LPM 2001
Field performance summary

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CONTENTS

1. Introduction

This report gives an analysis of the performance of the seven LPMs operating on the Plateau in 2001.

The site positions, names and deployment dates are given in appendix 1. It should be noted that we are midway in a name change from Mxx to Mxx/yy where xx is the nearest whole latitude and yy is the nearest whole longitude – this change is necessary due to the increasing numbers of LPMs. The new and old names are given in table 2 for cross reference.

Comments on sites deployed in 2001/2 are given in section 5

Recommendations and comments about future work are given in section 7

2. Basic performance

Table 1 contains a summary of the basic operating performance of the LPMs. Six of the seven units operated throughout the year.

The remaining one, M84, stopped after two months for reasons unknown, this was also the only logger that had a restart (again for reasons unknown). During this logger's rebuild and upgrades (new analog card, new program ROM), no faults could be found (although a metal thermal insulation tie post had come adrift, it was not thought to have caused the problem). The logger has been redeployed into M77 in order to help determine if the problem lies with the logger or the system.

All the systems received very good GPS coverage apart from M81 which missed many GPS fixes, the GPS card and antenna will be replaced in this logger next season. There is no obvious degradation in GPS fixes with latitude.

The loggers at the highest latitudes switched sampling rate from 3s to 9s during the winter period in response to low battery voltage, with M85 switching to the dead slow rate of 60s. The implications for this are discussed in section 4.2 "Voltage data"

Site	Deployed	Recovered	Working	3s data	9s data	60s data	Restarts	GPS coverage
M77	04/01/01	02/12/01	100%	All			0	Very Good
M79	07/01/01	13/12/01	100%	All			0	Very Good
M80	07/01/01	03/12/01	100%	All			0	Very Good
M81	21/01/01	17/12/01	100%	All except	16/04 - 15/09		0	Poor
M83	24/01/01	13/12/01	100%	All except	14/05 - 05/09		0	Very Good
M84	15/01/01	13/12/01	until 15/03/01	All			1	Very Good
M85	24/01/01	17/12/01	100%	All except	04/04 – 14/09	09/05 – 14/09	0	Very Good

Table 1. Basic performance.

3. Magnetometer data.

3.1 Absolute values.

Table 2 contains a comparison of a spot value from each system (the second sample after the first midnight of operation) compared with the IGRF modelled value for January 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**	**IGRF Z in nT**	**2001 H in nt**	**2001 Z in nt**	**% difference Total Field**	**Old Site Name**
M78/337	19590	40978	19045	40835	-0.80	M77
M81/338	19251	44348	19332	44281	-0.13	M80
M82/003	18974	45079	19674	44511	-0.50	M81
M84/336	18519	47860	17850	47511	-1.10	M84
M79/336	19490	42566	19787	41951	-0.92	M79
M83/348	18837	46274	18873	46217	-0.08	M83
M85/002	18139	48909	17757	48669	-0.68	M85
M87/028	17495	50792	New 2002			
M87/069	16678	52773	New 2002			
M85/096	15752	54672	New 2002			
M88/316	17276	51644	New 2002			

Table 2. 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.

3.2 Magnetometer noise.

Fig 1a-1u show the first full days data from each site. In general it can be seen that each site is at least measuring a changing magnetic field, however the noise is greater than had been hoped – around 50nT. These measurements were taken with Loggers fitted with analog card V4c which was known to have noise problems, for 2002 all sites have been fitted with Loggers with analog card V5a which has various noise fixes in place.

The noise varies from site to site with M77 being the worst and M80 being the cleanest.

The graphs are presented as X,Y,Z where these are the raw values. Z is aligned to be normal to the surface of the earth with a spirit level, and will be negative in the southern hemisphere and positive in the north. X and Y are orthogonal to Z but at an arbitrary angle with respect to either the local magnetic or geographic north.

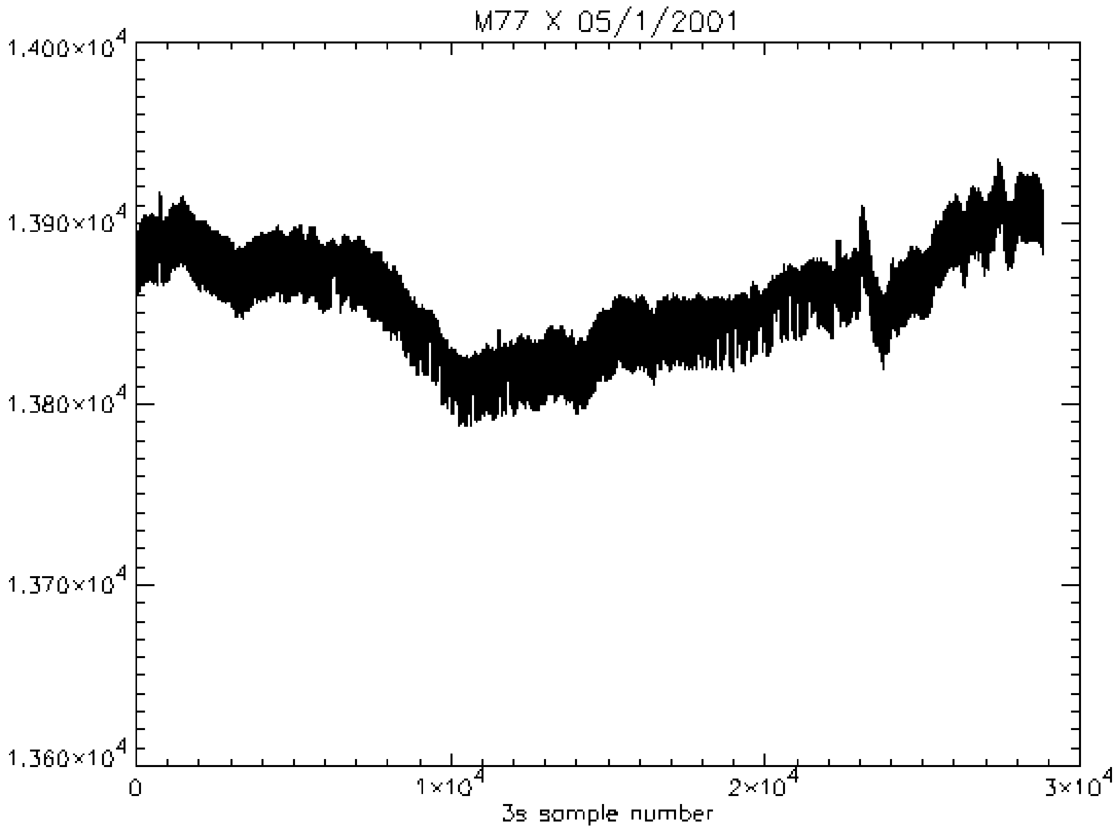


Fig 1a - M77 X channel, a full days data. Y axis is in nT. X axis is the sample number into the day sample 0 is the first sample after midnight. There are 28800 three second samples per day.

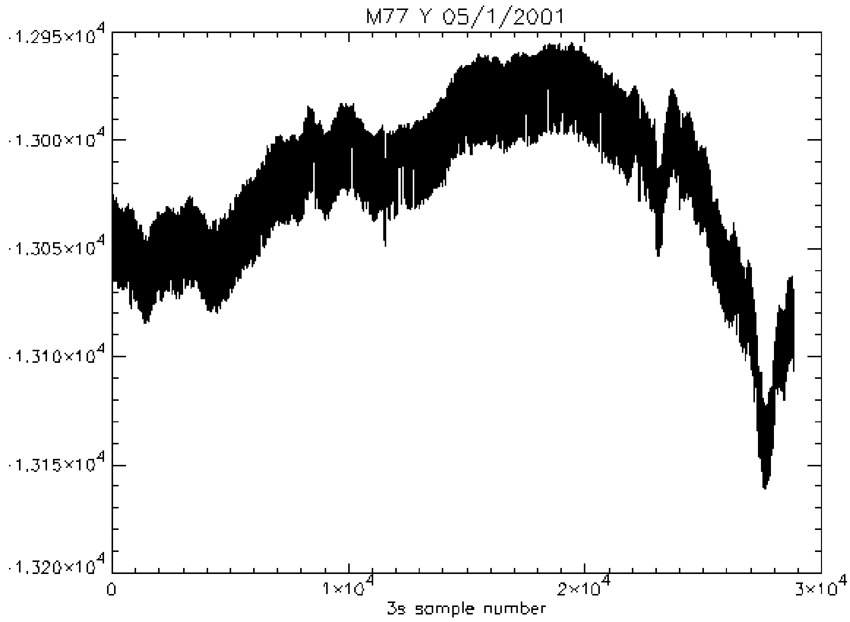


Figure 1b – M77 Y channel.

