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Estimating the geomagnetic secular change at Mawson, Antarctica

by

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Abstract

The provision of basic long-term data on the Earth's magnetic field and its secular changes requires, in classical magnetic observatories, the regular and frequent attention of a skilled magnetician.

At Antarctic observatories, which are manned throughout the year, this is an inefficient use of professional manpower; but the imminent availability of automatic magnetographs with long-term stability raises the possibility of obtaining the requisite data without recourse to full-time attendance by a geophysicist.

For example, it may be practicable to obtain sufficiently accurate estimates of the field by absolute calibrations made only during the annual relief operations.

Analysis of ten years' preliminary data from Mawson magnetic observatory shows that December mean values give adequate estimates, provided that a minimum time-span of about 5 years is used; over lesser intervals the variability from year to year produces up-and-down errors in the estimates.

Suitable automatic magnetographs should be developed and tested quickly with the object of replacing traditional magnetographs, and reducing the manpower required for everyday attention.

Introduction

Magnetic observatories provide data for two principal fields of study: short-period ('transient') data for upper atmosphere/magnetosphere researches; and long-period ('secular change') data for specifying the Earth's main or internal magnetic field. Transient variation data are also applied in researches into the conductivity-structure of the crust and upper mantle. Only for specifying the internal field is it essential to have the data in absolute terms; for the other studies, data in relative terms suffice.

BMR's network of magnetic observatories includes two in Antarctica and the sub-Antarctic which have been manned for up to 27 years. They are equipped with classical suspended-magnet, analogue-recording magnetographs which require the full-time attention of a skilled observer to ensure that they produce accurately calibrated records of acceptable quality. But the imminent availability of highly stable electronic variometers recording digitally on magnetic tape - so-called automatic digital magnetographs (ADM) - makes it opportune to examine whether the main objectives can be met at the Antarctic observatories in a more efficient way.

In practice, this reduces to determining whether the Earth's main field and its secular change can be derived sufficiently accurately from an abbreviated series of periodic measurements. For example, if an ADM is capable of several weeks' stable operation it may suffice to calibrate it during the annual relief of the Antarctic stations, tnus releasing an observer for most of the year. Sensitivity tests can be automated easily, so there is no difficulty in providing continuous records calibrated for transient variations.

This note gives an assessment of what inaccuracies or differences might arise from using one month's Antarctic data each year, rather than annual mean values.

Data and methods

Opportunities to visit Australian Antarctic stations have been confined to the summer (December, January), and it is likely that this pattern will continue for some considerable time. Therefore it is assumed that a future unmanned ADM would be calibrated during December each year, so actual monthly means at Mawson for December have been compared with an 'annual' mean centred at about the same epoch.

The data used are preliminary monthly and annual mean values published in the 'Geophysical Observatory Reports' for the years 1968-1977 (more precise data derived from digitising the magnetograms were not available). Similar data before 1968 are either not published (1957-1961) or not readily accessible (1962-1967); however, inspection of the latter group of data showed that they supported the results discussed here.

Preliminary monthly data are derived from the locally-chosen 10 quiet days, and on average should be free from short-term disturbance effects (e.g. the post-perturbation depression of horizontal intensity which is a feature at low/mid latitudes is negligible at Mawson, geomagnetic latitude -73.2^{o}). However, they include longer-term seasonal effects (Fig. 2) and these need to be taken into account.

The 'annual' means at the December epoch were obtained by averaging consecutive yearly means; e.g. the average of the annual means for 1970 (i.e. the value at 1970.5) and for 1971 (at 1971.5) gives the average at 1971.0, i.e. at the end of December 1970: this is compared with the observed average value for the month of December 1970. The difference in epoch of 15 days between the two sets of data gives a systematic error due to secular change which is a maximum (in vertical intensity) of about 4 nT.

Results and discussion

Table 1 gives for the three elements declination (D), horizontal intensity (H), and vertical intensity (Z): the annual and December mean values; their differences; and the secular change derived from each set. Mean results are included for the entire interval and for each half of the interval. The differences are displayed in Figure 1.

Table 2 and Figure 2 give the average differences between the monthly and annual means; these monthly departures show the approximate seasonal variation. The data plotted in the figure have been normalised by correcting the observed values for secular change: for D and Z the rates for the entire interval were essentially constant so the mean values in Table 1 were used; for H there were significant changes in rate, and the prevailing values were used.

The results are discussed under two headings: level, and secular change; clearly the two are inter-related.

Level

Values obtained at some epoch generally differ from long-term average values by amounts depending on the season, secular-change, and other transient fields. Because the data used here are based on local quiet days it is assumed that the average effects of short-period transients are negligible. The individual monthly values (not reproduced) show this to be a reasonable assumption, but there are exceptions and this needs to be borne in mind.

