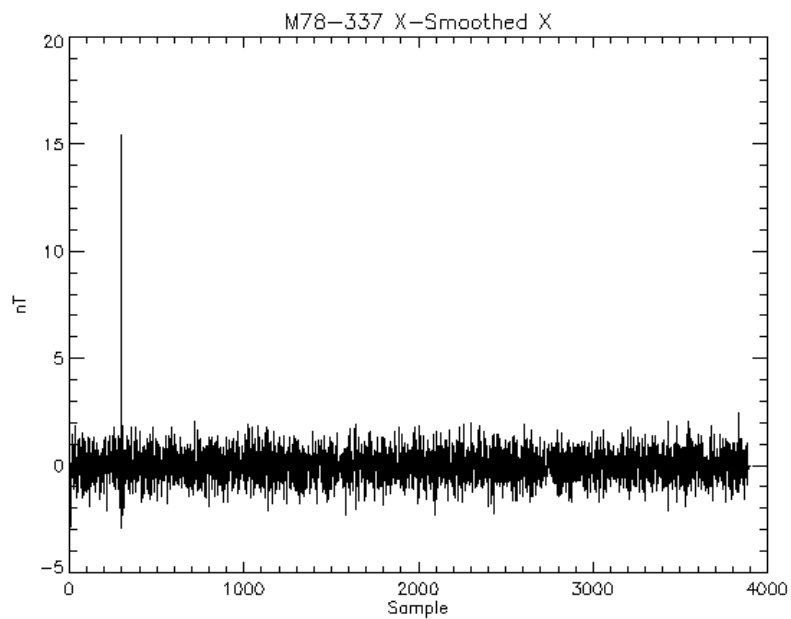


Figure 3 - Residual of Raw X minus 20s smoothed X.

Figure 4 shows the raw Y values, and figure 5 the raw Z values. They both show general noise similar to that on the X channel (ie better than +/- 2.3nT) but both show a blip and an offset when the GPS is turned off (sample 300). In the case of the Z channel this offset is around 12nT – This will be discussed latter.

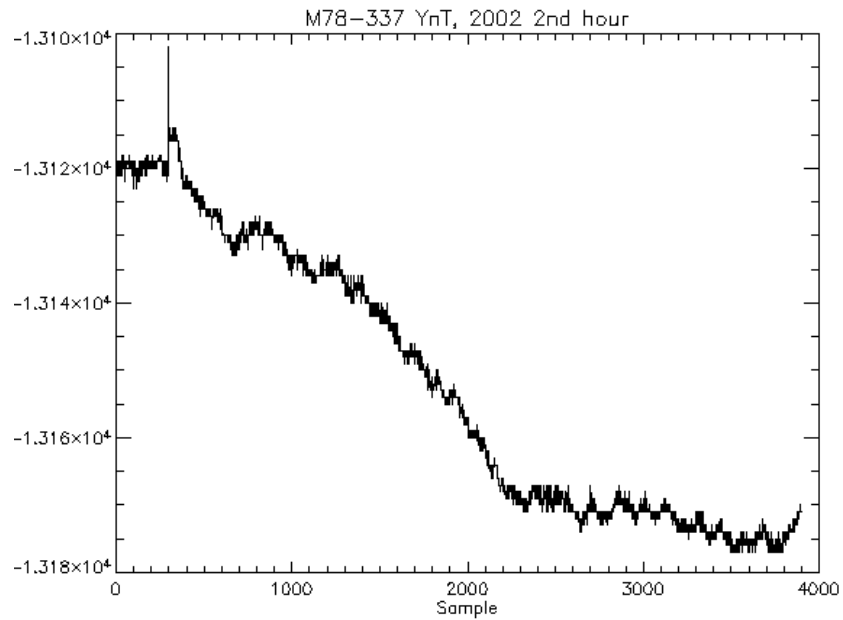


Figure 4 - Raw Y from M78-337

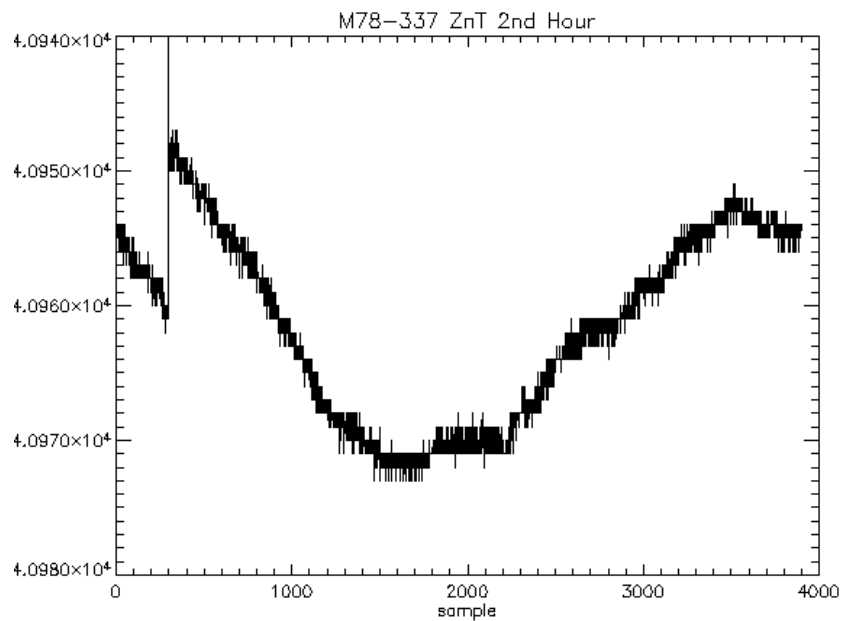


Figure 5 - Raw Z from M78-337.

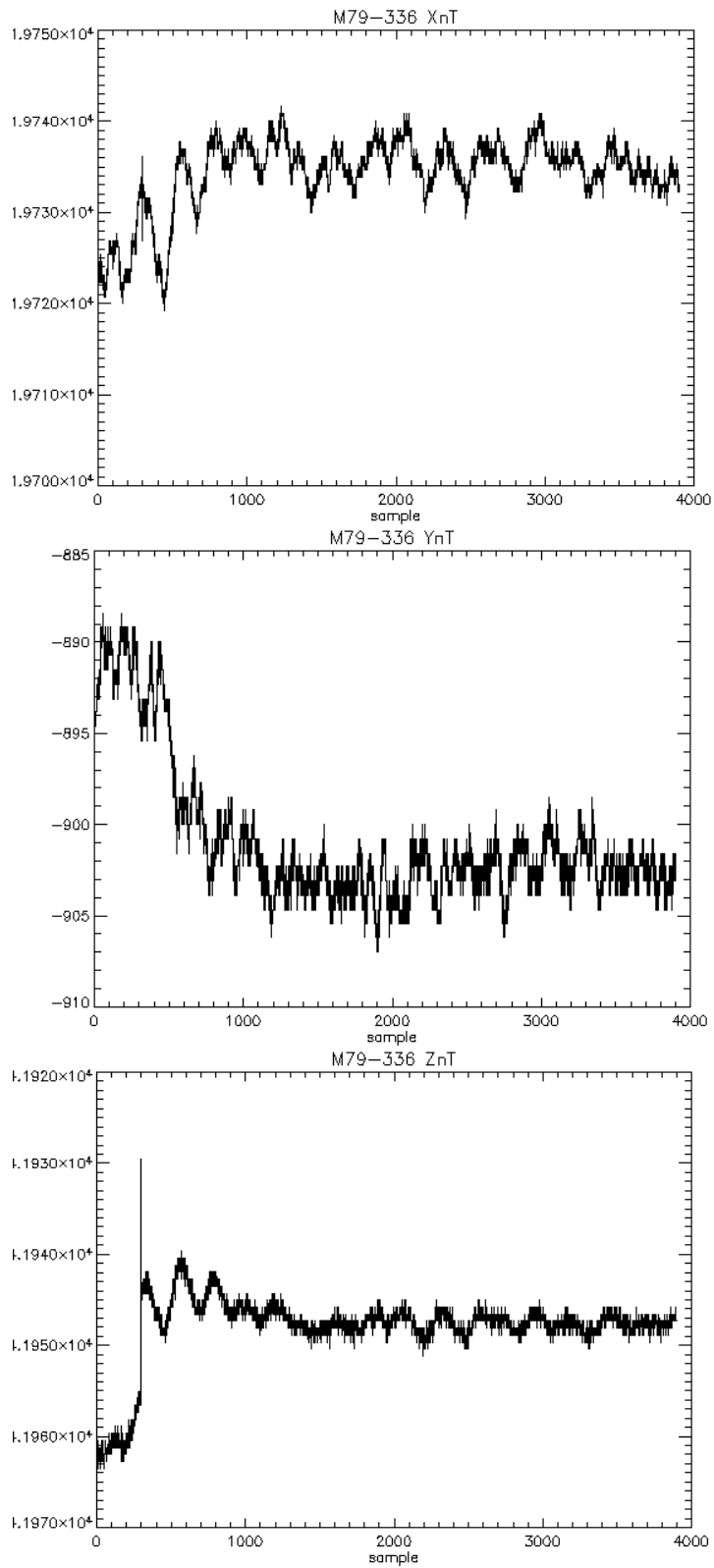


Figure 6 – X,Y,Z from M79-336.