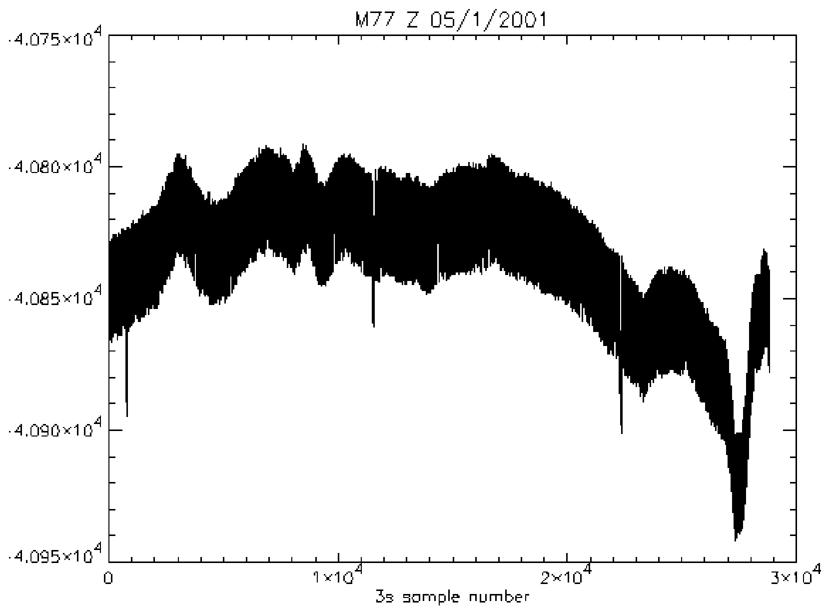
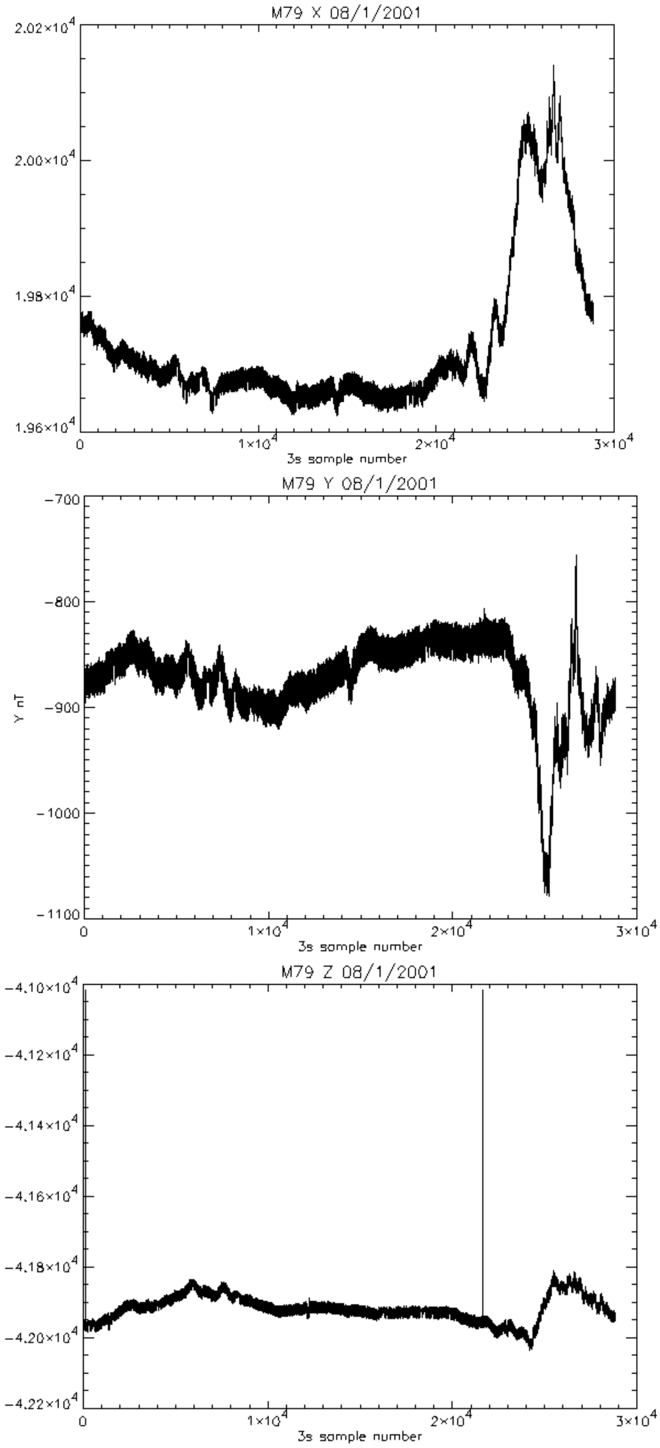


Figure 1c – M77 Z channel. The large negative spikes at around sample 1000,11000 and 22000 coincide with the GPS being on. This was a known noise problem with analog card 4c.



Figs 1d-1f. M79. The large (800nt) spike on the Z channel around sample 22000 is not understood.

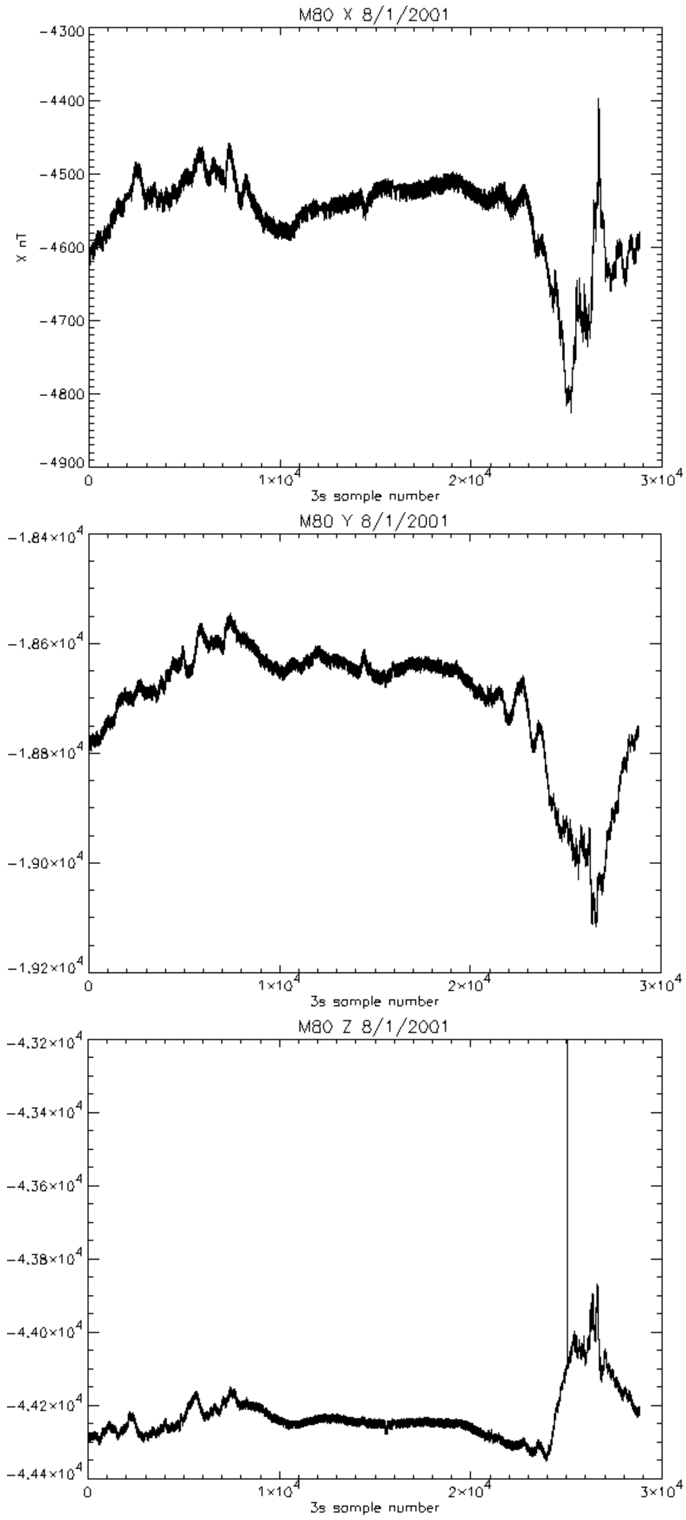


Fig 1g-1i, M80. This is the cleanest data set from 2001, the noise have a full scale range of around 20nT. The large spike on the Z channel is similar to that seen on M79 and is not understood.