The question to be considered is whether the values obtained in December are different enough from the annual values to give an erroneous estimate of the main field. The seasonal data (Table 2, Fig. 2) show that December values differ systematically from the annual values by 3 to 9 nT; considering that crustal anomalies produce a 'noise' on the global scale of 100 to 200 nT, this difference is negligible.

TABLE 1
Magnetic Mean Values, MAWSON

(December values are those at mid-December prior to epoch)

	Year												
	1968.0	1969.0	1970.0	1971.0	1972.0	1973.0	1974.0	1975.0	1976.0	1977.0	68/77	68/72	72/77
Declination													
Mean values (-62° minus tabular values)													
Annual	39.1	48.4	56.8	62.9	68.4	74.5	81.2	88.1	94.4	100.6	71.4	55.1	87.8
December	38.1	45.1	54.5	62.3	66.9	73.0	80.3	85.4	93.6	99.9	69.9	53.4	86.4
Difference	-1.0	-3.3	-2.3	-0.6	-1.5	-1.5	-0.9	-2.7	-0.8	-0.7	-1.5±0.6	-1.7±0.7	-1.4±0.5
Secular change													
Annual		-9.3	-8.4	-6.1	-5.5	-6.1	-6.7	-6.9	-6.3	-6.2	-6.8±1.2	-7.1±1.1	-6.4±0.2
December		-7.0	-9.4	-7.8	-4.6	-6.1	-7.3	-5.1	-8.2	-6.3	-6.9±1.4	-7.0±1.2	-6.6±0.8
Horizontal Intensity													
Mean values (18000 plus tabular values)													
Annual	370	359	356	366	378	386	390	394	408	422	383	366	400
December	374	387	370	374	387	383	400	411	408	427	392	378	406
Difference	-4	-28	-14	-8	-9	+3	-10	-17	0	-5	-9	-12	-6
Secular change													
Annual		+11	-3	+10	+12	+8	+ 4	+ 4	+14	+14	6 ± 7.9	3 ± 6.3	9 ± 5.6
December		+13	-17	+ 4	+13	-4	+17	+11	- 3	+19	6 ± 11.2	2 ± 8.1	8 ± 6.9
Vertical Intensity													
Mean values (-4700 minus tabular values)													
Annual	1114	1007	897	780	660	543	433	324	213	104	607	892	323
December	1127	995	900	782	671	544	427	326	221	108	610	895	325
Difference	+13	-12	+3	+2	+11	+1	-6	+2	+8	+4	3 ± 7.1	3 ± 9 "	2 ± 4.9
Secular change													
Annual		+107	110	117	120	117	110	109	111	109	112±4.3	114±5.1	111±3.1
December		132	95	118	111	127	117	101	105	113	113±11.2	117±12.9	113±9.6

