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DATA ACQUISITION FOR THE INTERNATIONAL MAGNETOSPHERIC STUDY AT THE CHURCHILL ARRAY OF MAGNETIC VARIOMETER STATIONS

Plet, F.C. and G. Jansen van Beek

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RE: ERRATA, EPB OPEN FILE #82-4

Dear Sir/Madam:

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/bh

ERRATA, EPB OPEN FILE #82-4

Page 32, paragraph 2, line 3 - should read Satellite[4] (GOES)

Page 37, paragraph 1, line 4 - should read Figure 8

Page 37, paragraph 2, line 2 - should read Figure 9(a)

Page 37, paragraph 2, line 3 - should read Figure 9(b)

Page 37, paragraph 3, line 1 - should read Figure 8

Page 38, paragraph 1, line 1 - should read A review of the literature [3, 4] does not........

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In 1975 the United States undertook development of the Data Collection Platform Radio Set (DCPRS) as the principal pivot of its IMS data acquisition program to serve a far-flung network of 25 stations spread throughout North America and the Pacific. It was designed to interface with link relay capabilities of the Geostationary Operational Environmental Satellite (GOES), a joint creation of NASA and NOAA primarily directed to weather monitoring.

When implemented, the platform device received time information from the satellite to control its own internal clock which in turn determined when a self-timed data transmission was to occur. Data measured by the station sensors were transmitted every 12 minutes via GOES by radio signals of approximately 110 seconds duration. The repeating pattern was fixed relative to the hour for any given station but differed one from the other for the purposes of station identification and central reception in time sharing of channels.

Relayed by the satellite to a decode depot in Wallops Island, Va., the IMS data were then routed via dedicated telephone link to the SELDADS receiving facility in Boulder. (Descriptions of the satellite data route have been given by D.J. Williams[3], C.E. Hornback (personal communication, 1977) and a NOAA Technical Report[4]). Following automated processing through a mini-computer, the data were made available on line for up to one week, converted to 1-minute averaged values, stored on disc and copied to tape for deposit with WDC-A.

The DCPRS platforms at the stations were jointly operated by the USGS, SELDADS group and EPB. Remote status interrogation was cooperatively performed by the three agencies and corrective command functions applied by SEL using equipment designed for the purpose.

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An on-site digital data-logger system recording on magnetic tapes which were periodically mailed to Ottawa by a local contractor.

The device, designed and developed as a field variometer by EPB's Geomagnetic Laboratory at Blackburn (D.F. Trigg[5], 1975), was low-powered and possessed a high recording capacity to minimize the frequency of human intervention required for the dismounting and re-loading of tapes. (e.g. A station recording only three channels of information can run about three months before filling a 730 m tape).

Data collected by this system were batch-processed on a CDC computer in Ottawa by a software package developed to meet the edit requirements.

BACKGROUND AND IMPLEMENTATION CHRONOLOGY

In advance of the scheduled commencement of digital-data acquisition in September 1976, both the tape data-logger and the satellite relaying platform were unproven, so direct experience could play no role in any comparative assessment of either cost-effectiveness, quantity, or quality of output.

Some of the known and anticipated advantages of the satellite system over the tape-logger system were:

- The satellite platform was presumed to have better resolution with 14 bits (compared to 12 bits for the

A COMPARISON OF DATA RETRIEVAL EFFICIENCIES AT AN IMS STATION PART IV

RESOURCES AND OPERATIONAL COSTS

Cost of Station Equipment

Excluding the cost of the magnetometer and photometer the cost of both the satellite transmission system and the tape data-logger system roughly balanced out at about $10,000 each. The cost of the tape deck was slightly higher than the satellite radio but the radio interface /controller/A to D converter was more expensive than its equivalent for the digital tape-logger. Other equipment such as clock, regulated power supply and standby power were the same for both systems.

Cost of Data Transmission

As the IMS program was scientific in nature and of limited duration, it was allowed to use, at no charge, the highly sophisticated Geostationary Operational Environmental Satellite[4] (GOES) developed jointly by National Oceanic and Atmospheric Administration (NOAA) and National Aeronautics and Space Administration (NASA), both of the United States. In Canada, no such national satellite was available to the scientific community at that time. Cost of data transmission by using the tape-loggers was $20.00 Canadian for a 730 m magnetic tape and $4.50 per shipment via registered mail.