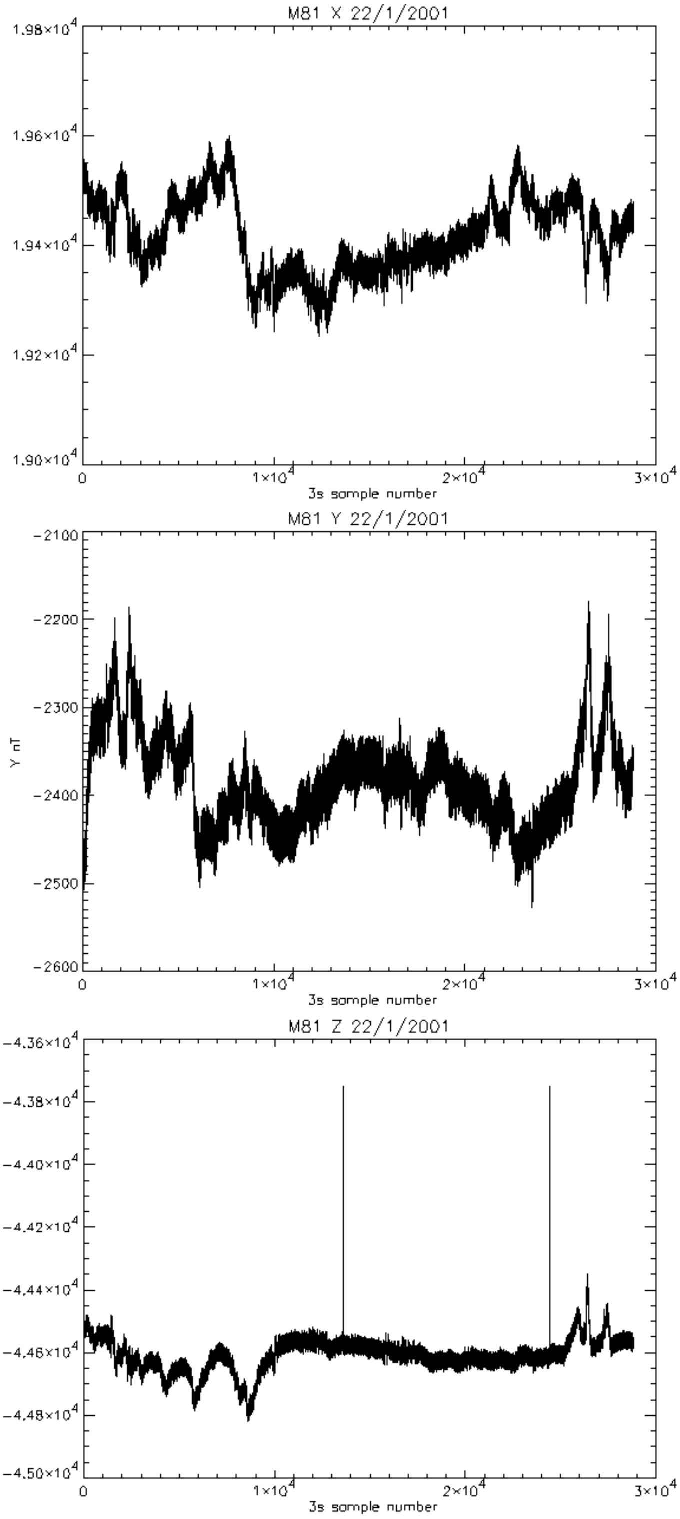


Fig 1j-1l, M81, Again single sample spikes on the Z channel.

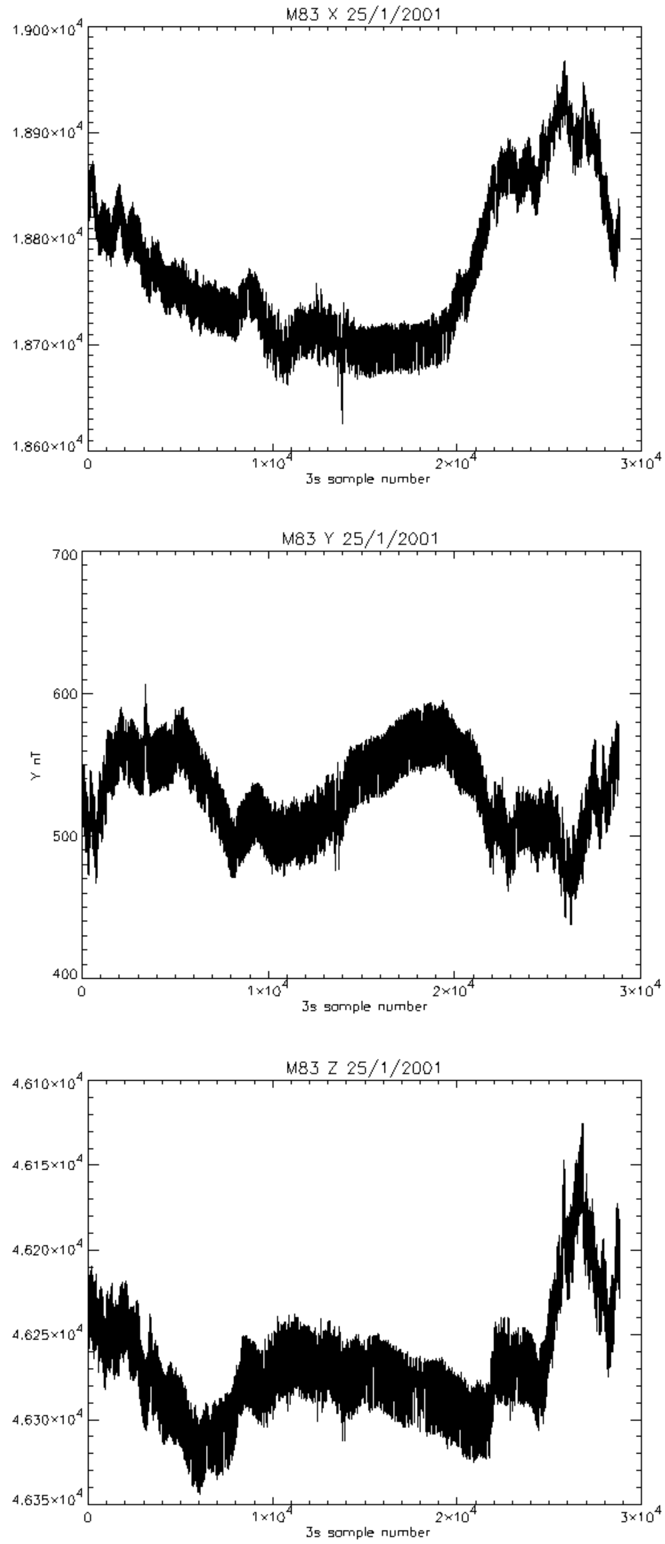

M83 X 25/1/2001
1.900×10^4
1.890×10^4
1.880×10^4
1.870×10^4
1.860×10^4
0
1×10^4
2×10^4
3×10^4
3s sample number
M83 Y 25/1/2001
700
600
500
400
Y nT
0
1×10^4
2×10^4
3×10^4
3s sample number
M83 Z 25/1/2001
4.610×10^4
4.615×10^4
4.620×10^4
4.625×10^4
4.630×10^4
4.635×10^4
0
1×10^4
2×10^4
3×10^4
3s sample number

Fig 1m-1o, M83.