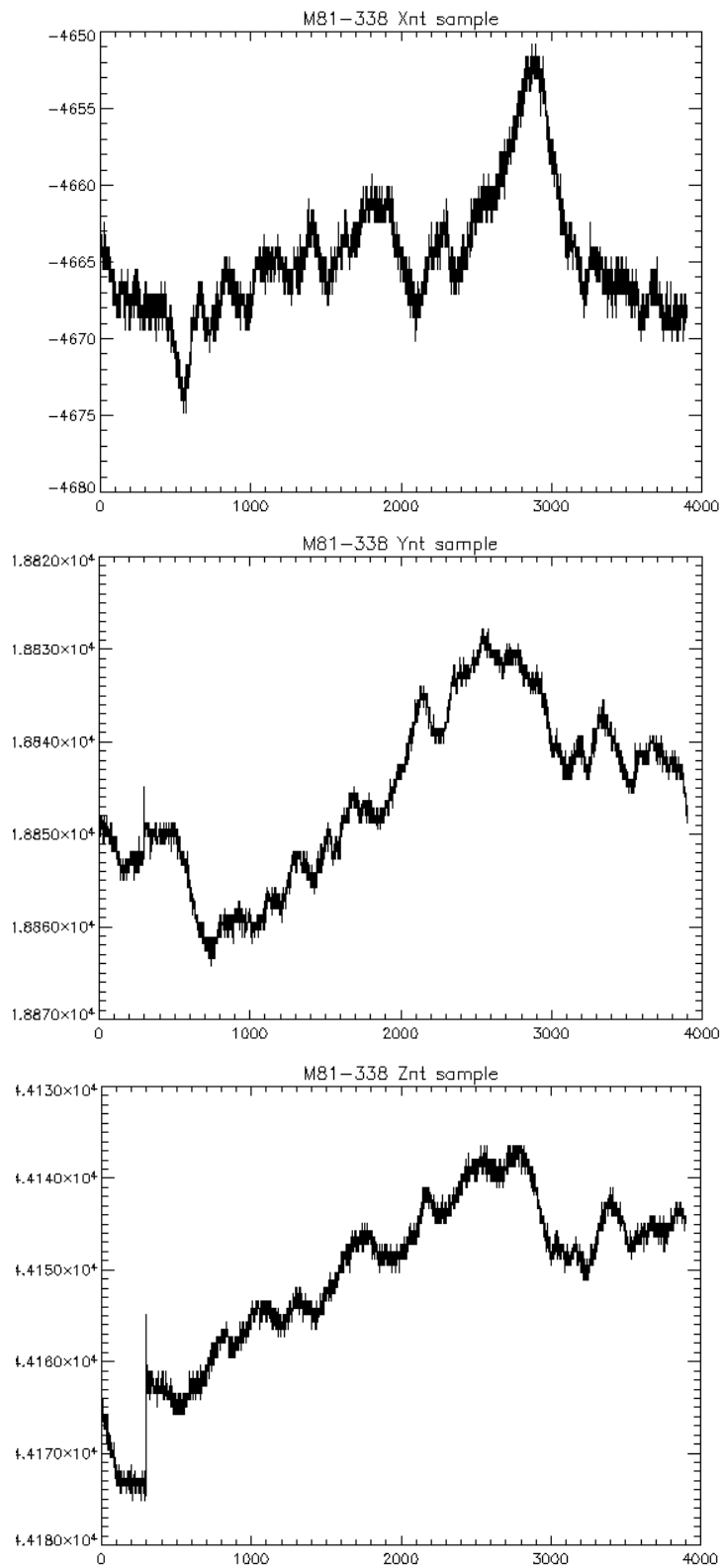


Figure 7 – X,Y,Z values from M81-338.

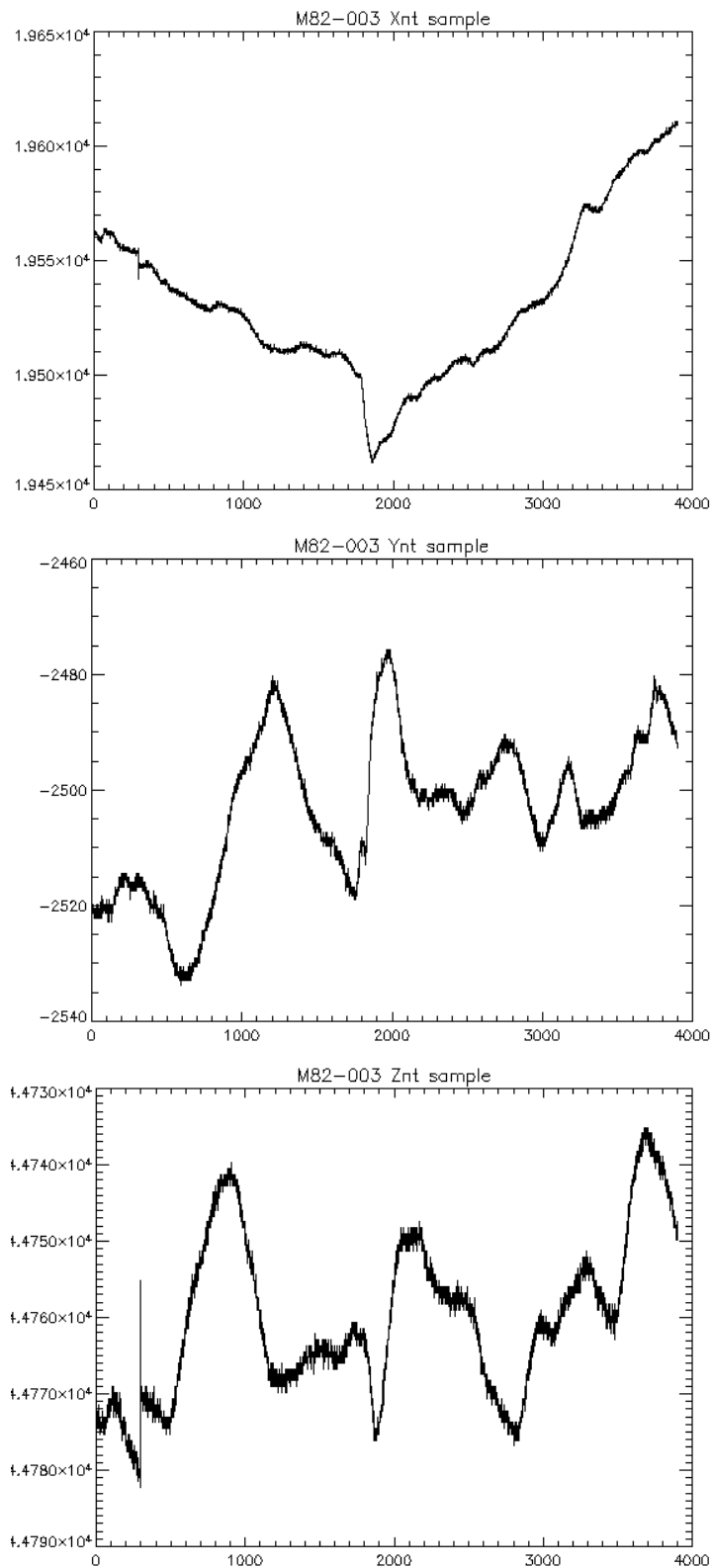


Figure 8 – X,Y,Z values from M82-003.