Cost of Software Development

In any new system relying heavily on computers for control and processing, a great proportion of the development cost lies in the writing of computer programs. The system development for the acquisition of data brought to Boulder via SMS-GOES (satellite data) required four person-years for providing the necessary programs (Hornbach, personal communication, 1979). In satellite data, there does not appear to be any pattern to the distribution of missing values. To make sure that there were no cyclic patterns with periods longer than a week, the percentage of missing data as noted by the satellite platform status reports from Boulder were plotted in Figure 8 along with the International Disturbed Days. Again, there is no apparent cyclic behaviour or correlation between missing data and magnetic activity.

With the aid of Table A(4) in the Appendix a few representative days using the "satellite" data set were plotted. Figure 9(a) contains reconstituted magnetograms at 10 nT/mm from Island Lake. Figure 9(b) is a magnetogram from the "tape" data set to cover the missing period in day 206 (July 25, 1978) from the "satellite" data set. It is evident that no unusual magnetic or instrumental events are associated with the data breaks.

Re-examining Figure 8, the visual average of the percentage of missing data as indicated by the platform status report does not agree with the percentage of missing data as indicated by a tally of the data set from the 1-minute satellite tapes. Therefore, a more detailed compilation of missing data from the satellite (Table A(4)) was made for comparison to the platform status reports. Inconsistencies are apparent. It is evident that platform status messages tend to indicate a lesser amount of missing data than a detailed tally of the final 1-minute "satellite" data set.

A platform message consists of 12 minutes of real-time data or 0.8% of the "satellite" data set for one day. Therefore, even if the percentages of missing platform messages are truncated (they apparently are from 7 July to 17 September, 1978), it still does not explain the discrepancy between platform messages and the data tally. Furthermore, although the platform messages and station logs do not show any instrumental malfunction, the following days are missing from the final 1-minute "satellite" data set:

March	29	Z Component only
April	4	Z Component only
May	10,17	D. H, Z Components
June	1,2,3,4,5,6,28,29,30	D, H, Z Components
September	6,7,8,9,10,11,12	D, H, Z Components

A review of the literature [3, 4] does not reveal the source of these errors. However, the data linkage from Island Lake to Boulder, Colorado has many places where errors could be injected into the data.

CONCLUSION

If the cost of the satellite, ground receiving station and data collecting platform/radio are included in the cost of the "satellite" data set, then certainly the "tape" data set is produced at less cost. If only the cost of the data collecting platform/radio is compared to the tape-logger, then costs of data production are comparable. In the latter case, the cost of dedicated mini-computer(s) for the processing of "satellite" data is balanced by the cost of tape processing and the person-years associated with it. If the amount of missing data is taken into account then the "tape" data is a more effective method of data collection. If data quality is taken into account, then the tape-logger method is definitely more effective. However, immediacy of data and uniformity of data format over a very diverse (international) network of variation stations are strong arguments for a SMS-GOES type data routing.

Increased automatic control over the production of data relieves the investigator of much of the drudgery of editing data. This works well when instrumentation is stable and error free or when technical assistance is

CONTENTS

ABSTRACT

Review is made of the implementation of the Churchill Array of magnetic variometer stations undertaken as an Earth Physics Branch contribution to the International Magnetospheric Study digital data acquisition program. Consisting of eight stations close to the meridian of Fort Churchill, the array was maintained from September 1976 until mid-1980. Two separate recording systems (1. EPB's on-site tape-logger; 2. a real-time system telemetered via satellite to Boulder, Col. from six of the stations) were in concurrent service commencing in December 1977.

Data recovery problems occurred with each system and measures that were taken to resolve those difficulties for the EPB tape-logger record are discussed in the contexts of timing errors and noise interference. The software package developed to apply the corrective computer processing is outlined in terms of its bearing on resultant data quality of the EPB system.

Available data in EPB archival files are illustrated for the eight stations in the form of bar graphs. A recovery rate of ~60% averaged over the total recording period was realized with the tape-loggers, representing edited data of high quality and comparatively free of short gaps. An additional ~10% coverage was retained at varying degrees of lesser quality (usable with restrictions). First quality data recovered by 1979 had improved to ~73% for that year.