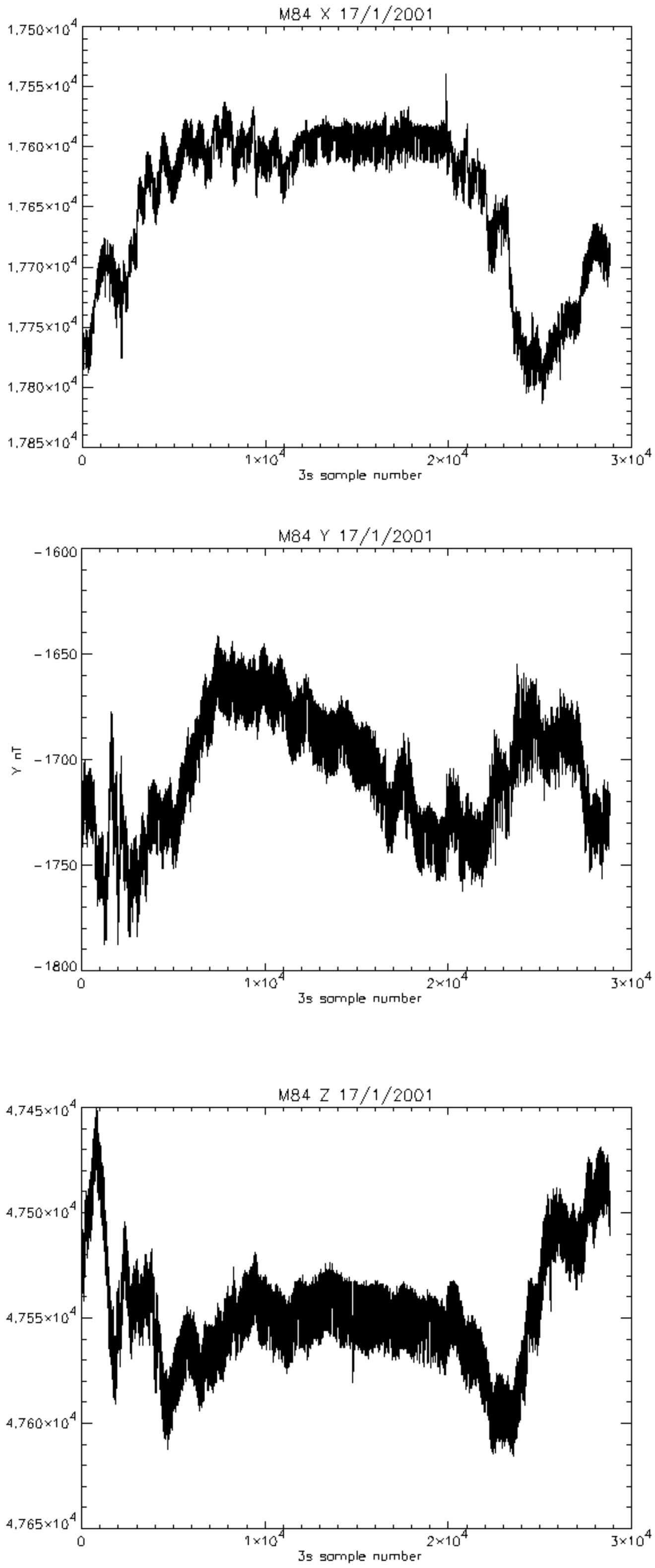

M84 X 17/1/2001
1.750×10^4
1.755×10^4
1.760×10^4
1.765×10^4
1.770×10^4
1.775×10^4
1.780×10^4
1.785×10^4
0
1×10^4
2×10^4
3×10^4
3s sample number
M84 Y 17/1/2001
Y nT
−1600
−1650
−1700
−1750
−1800
0
1×10^4
2×10^4
3×10^4
3s sample number
M84 Z 17/1/2001
4.745×10^4
4.750×10^4
4.755×10^4
4.760×10^4
4.765×10^4
0
1×10^4
2×10^4
3×10^4
3s sample number

Fig 1p-1r, M84

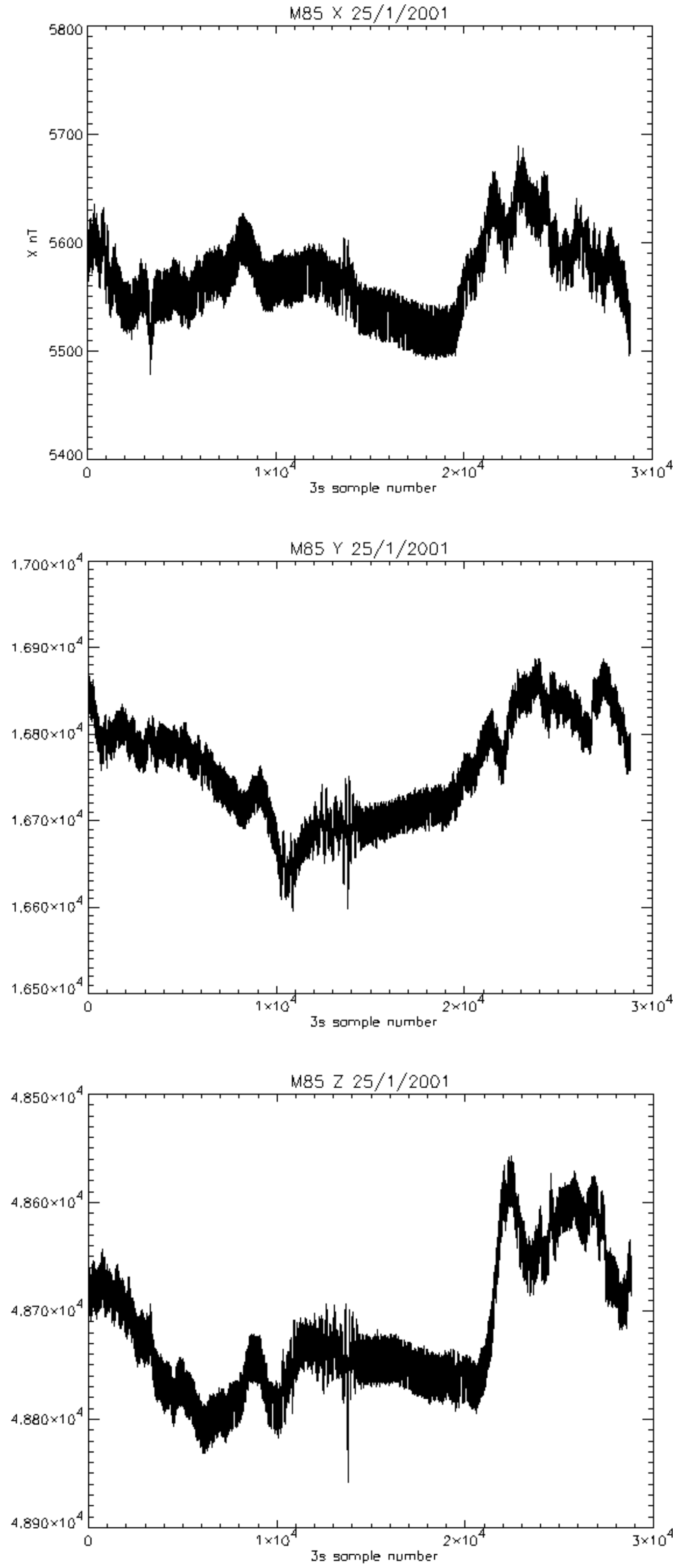

M85 X 25/1/2001
X nT
5800
5700
5600
5500
5400
0
1×10^4
2×10^4
3×10^4
3s sample number
M85 Y 25/1/2001
1.700×10^4
1.690×10^4
1.680×10^4
1.670×10^4
1.660×10^4
1.650×10^4
0
1×10^4
2×10^4
3×10^4
3s sample number
M85 Z 25/1/2001
4.850×10^4
4.860×10^4
4.870×10^4
4.880×10^4
4.890×10^4
0
1×10^4
2×10^4
3×10^4
3s sample number

Fig 1s-1u, M85.

Figure 2a and 2b show zoomed in sections of perhaps the best and the worst data as far as noise goes.

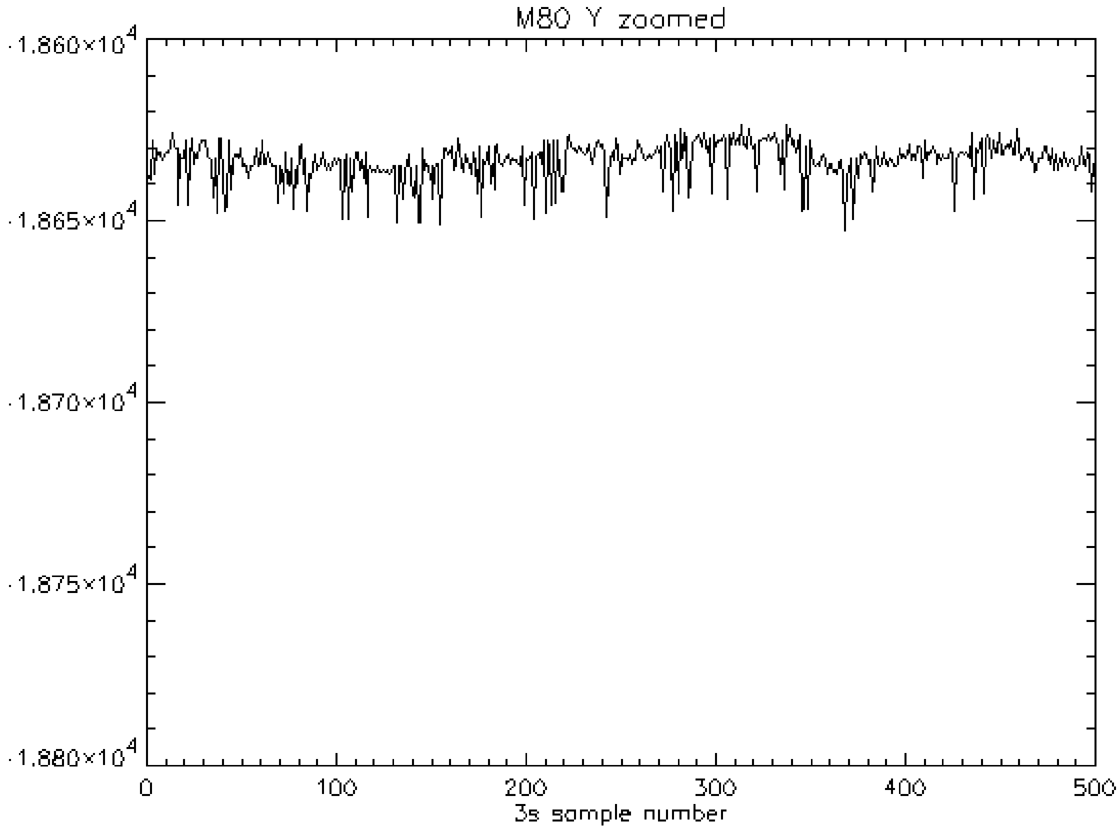


Fig 2a. 25 minutes of Y channel data from M80. The minor Y channel axis ticks are at 10nT intervals. The signal appears to consist of an underlying trend with negative noise spikes – the addition of ADC noise results in negative spikes.