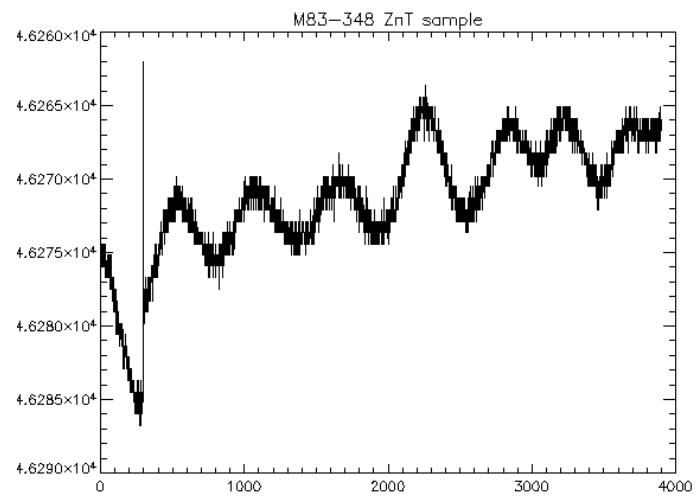
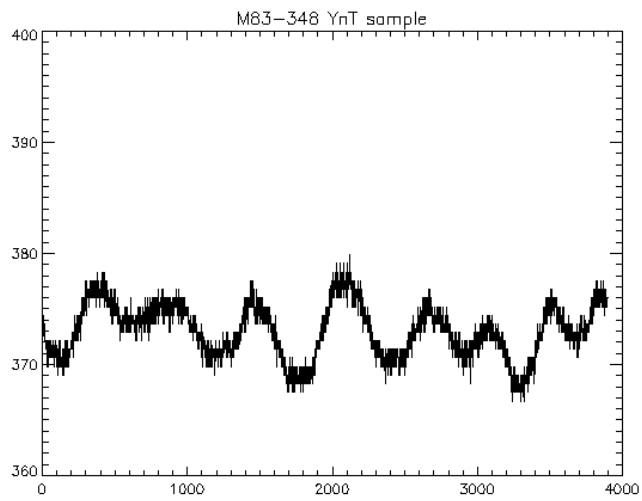
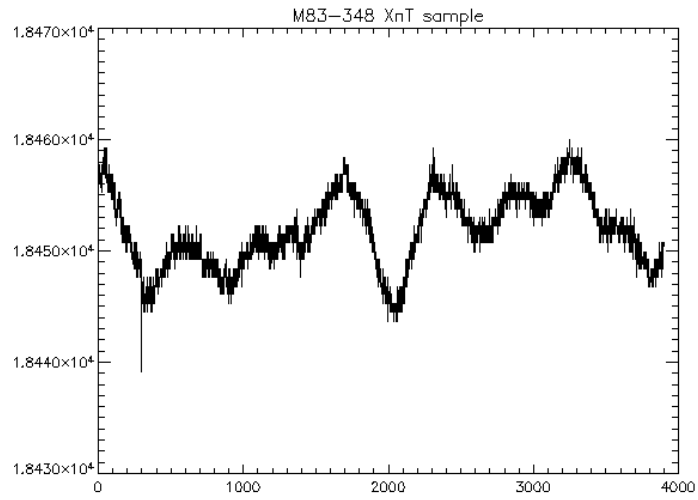


Figure 9 – X,Y,Z values from M83-348.

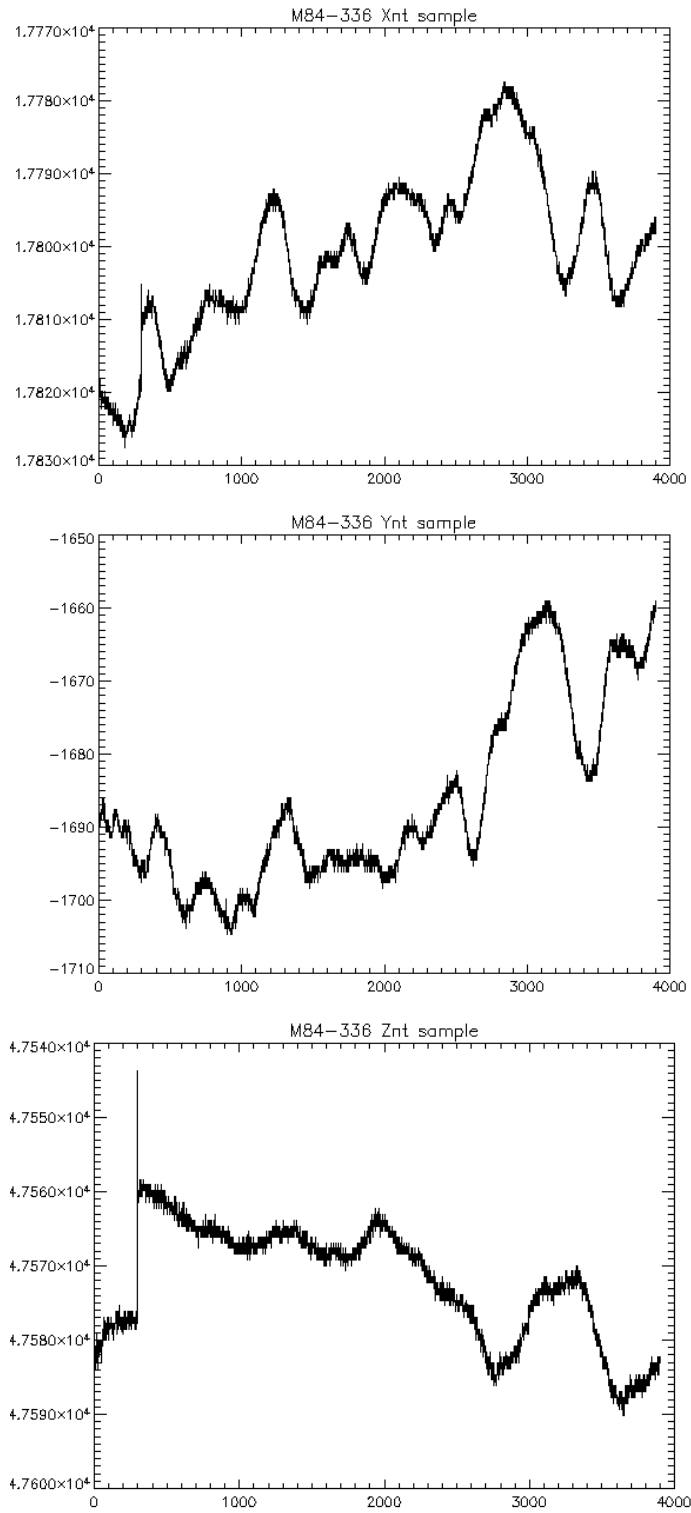


Figure 10 – X,Y,Z values from M84-336.