Output from one of the stations is used to compare the effectiveness of the two recording systems in retrieving data. Limited to a selected period when both systems were fully operational at the site, the assessment is made of the extent and distribution of missing data. A general evaluation of resource and operations costs is given.

All EPB data files are stored on magnetic tape at the recording interval of 10-seconds or in a derived version comprising 1-minute averaged values in standard IAGA format. They are available to the Canadian and international user communities on request and on a cost recovery basis from EPB. The 1-minute data have also been deposited with World Data Center A in Boulder in addition to (and separate from) the satellite-relayed 1-minute data set from the Churchill Array.

RESUME

Dans cette publication nous décrivons la contribution de la Direction de la Physique du Globe (DPG) à l'Etude magnétosphérique internationale (EMI). Nous avons exploité la ligne "Churchill" de postes où les variations géomagnétiques ont été enregistrées sous forme numérique. Huit stations près du méridien de Fort Churchill étaient en service de septembre 1976 jusqu'à mi-1980. Deux systèmes indépendents d'enregistrement existaient simultanément à partir de décembre 1977; 1. l'enregistreur sur bande magnétique de la DPG, sur place; et 2. à six des stations, un système de télémetrie en temps réel par satellite à Boulder (Colorado).

Pour chaque système nous décrivons les problèmes rencontrés pendant la rédaction des données et, pour le système de la DPG, les mesures prises pour corriger les erreurs d'heure et de bruit. Des programmes en informatique ont été écrits pour redresser ces erreurs; nous montrons comment l'usage de ces programmes a amélioré la qualité des données du système de la DPG.

Les périodes de temps pendant lesquelles les données de la DPG sont disponible aux huit stations sont indiquées sous forme graphique. Pendant ~60 pour cent de l'EMI, les données enregistrées sur bande ont une haute qualité, et il n'y a que très peu de petites brèches quand les données ont été perdues. Pendant ~10 pour cent de plus, des données d'une qualité dimininuée sont utilisable sous restriction. Pour l'année 1979, des données de la première qualité sont disponibles pendant ~73 pour cent du temps.

A l'un des postes, nous avons comparé les résultats de deux systèmes d'enregistrement. Pour une période choisie quand les deux étaient en pleine forme de marche, nous donnons la quantité et distribution des données perdues. Nous faisons aussi une évaluation générale des coûts de ces systèmes.

Toutes les données de la DPG sont archivées sur bande magnétique à l'intervalle original d'échantillonage de 10 secondes, ou dans une version retirée de l'original, soit des valuers moyennes prises sur une minute. Elles sont disponibles aux usagers canadiens et internationals sur demande mais il y aura des frais de reproduction. Les données prises sur une minute ont été déposées au Centre mondial de données A, à Boulder, en plus et indépendamment, des données transmises directement par satellite.

INTRODUCTION

The International Magnetospheric Study (IMS) was conceived as an international cooperative program to study key problems of the nearby space environment, the region known as the magnetosphere, which is controlled by the extension of the earth's magnetic field.

In 1969 the International Council of Scientific Unions initiated plans for the data acquisition phase of the IMS program from whence a global enterprise of coordinated ground-based and satellite measurements was implemented. All data issuing from the IMS were to be deposited in the World Data Centers. It was hoped a more enlightened understanding of magnetospheric processes and their parameters might be served by the extensive information on events that such a databank could gather.

Duration of the observational period was chosen for mid-1976 through 1979. Commencing shortly after a low point of the solar activity cycle and lasting to the high, the IMS was considered opportunely timed as advantage could also be taken of unique spacecraft communication facilities and utilization of new recording techniques which were becoming available.

A major United States contribution to the IMS arose from a family of some dozen satellites placed by NASA in various earth orbits for other national programs during the 1975-79 period. Generally where less-than-full channel capacity was employed by such spacecraft in the programs for which they were primarily designated, accommodation was made available to IMS in the interest of cost effectiveness. The European Space Research Organization played a major role in IMS through operation of experiments built by research institutions of seven European countries and carried aboard the ESRO geostationary satellite GEOS. Other major IMS spacecraft included the Japanese EXOS series.