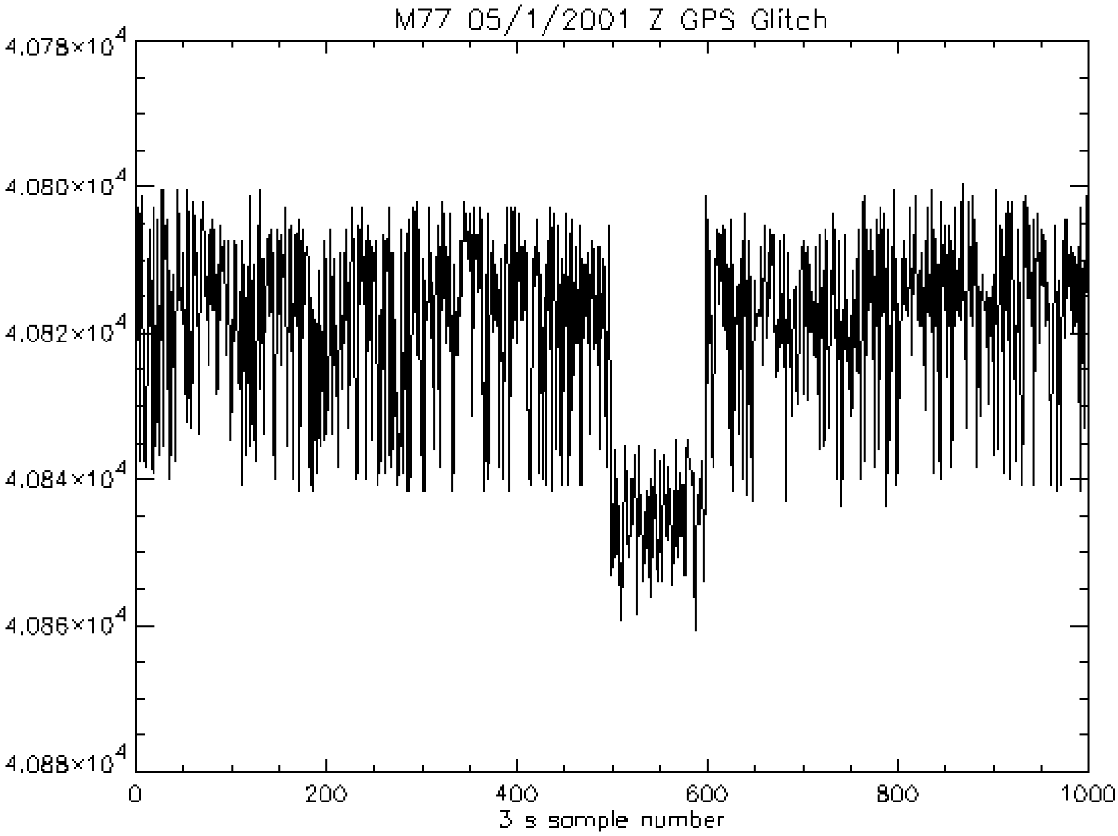


Fig 2b, 50 minutes of M77 Z channel data. The Y axis is negative, and the minor ticks are at 5nT intervals. The lower section of data between sample 500 and 600 coincides with the GPS being on.

4.0 Housekeeping data.

The 2001 and 2002 loggers record housekeeping data every 9 hours – although the actual time is not synchronised with GPS time or solar angle but depends only upon when the logger was powered up.

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

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.

Typically the outside, enclosure and logger temperatures show a large seasonal and daily variation such as that shown in fig 3.

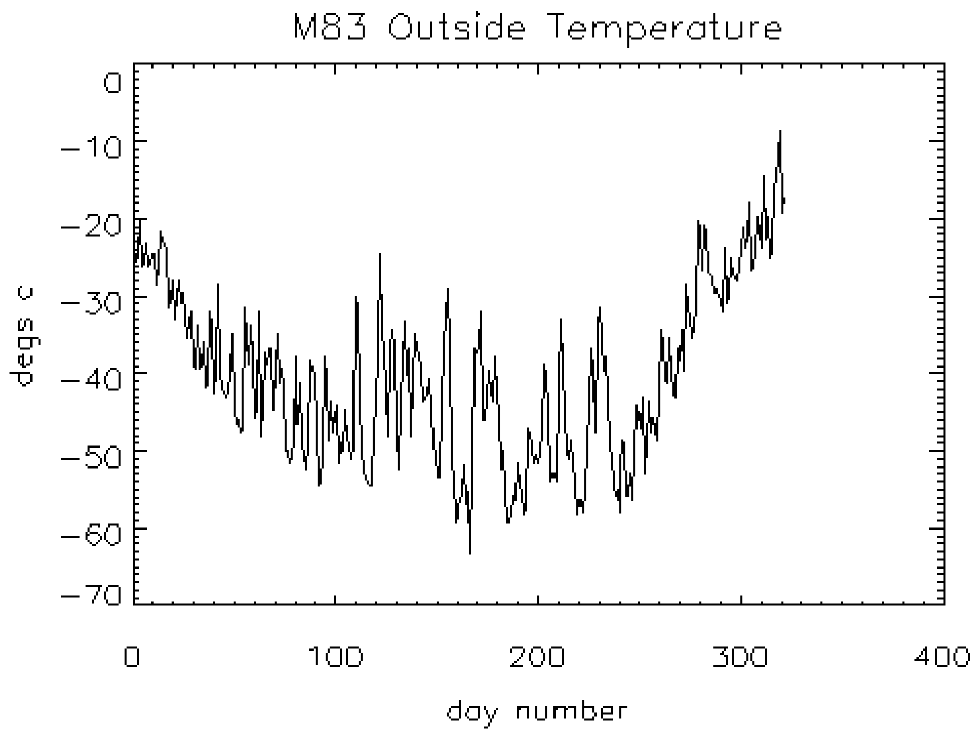


Fig 3. Outside temperature at M83.

Table 3 shows the minimum and maximum temperatures recorded at each site. The positive temperatures are also recorded in the enclosure and logger temperatures and are probably due to solar heating on calm days. The temperature of –70.5°C at M85 is to date the coldest that an LPM has operated – some 3°C colder than our old freezer could go, although our new test freezer is capable of –86°C (which may also be typical of the higher and colder sites that the LPMs were deployed at in 2001/2.)

Site	Max °C	Min °C	Notes
M77	+4.2	-52.0	
M79	+6.1	-51.0	
M80	+5.1	-60.7	
M81	-9.0	-66.6	
M83	-8.5	-65.1	
M84	-17.8	-48.1	First 60 days only
M85	-13.4	-70.5	

Table 3. Outside temperature extremes.

Table 4 shows the difference between the outside temperature and the logger (which has some insulation and is also dissipating a small amount of power). The insulation acts like a low pass filter on the temperature and adds not only some warmth but also some phase delay and attenuation on temperature changes. Two values of temperature difference are quoted; the 'Ave Delta' is the average difference between the logger and the outside temperature, 'Delta Min' is the difference between the minimum temperatures recorded between the logger and the outside temperature sensors. In both cases, +ve is logger warmer than outside.

Site	Ave Delta °C	Delta Min °C	Notes
M77	+1.46	+1.95	
M79	+1.46	+2.44	
M80	+1.95	+2.94	
M81	+0.98	0.00	
M83	+0.98	+0.98	
M84	+2.44	+2.93	First 60 days only
M85	+1.46	-0.98	

Table 4. Logger Temperature compared to outside.