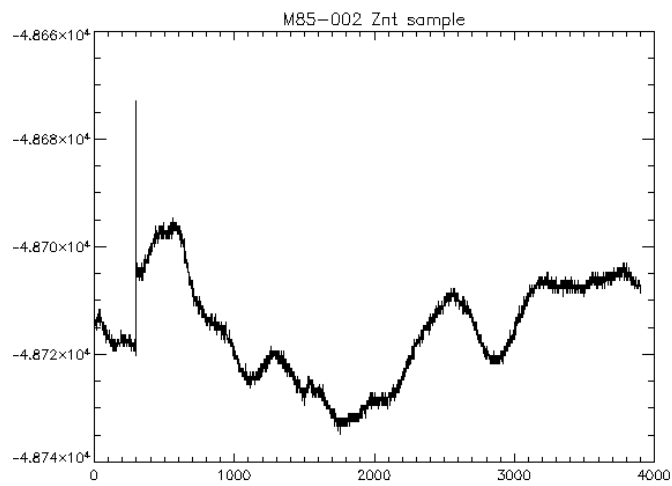
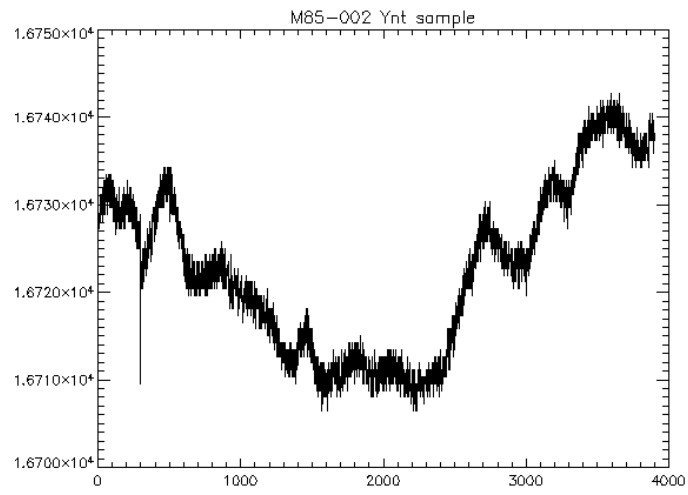
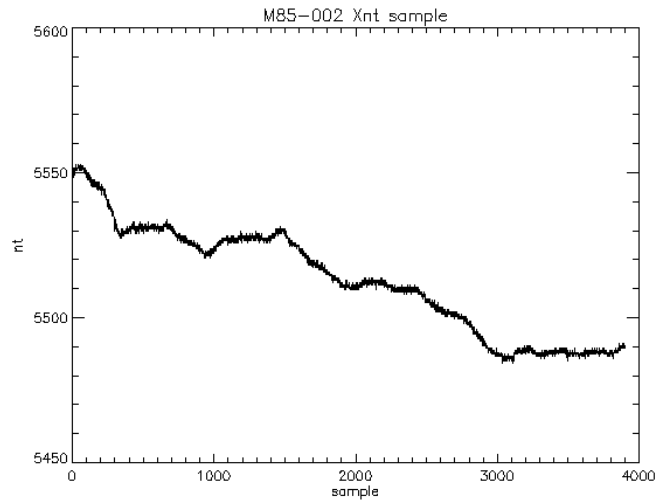


Figure 11 – X,Y,Z values from M85-002.

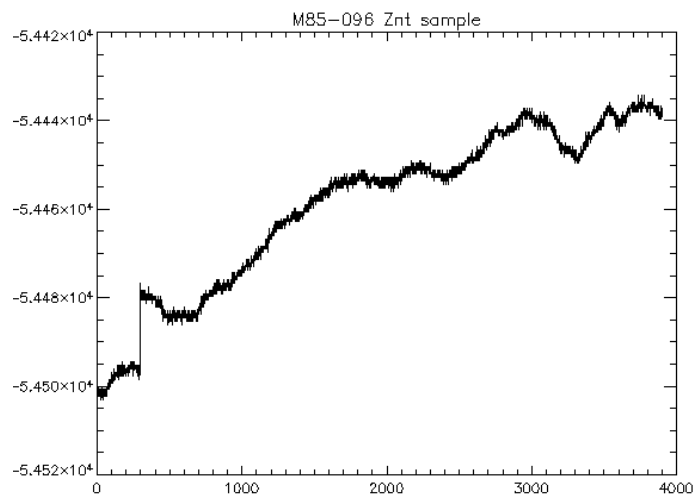
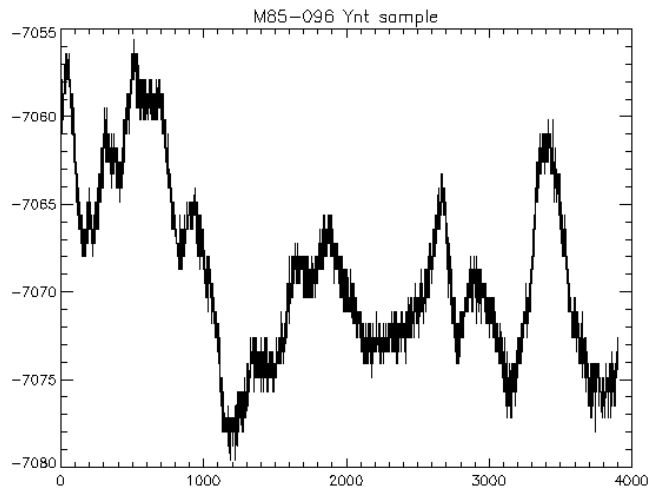
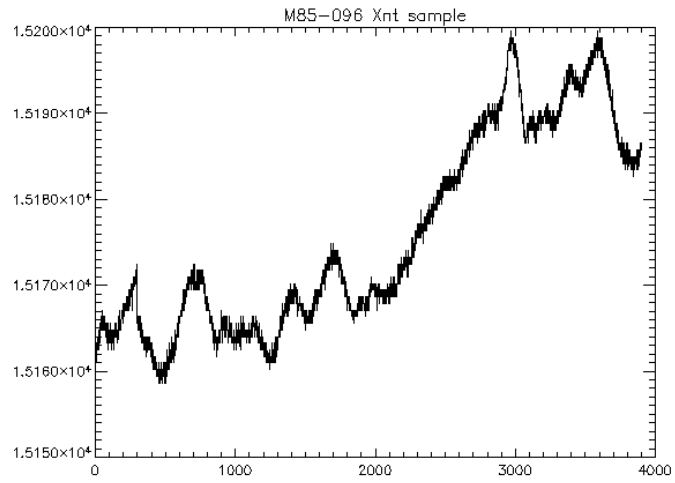


Figure 12 – X,Y,Z values from M85-096.

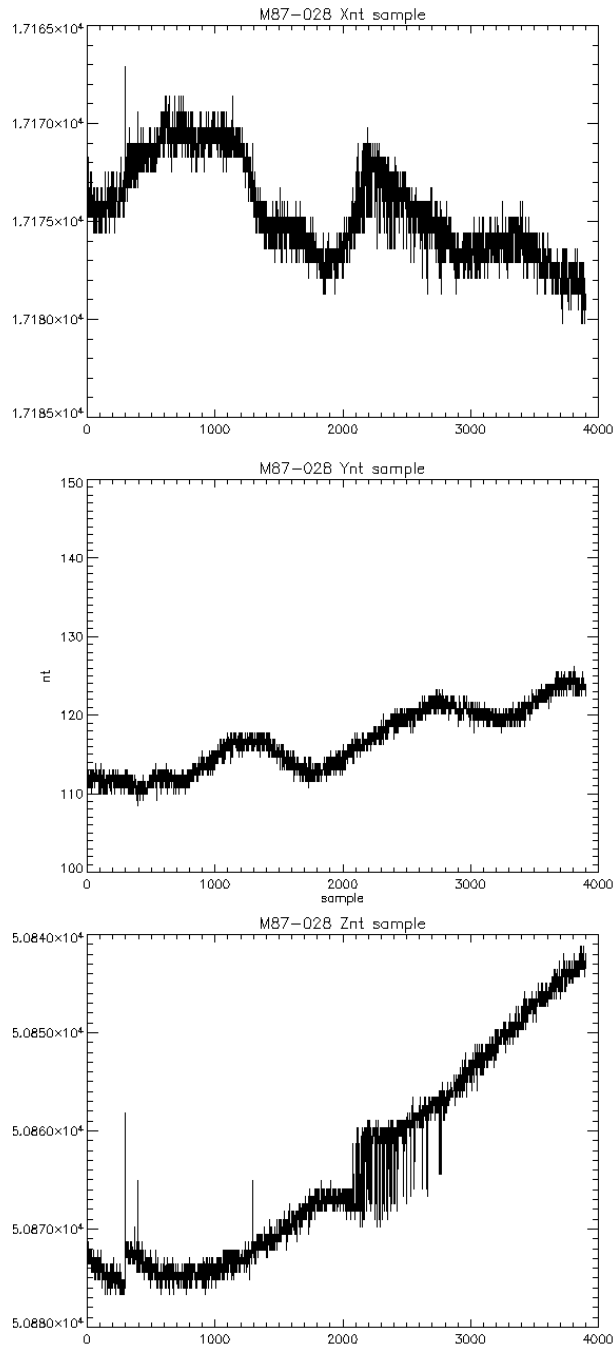


Figure 13 – X,Y,Z values from M87-028.

It is thought that the larger noise spikes seen on the Z value are due to thermal stabilisation of the system, as they do not appear on later data blocks – for example see figure 13b, the 10<sup>th</sup> data block (9 hours on from the above data).