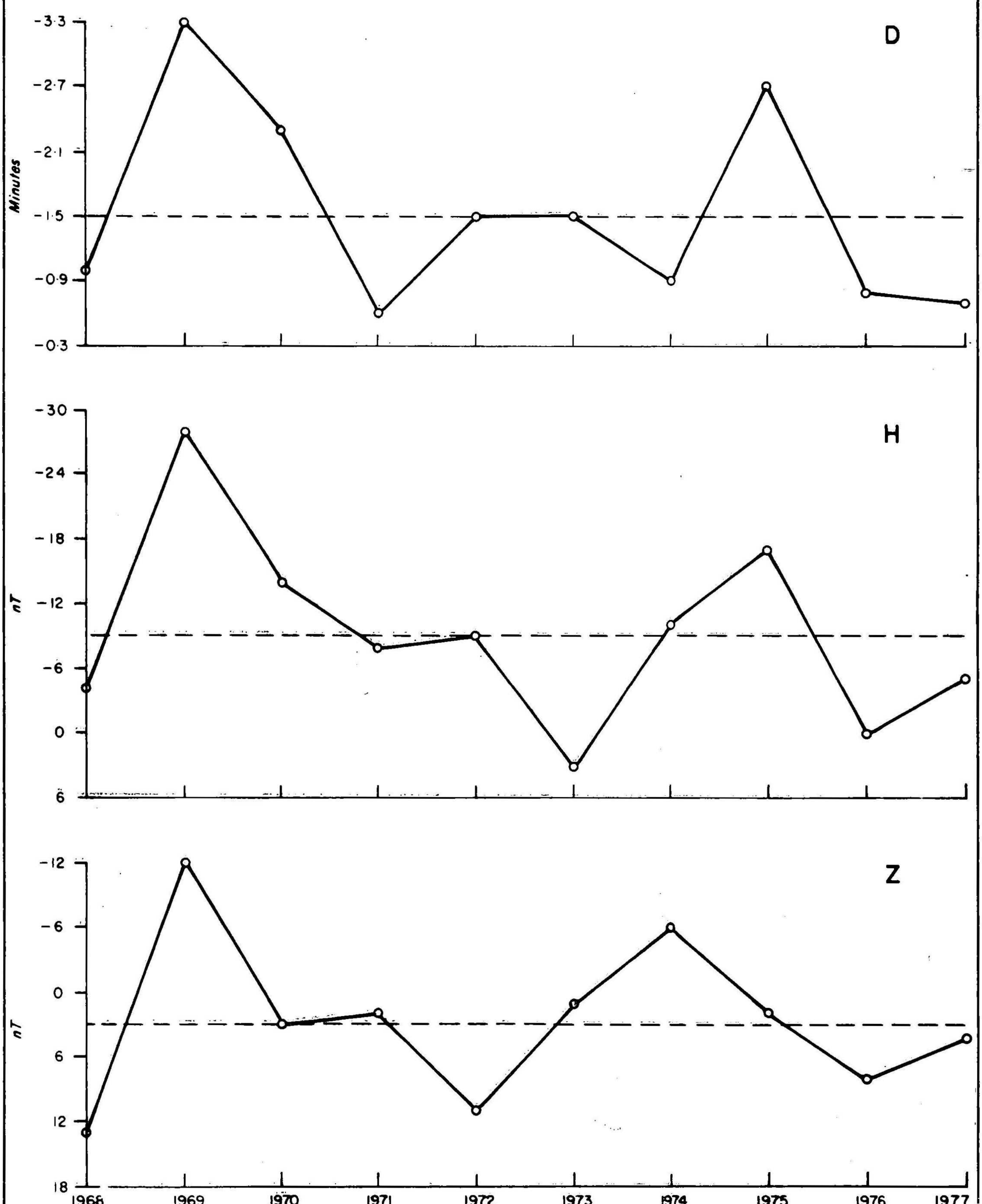

Fig. 1 Mawson Difference: (Annual Mean) Minus (December Mean)