The negative value for M85 probably indicates recent warming before the measurement was taken, the outside temperature sensor would respond immediately whilst the loggers

temperature would take some time to respond because of the low pass effect of the insulation. The minimum logger temperature at M85 was –71.4°C.
With 0.33Hz sampling a unit would be dissipating on average about 0.15W, with 0.11Hz sampling a unit would be dissipating around 0.08W. Averaging the figures from table 4 and taking into account the sampling rate of each unit it is possible to estimate that the insulation of the logger amounts to 8-10°C/W. With 1Hz sampling (0.37W) the logger will still only be 2-3°C warmer than ambient – assuming the power is available to stay at 1Hz sampling.

At the furthest south sites where the ambient temperature may be very cold (-90°C) we must expect equipment failures. Adding extra power sources such as a small wind generator or a once only battery may help but probably won't allow us to keep the logger above –70°C. (The wind generator won't spin below –60°C, although it will already have added to the charge of the batteries, it's power won't be available when needed. Lithium Ion or Air Depolarised batteries could add to the total charge available in winter, but it would require around 500AHrs to allow the power dissipation required to keep the logger above –70°C). It is planned to add small wind generators in the 2002/3 season, and the temperature characteristics of suitable once only batteries are being investigated.

An alternate strategy for the future might be to investigate an enclosure with considerably more insulation or to bury the logger unit (although this would add significantly to the maintenance time). The temperature at 1m depth is monitored as a proxy for the fluxgate sensor temperature and is shown as the dashed line in fig 4.

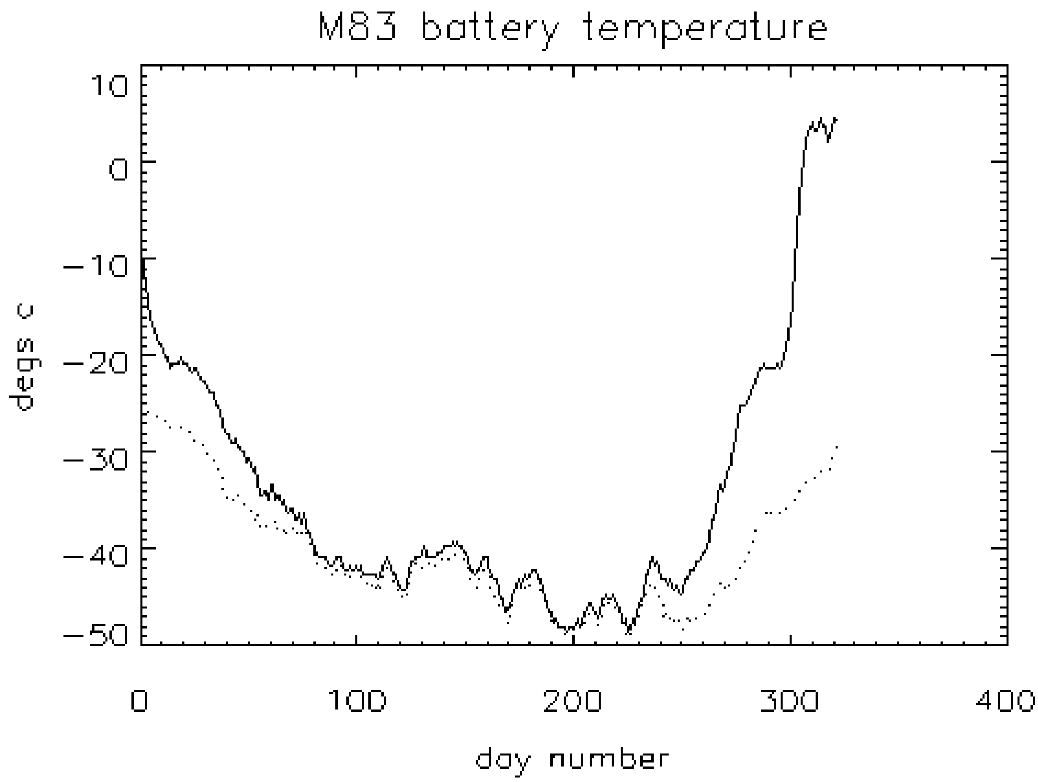


Fig 4. Battery (solid) and 1M snow depth (dashed) temperatures at M83.

The 1m snow depth temperature can be compared to the outside temperature in fig 3. The 1m snow depth temperature is a low pass filtered version of the outside temperature, hence their averages are very similar, although the extreme minimums are very different, -65°C ambient, -49°C at 1M depth.

The temperature of the batteries (solid line in fig 4) is higher than the 1m snow depth temperature when the batteries are being charged as waste heat from the regulator is used inside the insulated battery enclosures. When no charging is taking place then the battery temperature closely follows the 1m snow depth temperature. Table5 shows the maximum difference between the battery temperature and the 1m snow temperature post winter.

Site	Max delta °C	Max battery temp°C	Battery type
M77	7	-20	Cellyte
M79	13	-10	Cellyte
M80	13	-20	Cellyte
M81	39	+4	Sunlyte
M83	37	+5	Sunlyte
M84			Sunlyte
M85	49	+13	Sunlyte

Table 5. Post winter battery temperature compared to 1M snow depth and extreme.

Fig 5 shows the 1m snow depth temperature for M80, a site fitted with Cellyte batteries. It is clear from table 5 and fig 5 that Cellyte batteries have different characteristics than the Sunlyte batteries.

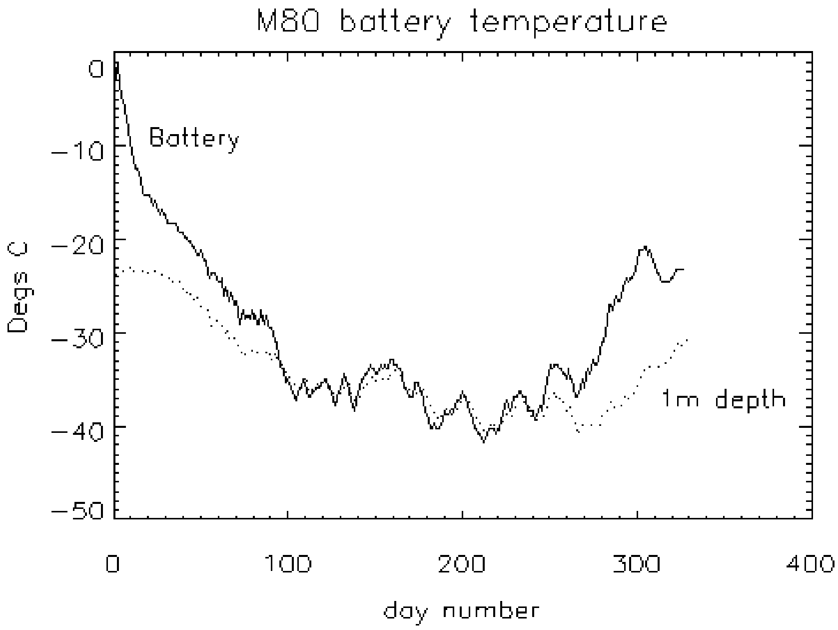


Fig 5. Battery and 1m depth temperature at M80.

It is likely that three effects are happening here

a/ The Cellyte and Sunlyte batteries have different characteristics, with the Sunlyte batteries taking a higher trickle current.

b/ The sites that are further south have longer winters and take more charging during the summer and hence receive more heating from the regulator.

c/ The sites further south have colder solar panels which give out higher voltage for the same illumination – this results in a greater power dissipation in the regulators.

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, down to 8V is not important for correct operation of the instrument as all power supplies are derived from DC-DC converters rated down to at least 8V.

Fig 6 shows the measured battery voltage for M80. During sunlit hours the batteries will be at the charging voltage, whilst during darkness the battery voltage will depend upon the charge state of the battery. This graph has been smoothed to remove the effect of partial darkness days. The plateaus around day 80 and day 260 are thought to be due to poor weather.