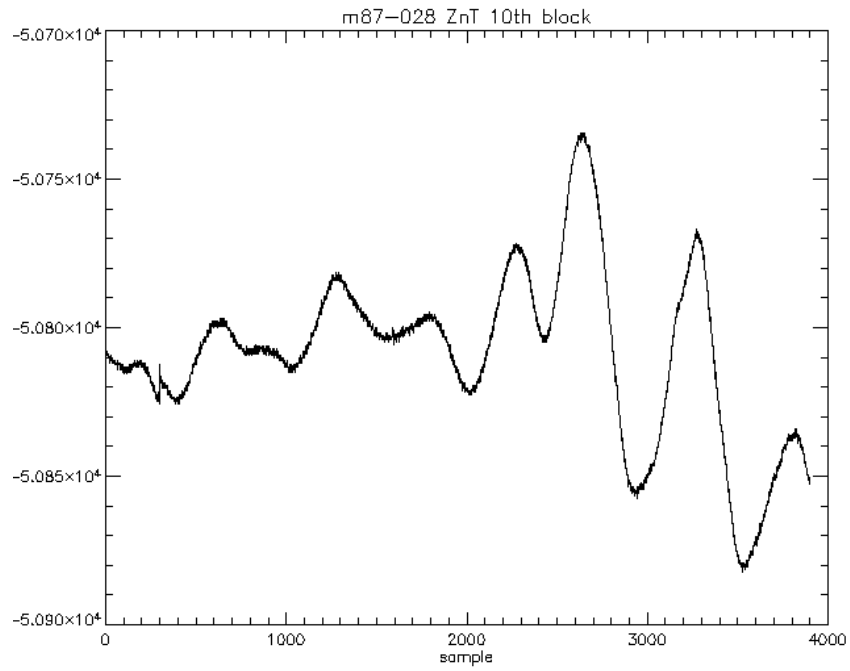


Figure 13b – Z sample from the 10<sup>th</sup> data block.

The cause of the noise spikes during thermal stabilisation is under investigation.

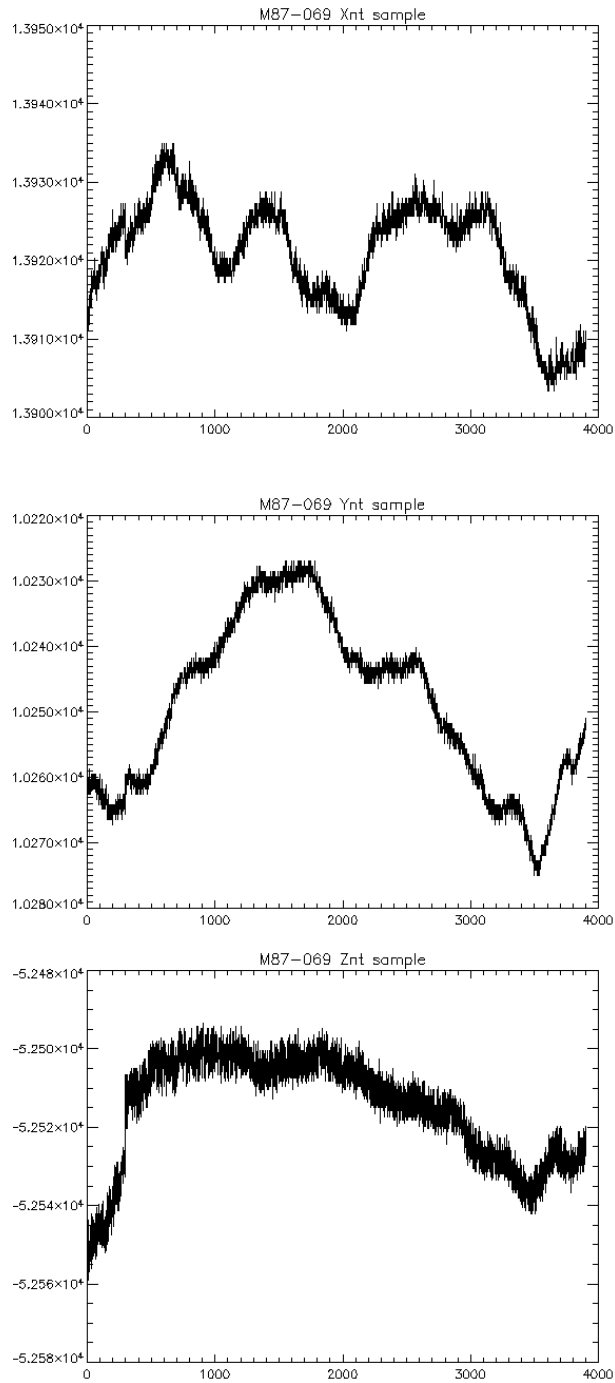


Figure 14 – X,Y,Z values from M87-069

The Z channel of M87-069 shows more noise than any other channel on any other system – approx +/- 7nT.

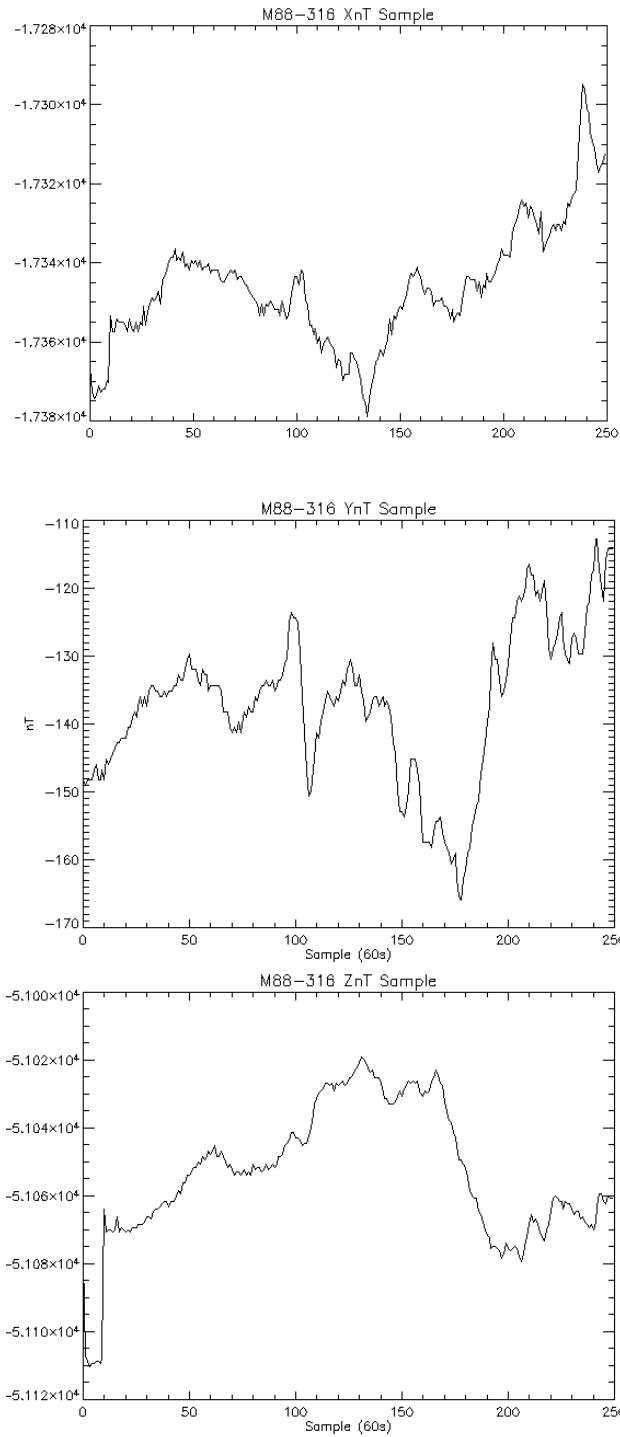


Figure 15 – X,Y,Z values from M88-316, NB sampling at 60s.

### **3.3 Magnetometer Noise.**

The noise is now +/- 2.33 nT on all systems and all channels apart from the Z channel of M87-069 which appears to have +/- 7nT noise. This system was running podule number L23 and this will have its analogue card replaced as an attempt to bring it inline with the others.

The noise is considerably improved from last year (when +/-25nT was the norm), this was expected from the fixes put in place on analogue card 5a. It is now thought that further reductions in noise (to sub 1nT) can not be made without adding to the analogue filter time constant and hence requiring the system to have a longer on period for each measurement, and hence using more power, and hence having less data at 1s sampling.