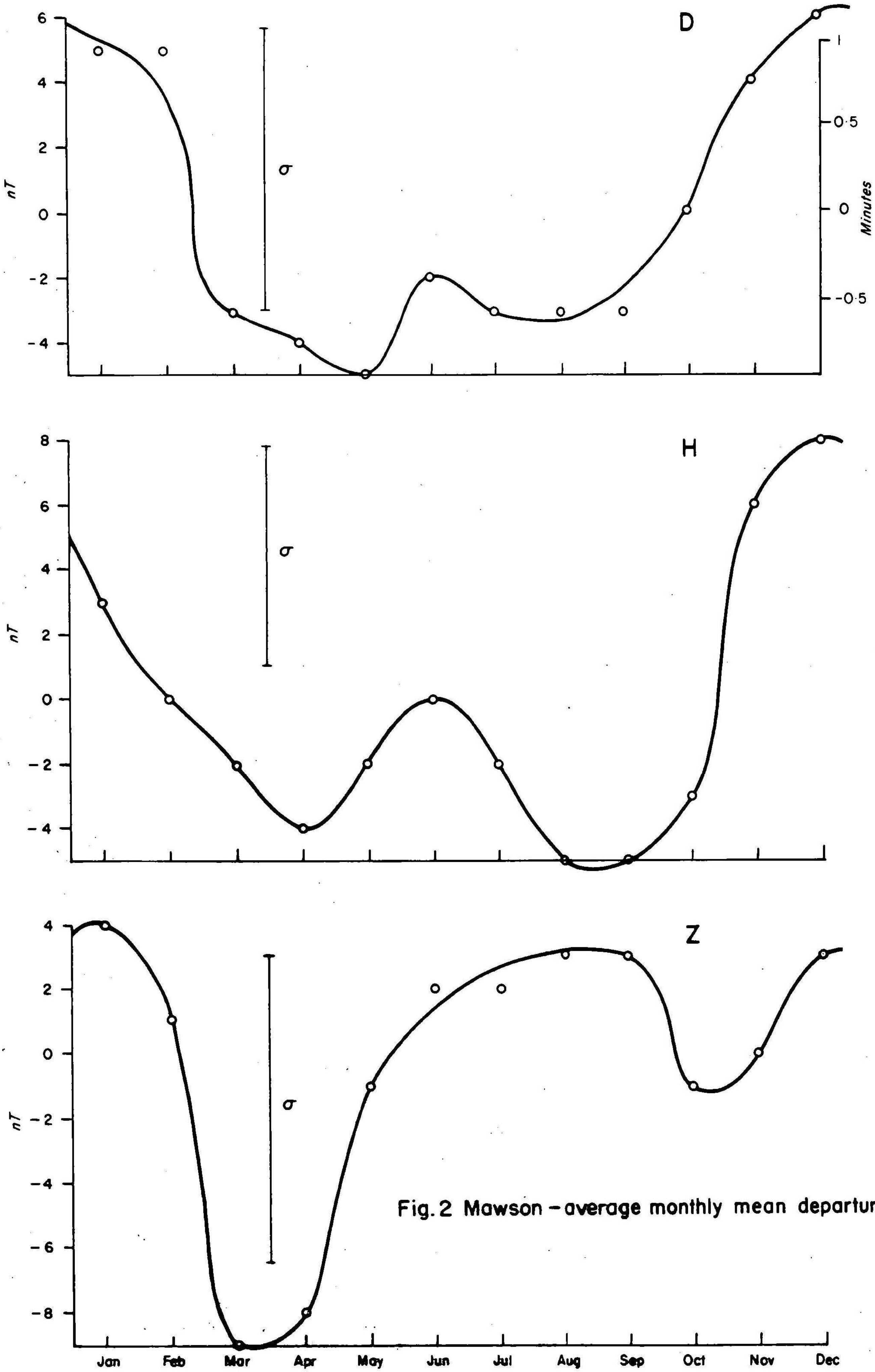

Fig. 2 Mawson – average monthly mean departures

Secular change

The secular-change results in Table 1 show that estimates based on consecutive December values can differ greatly from the general trend given by the annual means (the standard deviation bars in Fig. 2 indicate the magnitude of the variability). Obviously an 'abnormal' value in one December (e.g. 1968) affects the estimates for two years, but in the long term these effects must average out. Thus the results for the two 5-year intervals (Table 1) are not significantly different from the annual results. Results over shorter intervals are not so good so it seems that 5 years is about the necessary time span for reliably estimating the secular change.

Conclusions

Analysis of monthly magnetic values on quiet days at Mawson has shown that although average seasonal effects are negligible, individual December values can differ markedly from general trends; but over intervals of about 5 years the December means give good estimates of the Earth's main field and its secular change.

Therefore the main objectives of high latitude observatories could be met by obtaining recordings calibrated in absolute terms over about a four-week interval each year; and for the remainder of the year recordings calibrated only for scale values would provide data on transient variations.

Operation of an observatory in this way would obviate the need for a full-time geophysicist at the observatory. Instead there would be a need for an on-site attendant for a few hours a week (to make diagnostic system checks, to change records, to replace faulty modules, and the like); and for annual visits by a professional and a technical officer (to thoroughly overhaul and calibrate the magnetograph).

Table 2

Magnetic annual variations Mawson (1967-76) - algebraic

(Monthly mean - Annual mean)

	D				H			Z		
	Mean		Monthly depture		Mean		Monthly	Mean		Monthly
	Observed	Corrected (a)	min	nT	Observed	Corrected (b)	Departure	Observed	Corrected (c)	Departure
Jan.	-27.8	-27.5	1.0	5	381	383	3	-241	-246	4
Feb.	-28.5	-27.6	0.9	5	380	380	0	-235	-249	1
Mar.	-30.5	-29.1	-0.6	-3	375	378	-2	-236	-259	-9
Apr.	-31.2	-29.2	-0.7	-4	376	376	-4	-225	-258	-8
May	-32.0	-29.4	-0.9	-5	378	378	-2	-209	-251	-1
Jun.	-31.9	-28.8	-0.3	-2	381	380	0	-197	-248	2
Jul.	-32.8	-29.1	-0.6	-3	379	378	-2	-187	-248	2
Aug.	-33.2	-29.0	-0.5	-3	376	375	-5	-177	-247	3
Sep.	-33.9	-29.1	-0.6	-3	377	375	-5	-164	-243	7
Oct.	-33.9	-28.5	0.0	0	379	377	-3	-162	-251	-1
Nov.	-33.8	-27.8	0.7	4	388	386	6	-152	-250	0
Dec.	-33.9	-27.4	1.1	6	392	388	8	-140	-247	3

(a) D secular correction -6.8'/yr (b) H secular correction variable (c) Z seecular correction 112nT/yr

Development and proving of suitable magnetographs should proceed vigorously to enable this mode of operation to be adopted. The benefits are the elimination of the need to recruit inexperienced geophysicists for Antarctic duty every year: one permanent officer could be devoted to the operation of several Antarctic stations and to the analysis of results. All the data required for national and international programs would be produced, but delays in reporting some of them (e.g. K-indices of disturbance) would be introduced.

The concurrence and co-operation of the Antarctic Division would have to be obtained for this change: firstly, an expedition member would have to provide the part-time servicing of the magnetograph (and seismograph); secondly, berths (on ship or aircraft) would have to be provided at each relief operation for two persons to make the annual calibrations.