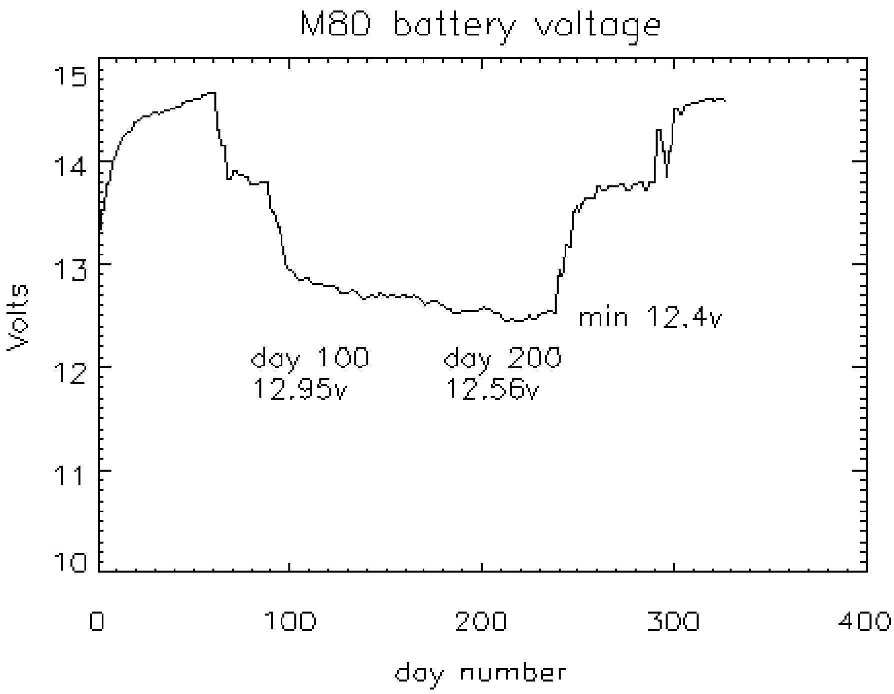


Fig 6. Raw battery voltage at M80.

Of chief importance is the state of charge of the batteries. At room temperature 13V would indicate 100% available, and 12V 20% available, fig 6 would therefore suggest that M80 used about 35% of available battery capacity between day 100 and 200. Calculation of the amount used in a 400AHr system at an average power usage of 0.15W would be about 7%. The discrepancy in the 7% and the 35% figure is because of two effects that are difficult to disentangle.

a/ The batteries have lower capacity than 400AHr at low temperatures. Unfortunately this is not easy to measure as the capacity is dependant upon the discharge current and the profile of the discharge, needing a 3 month test at each temperature.

b/ The voltage measured for a particular charge state is temperature dependant. Again this is difficult to measure as it is current dependant and also prone to memory effects in the batteries. To characterise it properly would require many multi-month experiments in many freezers.

Figure 7 shows the battery voltage for M83 – a considerably colder site than M80.

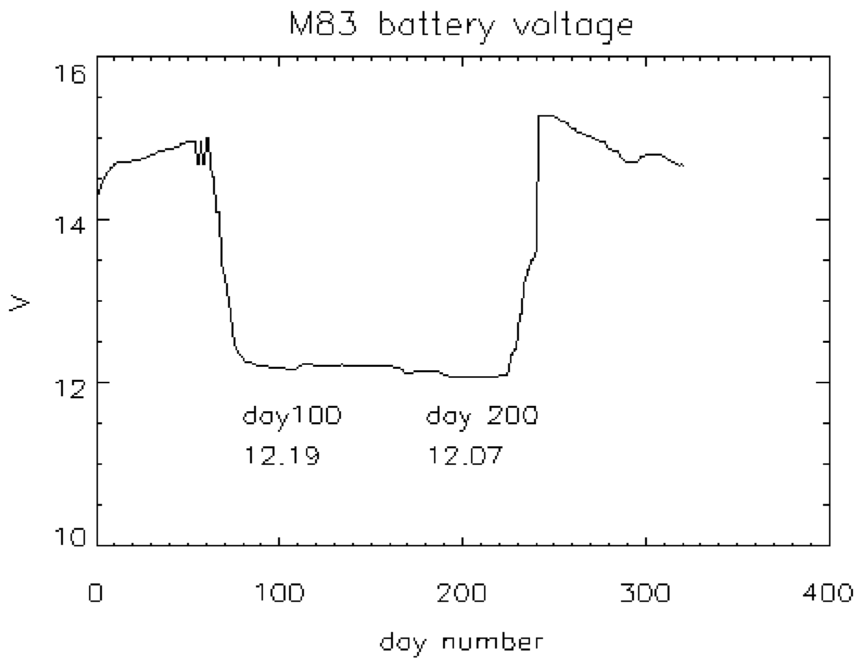


Fig 7. Raw battery voltage at M83.

At M83 the battery voltage has dropped to 12.19V by day 100 – very shortly after sundown when it can be assumed that the batteries are still reasonable full.

The battery voltage graph of M83 indicates a capacity usage of around 6%(compared to 400AHr) where as the calculated consumption is about 5%.

Table 6 shows the measured and calculated usage figures for 100 days in winter from all of the sites. The % usage is calculated not from the batteries absolute voltage values but the change in battery voltage with time.

Site	Middle winter V	Measured usage %	calculated usage%	Ave battery temp °C	Battery type
M77	12.78	35	7	-34	Cellyte
M79	12.77	35	7	-33	Cellyte
M80	12.64	35	7	-37	Cellyte
M81	12.09	5	4	-45	Sunlyte
M83	12.20	6	5	-43	Sunlyte
M84					Sunlyte
M85	11.98	19	3	-55	Sunlyte

Table 6. Calculated and measured battery usages at each site for 100 days with no charging. Battery voltages and temperatures are given for the middle of the period in question.

The data in table 6 is also shown graphically in figure 8.

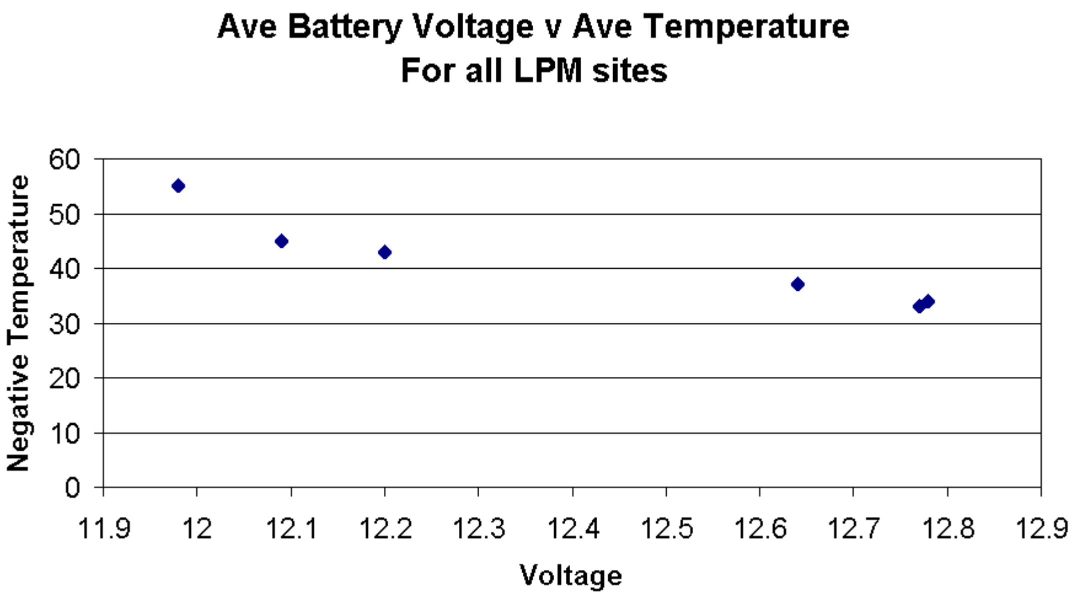


Fig8. The middle of winter voltage v temperature for each LPM site.

Although on first view it appears that the Sunlyte and Cellyte batteries have different characteristics, they are broadly on the same temperature/voltage line which has the rather large 60mV/°C slope. It should be noted that M85 actually has a higher voltage than would be expected for the temperature (11.98V compared to expected 11.5V). The coldest sites deployed in 2001/2 may be expected to have battery temperatures as low as –70°C and hence battery voltages as low as 10.5-11V).

It is also possible to look at the battery voltages of each site in the winter period (ie when there is no charging) in a scatter plot against temperature. The battery voltages on these graphs will of course be effected by power usage over the period as well as variations in the temperature of the batteries.

Figure 9 is a scatter plot of voltage and temperature for M79.

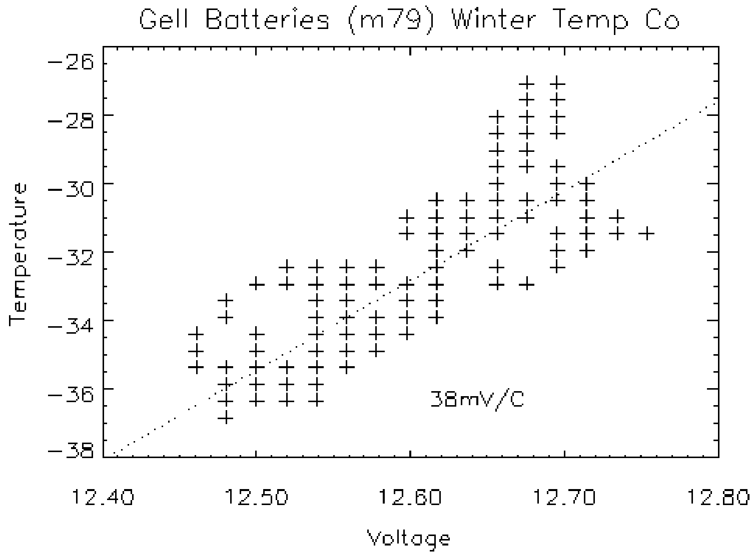


Figure 9. Voltage Temperature scatter plot for M79 in winter.