### **3.4 GPS offsets**

It can be seen from the graphs that the magnitude of the measured signal changes when the GPS is on. This is most apparent in the Z channel but the effect is also present on the other channels (for instance M78-337 Y channel).

The cause of the offsets is under investigation.

It is thought that the change is proportional to the magnitude of the signal being measured. Z is usually large as it is aligned to be perpendicular to the earths surface, X and Y are mutually perpendicular to Z but are at an arbitrary angle to the earths field and hence can be large (19700nT in the case of M79-336 X) or small (110nT in the case of M87-028 Y). However the amount of offset is not simply predictable from the magnitude of the signal – offsets of 4 to 20nT occurring for similar values of Z.

It may be possible to remove (or at least reduce the offset) by taking the whole years data for a site and obtaining a moving average signal level with and without the GPS – hence allowing a correction to be made. This should be relatively easy to do as it appears that the magnitude of the offset remains relatively stable, compare figure 5 with figure 16 which together show the Z offset at the start ,1 and 9 months into the year.

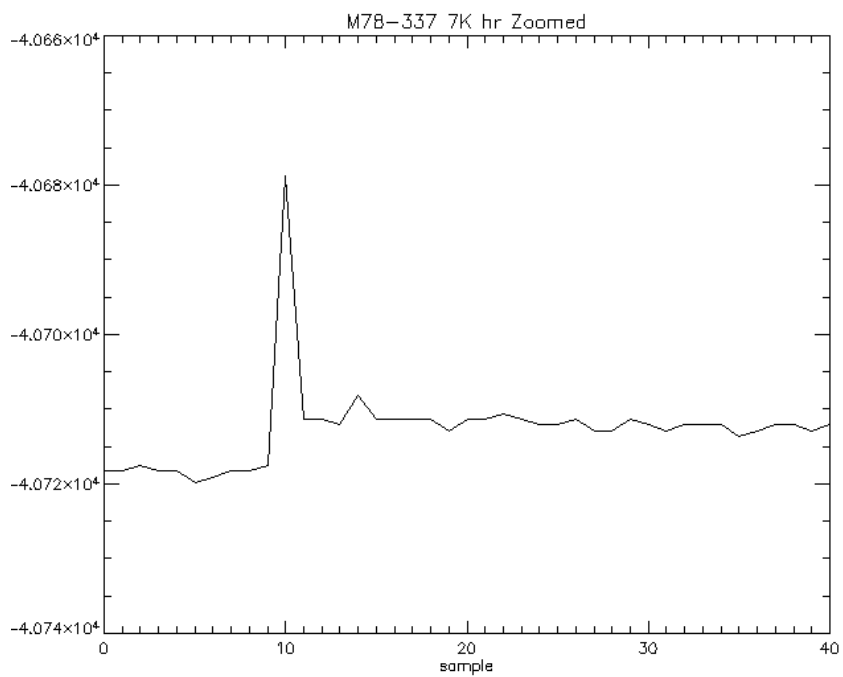
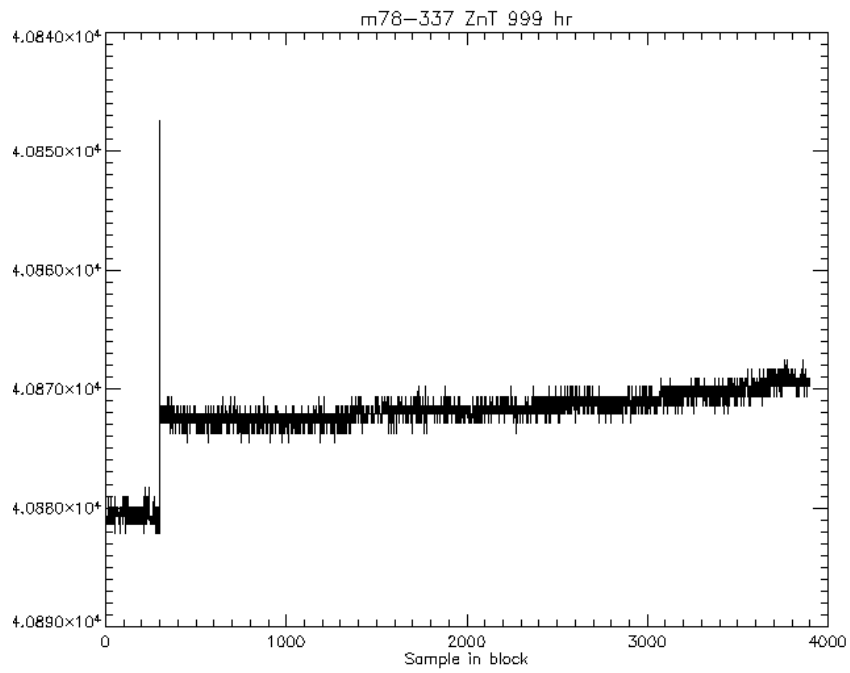


Figure 16. M78-337, Z values 1 and 9 months into the year. Note the second graph is zoomed into the region where the GPS is turned off .

#### **4.0 Housekeeping data.**

The 2002 loggers recorded housekeeping data every 65 minutes when sampling at 1s or 3s and every 250 minutes when sampling at 60s.

Housekeeping data consists of battery voltage, solar panel voltage, wind generator voltage (for future use) and a variety of temperatures from around the system and the environment.

Unfortunately the four systems deployed in 2001/2 have no external housekeeping data, this is due to a wiring error in 2001/2 loggers.

#### **4.1 Temperature data**

Temperature data recorded are:

- a/ Outside temperature – measured behind solar panel.
- b/ Enclosure temperature – in most instances identical to outside temperature.
- c/ Logger temperature.
- d/ 1M depth snow temperature – useful as a indication of magnetometer temperature.
- e/ First battery box temperature.

Table 5 is a summary of the temperature information from each site.

The Logger Min is the minimum temperature recorded in the logger electronics, M87-069 has the coldest operational temperature so far at  $-76.8^{\circ}\text{C}$ , unfortunately this was at a site that did not record its outside temperature but it was probably in the region of  $-78^{\circ}\text{C}$ .

‘Delta at min’ is the difference between the logger temperature and the outside temperature at the minimum outside temperature of the year. A positive temperature indicates the logger is warmer than outside – this is expected due to the small amount of power dissipated in the logger. ‘Ave Delta’ is the difference between the average logger temperature and the average outside temperature, again a positive temperature indicates the logger is warmer than the outside. Figure 17 shows this delta at one site during the year – as the power dissipated at different sampling rates changes so does the delta.

LPM	Logger Min	Outside Min	Outside Max	Delta at min	Ave Delta	Batt Min	Batt Max	Batt Delta Max	Notes
M78-337	-48.0	-51.4	-0.2	3.4	2.72	-38.7	-9.9	22.5	3
M79-336	-50.9	-55.3	-0.3	4.4	3.23	-37.2	-4.5	23.4	3
M81-388	-59.7	-61.2	1.8	1.5	2.77	-40.7	-8.5	23.9	3
M82-003	-64.1	-64.6	-5.0	0.6	1.64	-49.0	7.66	36.1	1
M83-348	-61.7	-61.7	-0.2	0.0	2.33	-46.5	7.66	41.0	
M84-336	-59.2	-60.2	+1.8	1.0	1.52	-49.0	14.5	41.5	
M85-002	-55.3	-59.7	-9.9	4.4	3.92	-44.1	15.0	48.8	1
M85-096	-78.3	?	-7.9			-63.6	2.8		2
M87-028	-66.5	?	-2.6			-57.3	0.8		2
M87-069	-76.8	?	-6.0			-62.7	5.2		2
M88-316									1

Table 5. Temperature information summary.

Note 1, Not a whole year.

Note 2, Outside max actually Logger Max.

Note 3, Cellyte rather than Sunlyte batteries.

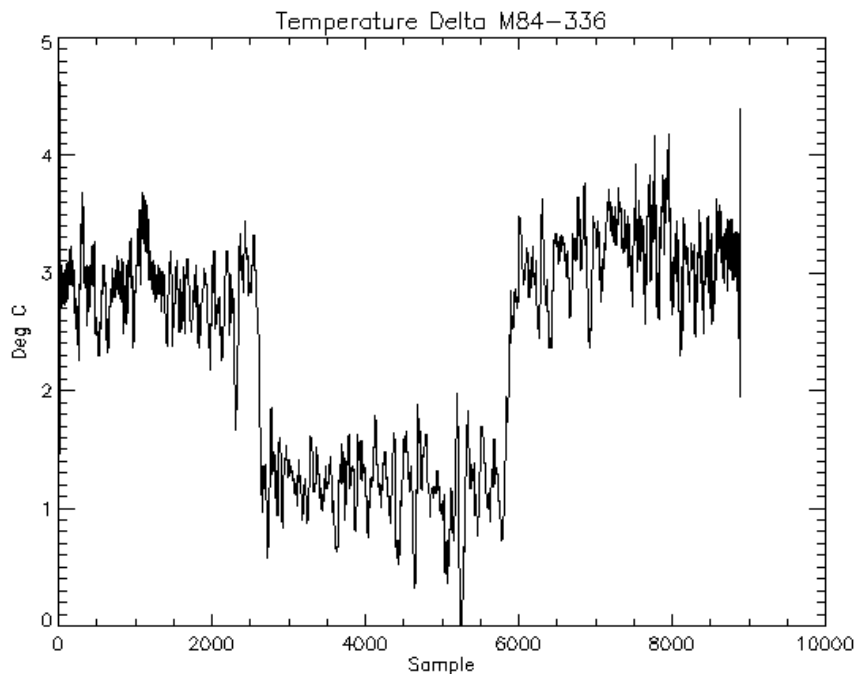


Figure 17. Delta Temperature for a year.

From the above, its estimated that the logger insulation is about  $8^{\circ}\text{C}/\text{W}$ .

The battery minimum and maximum show the extreme of temperatures measured within the first battery box. The battery box drops to ambient during the dark period and warms during charging. Figure 18 shows this effect. Note the Sunlyte and Cellyte batteries have slightly different characteristics.

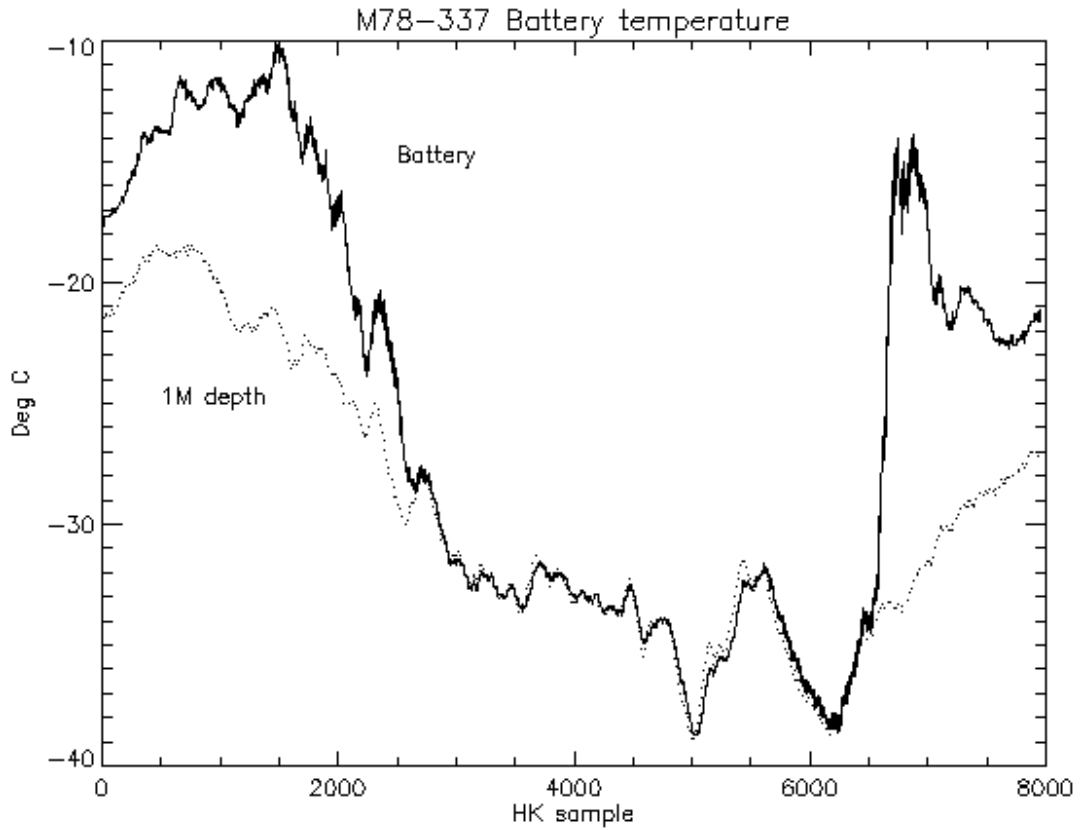


Figure 18. Battery temperature at M78-337.

## 4.2 Battery Voltage data

Battery voltage is important as it indicates the charge state of the batteries. If the batteries are too deeply discharged then they will have a shortened life (which could be as short as one discharge in the severe case). As the method of retaining battery charge is too slow down the sampling rate of the magnetometer, too conservative estimation of battery voltage will result in reduced high resolution data coverage.

Voltage itself is not important for correct operations of the instrument as all power supplies are derived from DC-DC converters which are specified down to 8v.

Figure 19 shows the battery voltage at M78-337 for the year. During darkness the voltage measured indicates the charge state of the batteries, whilst during charging the voltage measured is the temperature corrected charging voltage.

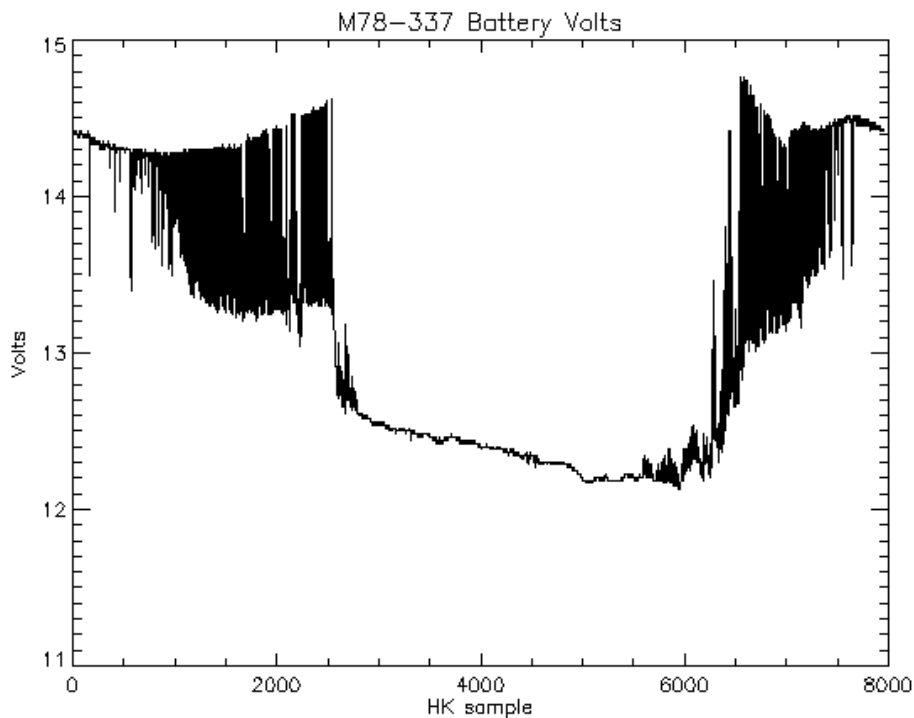


Figure 19. Battery Voltage at M78-337.

Of chief importance is the state of charge of the batteries. At room temperature 13V would indicate 100% available, and 12V 20% available. It is therefore possible to calculate how much battery power has been used during the winter and compare this with with the calculated usage.

LPM	Use Ratio	Use calc@ sample rate	Min Volts	mid V	mid T	Notes
M78-337	1.02	1	12.13	12.40	-32.9	3
M79-336	0.97	1	12.13	12.48	-31.4	3
M81-388	1.13	1	12.13	12.25	-34.8	3
M82-003	0.41	3	11.98	11.99	-43.1	1
M83-348	0.54	3	11.91	12.03	-42.1	
M84-336	1.05	3	11.91	12.05	-42.1	
M85-002			12.13			1
M85-096	0.50	3	11.64	11.91	-58	2
M87-028	0.40	3	11.86	11.95	-50	2
M87-069	1.12	60	11.74	11.91	-47	2
M88-316						1

Table 6. Battery data

Note 1, Not a whole year.