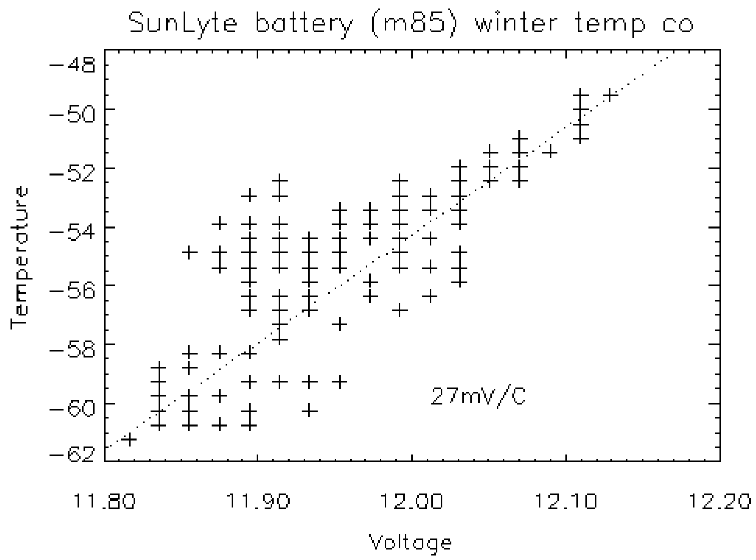


Fig 10. Voltage Temperature scatter plot for M85 in winter.

Both M79 and M85 (and all the other sites) show similar characteristics despite being different batteries and very different temperature ranges. Interestingly both show the maximum voltage range at particular temperature to be about 0.2V which suggests a capacity usage of around 16%.

Summarising the battery voltage and usage.

a/ The SunLyte batteries appear to have better low temperature characteristics than the Cellyte batteries – despite the fact that the Cellyte typically have higher voltage.

b/ The temperature coefficient of the batteries is significant when determining the charge state. The coefficients estimates vary from 60mV/°C (site to site) to 27mV/°C (M85).

c/ M85 is slightly anomalous in that the voltage is higher than expected and the rate of decline of battery voltage is also higher than other Sunlyte fitted sites.

In 2002 the sites will sample at 1Hz (in summer at least) with an expected battery usage of 30%. However, many sites will switch to slower sampling speeds in winter, prematurely as there is no allowance for the temperature coefficient of the voltage reading.

In 2002/3 it is planned to install small wind generators at most (if not all sites) which will provide more charge into the batteries but will also provide some heat energy into the battery boxes (although the wind generators themselves are unlikely to produce any energy below –60°C). In addition the voltage coefficient of the batteries will be allowed for when calculating the sampling rate – probably at 25mV/°C for temperatures below –30°C with an underlying tie point below which the batteries will not be allowed to discharge (say 11V).

4.3 Solar panel voltage

Figure 11 shows the voltage recorded off the solar panels at M80.

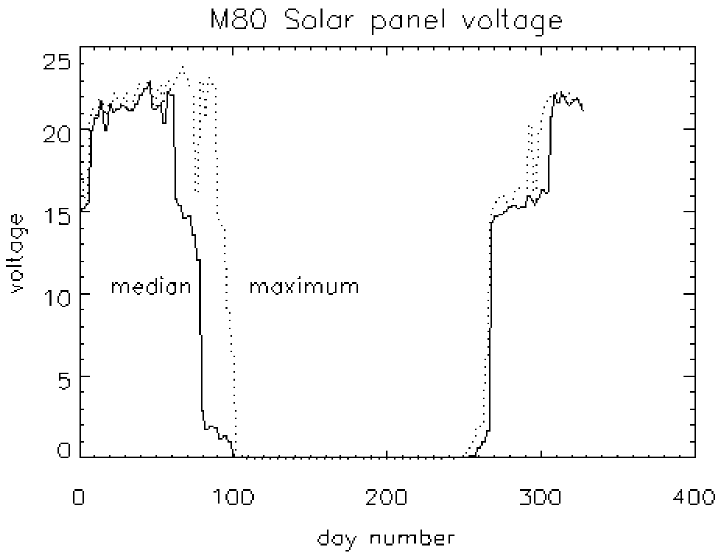


Fig 11. Solar panel voltage.

The voltage of the solar panel is not hugely useful data as its sampling is not synchronised with solar angle. However by considering both the median and maximum voltages recorded within a 24 hour period, some points do become apparent.

a/ The batteries took about 10 days to become fully charged at the start of the year – they were fitted at close to full charge.

b/ The batteries were not used until about day 60, ie up to that time the logger was running on the solar panel power, after that time some battery capacity was used at night. However, the batteries reached close to 100% every day up to about day 95, very close to sundown.

c/ The batteries recovered very quickly after sunup, probably reaching close to full charge in about 40 days.

d/ There seems to be only about 5-10 days either side of sun up/down on which the solar panel does not collect useful power.

5.0 Sites deployed in the 2001/2 season.

The four LPM's were deployed in a similar fashion to the seven deployed last season, except that they were deployed with buried cables (rather than catenaries) as it was felt that this was more robust and easier to deploy – also saving around 15Kg per system. Also, the battery boxes side by side rather than on top of each other, as analysis of the data from last year's systems showed that the marginal insulation benefit of having the boxes on top of each other was not worth the extra difficulty of deployment.

A deployment using three people took around an hour per system.

M85/096 was deployed at S85°23.37, E098°58.44, the highest (10550ft) and coldest of the LPMs – deployment temperature –29°C (but sunny with no wind).

M87/028 was deployed at S86°59.95, E028°24.82, some distance from the target position because of the crevassed nature of the area. An error in the deployment meant that this system was deployed with the solar panel facing south rather than north. The effect of this so far south is relatively minor, total output of the solar panel will be about 10% down with the winter dark period about 14days longer. Rotating the system next season should not be difficult.

M87/069 was deployed at S86°30.88, E068°10.30

M88/316 was deployed at S88°01.52, W043°51.93, the furthest south of all the LPMs.

It has not yet been decided how these sites will be serviced in future years, but considering the distance from Halley or Rothera its hard to see how it could be done without using Pole for both Fuel and for altitude acclimatisation.

It's worth recording that M83 (deployed last year) was reported as very difficult to service this season because of large sastrugi. An alternative position for this system should be considered, as the pilot next year will make the assessment whether the current site is safe to work

6.0 Logger positions

Table 7 contains the Podule serial number at each site. The Podules have been rotated to help locate the fault at M84/336.

Site	2001	2002
M78/337	L01	L03
M79/336	L02	L04
M81/338	L04	L06
M82/003	L06	L07
M83/348	L07	L01
M84/336	L03	L05
M85/002	L05	L02
M85/096	NA	L22
M87/028	NA	L21
M87/069	NA	L23
M88/316	NA	L24

Table 7: Podule locations.

L03 is the podule that failed in 2001.
L07 is the podule with poor GPS performance in 2001.

7.0 Summary of work for 2002 and 2002/3 season.

1. Run the system with analog card 5a in the UK to check for noise levels expected from data from 2002 .

2. Add temperature correction to battery charge state estimation so as to avoid premature switching to lower sampling frequency.

3. Add a small wind generator to each system.

4. Investigate winter booster batteries.

5. Add radar reflectors to each system (at pilots request).

6. Rotate solar panel on M87/028

7. Be prepared to move M83/348 to safer location.

8. Replace GPS components in Logger 07.

9. Synchronise housekeeping data with solar angle.

APPENDIX 1

LPM Positions

BAS Low Power Magnetometer Sites

Site	Name	1st 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

AFI/BAS Low Power Magnetometer Sites

These are 0.2nT/5s variants of the normal LPMs.

Site	**Name**	**1st Deployed**	**Latitude**	**Longitude**	**Elevation ft**	**IGRF Declination**	**IGRF H in nT**	**IGRF Z in nT**
Lockroy	Percy	29/11/00	64°49’28”	63°29’20”	10	+16°08’	21223	33010
Trump Island	Queenie	01/12/00	66°01’57”	65°58’12”	10	+18°27’	21366	34544
Rothera	Nursie	12/12/00	67°29’18”	68°09’47”	300	+20°46	21396	36279