Note 2, Mid T is Logger Temperature

Note 3, Cellyte rather than Sunlyte batteries.

The use ratio (calculated use/measured use) is somewhat puzzling as very similar sites with identical batteries appear very different. However, the voltage changes in the batteries are actually quite small and this figure can not be considered accurate, its probably best to view this as something we need more history on but at the moment it seems that on average the batteries give us about 80% of their rated value. The design value was 50% so it would appear that we are doing better than this for most sites and certainly on average.

The voltage during midpoint of winter (when all systems should be more or less at the same state of discharge) and the battery temperature can be used to estimate the temperature coefficient of measuring the battery charge state by voltage. Figure 20 shows the voltage v temperature data for the systems – the slope indicates a temp co of 22mV/C, which is close to the value used in the loggers of 25mV/C.

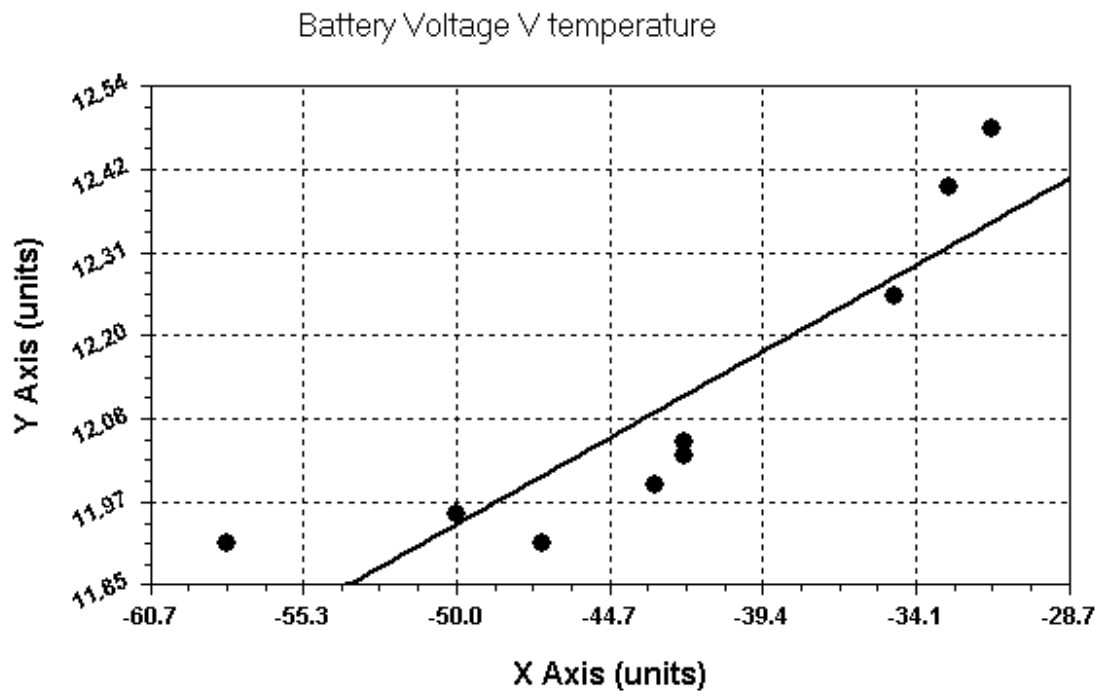


Figure 20. Midwinter voltage v battery temperature for all the sites.

### 4.3 Solar panel voltage

Figure 21 shows the voltage recorded off the solar panels at M78-337. The plateau post winter in the maximum shows the period where the panel is producing power and the battery is charging. When the solar panel voltage reaches 22-23V the battery is fully charged.

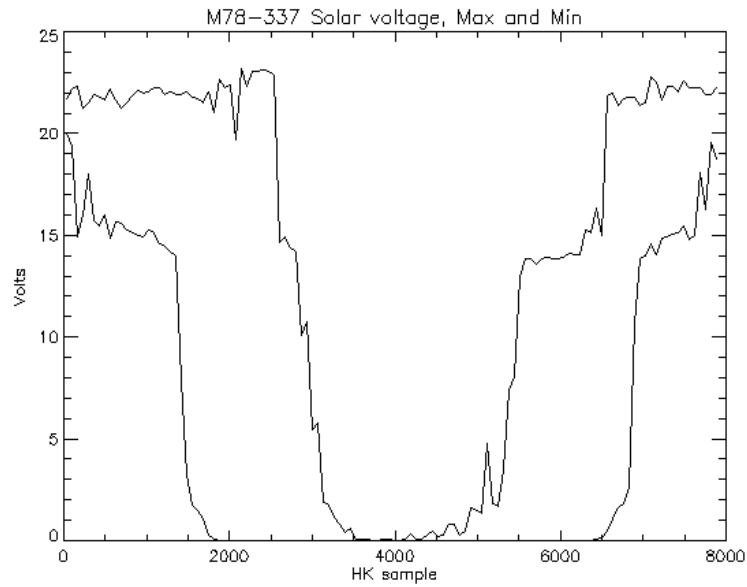


Fig 21. Solar panel voltage.

## **5.0 Site work in 2002/3 season.**

M87/028 was turned round to face North rather than South – this far south this has a relatively small effect on total power from the panel (adding about 10%) but more significantly shortens the winter by 14 days.

Wind generators were added at M83-348, M84-336, M85-002, M85-096, M87-028, M87-069 and M88-316; the seven sites furthest south.

There was some suggestion that M83-348 would need to move in 2002/3 due to large sastrugi in the area making aircraft operations difficult. This decision was left to the airunit who decided that the current site was fine.

## **6.0 Summary of work for 2003 and 2003/4 season.**

1. Provide refurbished loggers for all locations.
2. Replace GPS components in L07.
3. Replace analogue card in L23.
4. Plan 2003/4 season to take account of latest service dates.
5. Purchase 256MB disks for 2004.
6. Investigate source of GPS offset in data.
7. Investigate removing GPS offsets in data by data processing.
8. Investigate noise spikes on Z channel of M87-028.
9. Investigate lack of housekeeping data in the four systems deployed in 2001/2.
10. Consider adding radar reflectors to each system (at pilots request).

# **APPENDIX 1**

## **LPM Positions**

## BAS Low Power Magnetometer Sites

Site	Name	1 <sup>st</sup> Deployed	Latitude	Longitude	Elevation ft	IGRF Declination	IGRF H in nT	IGRF Z in nT
M78/337	Dr Leech	04/01/01	77°31'24"S	23°25'18"W	5200	-3°12'	19590	40978
M79/336	Bob	03/02/00	79°04'36"S	24°07'11"W	4000	-2°34'	19490	42566
M81/338	Edmund	07/01/01	80°53'30"S	22°14'48"W	3800	-3°59'	19251	44348
M82/003	Mrs Miggins	21/01/01	81°30'00"S	03°00'00"E	7900	-24°21'	18974	45079
M83/348	Baldrick	23/01/01	82°53'58"S	12°14'57"W	6900	-12°21'	18837	46274
M84/336	Baron Richthoven	15/01/01	84°21'34"S	23°51'06"W	6700	-2°58'	18519	47860
M85/002	Lord Melchett	23/01/01	85°21'25"S	02°03'44"E	9000	-25°57'	18139	48909
M85/096	Baby Eating Bishop	22/01/02	85°23'22"S	95°58'26"E	10550	-118°12'	15752	54672
M87/028	Flash heart	19/01/02	86°59'57"S	28°24'49"E	9350	-51°09'	17495	50792
M87/069	Speckled Jim	22/01/02	86°30'53"S	68°10'30"E	10500	-90°51'	16678	52773
M88/316	Lord Whiteadder	19/01/02	88°01'31"S	43°51'56"W	8400	+16°08'	17276	51644





## **APPENDIX 2**

### **Document History**

**V1.0 22/7/03 First public version.**

**V1.1 24/02/03 Typo corrections**

Values in table 4b for M85-096,M87-028,M87-069,M88-316, moved from 2001 to 2002.

section 2.2

M79-337, Bob, Operating date end corrected from 09-12-01 to 09-12-02, typo

M88/316 - Lord Whiteadder, actually operated longer than originally quoted. Originally thought it operated for 14 /383 days, but actually managed 167. Other day totals and coverage statistics updated to match.