A comprehensive ground-based network of geomagnetic observing stations was essential to meet the IMS objectives. As part of the overall plan[1] which included arrays in Scandinavia, Greenland and Alaska, two highly strategic networks of stations were operated in Canada by Canadian agencies[2].

These were:

- a meridian chain of stations in western Canada operated by of the University of Alberta.
- a meridian array in central Canada established and managed by the Earth Physics Branch (EPB), known as the "Churchill" line of stations (subject of the present report).

GEOGRAPHIC DISTRIBUTION

Evolved from an earlier program with NASA for measuring magnetic disturbances at the foot of the ATS-5 synchronous satellite fluxtube and to support a rocket range at Fort Churchill, the Churchill Line was an integral part of a joint U.S. - Canada network in North America. Revised and expanded for IMS, the array consisted of six magnetic variometer stations deployed roughly along the meridian through Churchill (both geomagnetic and geographic) from Island Lake in the south to Pelly Bay within the cleft region to the north (see Fig. 1). Two more east-west flanking stations at Fort Severn and Thompson completed a cross configuration. The higher density of stations recording within the auroral zone was established to provide greater resolution of disturbance detail.

RECORDING SYSTEMS (SATELLITE/TAPE-LOGGER)

Data of the Churchill Array were recorded concurrently through most of the life of IMS by two separate systems sharing a common triaxial fluxgate magnetometer at each of those six stations located on the north-south line . At each of all eight station sites, the one or two installed systems monitored the earth's magnetic field in three components sampled at intervals of 10 seconds. Ultimately 1-minute interval files derived from the original 10-second data were deposited with World Data Center-A in Boulder, Colorado. Photometry data in four emission bands were also recorded at three stations with a zenith photometer and were retained in the 10-second data sets. A fourth station recorded only one channel of emission data with a scanning photometer during a portion of the IMS.

Beyond the actual recording site operations, the course and handling of all data from the two systems were undertaken by separate organizations.

The systems were:

1.

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In advance of the scheduled commencement of digital-data acquisition in September 1976, both the tape data-logger and the satellite relaying platform were unproven, so direct experience could play no role in any comparative assessment of either cost-effectiveness, quantity, or quality of output.

Some of the known and anticipated advantages of the satellite system over the tape-logger system were:

- The satellite platform was presumed to have better resolution with 14 bits (compared to 12 bits for the tape-logger), microprocessor control and a real-time capability.

- The satellite platform was recognized to possess better time control, which was obtained directly from a beacon on the SMS/GOES (eastern or western twin).
- A built-in EPB digital field clock was used in the case of the tape-logger. The clock was not remotely controlled as with the satellite system, but was set manually whenever need arose.
- No editing of data by EPB was to be required for the satellite system as SELDADS group had invested substantially in program preparation and pretesting of an automatic processing software package.
- EPB at the time had prepared only the basic program for the preliminary reading of raw tapes sent back from the tape-loggers at field stations.

Notwithstanding these criteria, several concerns led to the installation of seven tape-loggers at Rankin Inlet, Eskimo Point, Back, Gillam, Thompson, Island Lake and Fort Severn by early October 1976.

- The satellite data acquisition system was unproven.
- The IMS program afforded an opportunity for application of the unproven tape-logger hardware developed at EPB.
- Raw data would be immediately retained by EPB for first-hand control over quality.

As it turned out, the satellite radio platform units expected from Boulder were not functional or available for delivery by the beginning of IMS. The delay which ensued sealed the options, leaving all other considerations superfluous: i.e. the seven tape-loggers were the only digital recording devices operating until the radio platforms were made ready for installation after the first year of the IMS program.

Subsequently in the fall of 1977 five of the satellite relaying units were delivered to Ottawa, tested at the Blackburn laboratory and installed during December at Gillam, Rankin Inlet, Eskimo Point, Island Lake and Pelly Bay, to operate alongside the tape-loggers already in place. An eighth tape-logger had been installed at Pelly Bay in September 1977 and the last satellite platform was introduced at Back in late January of 1978. Except for a variety of occurrences causing interruptive gaps in the data, both systems then continued in service for the remainder of the IMS and were further extended until mid-1980 to provide additional support for MAGSAT.

STATION SERVICING

The SELDADS group acted as the focal point for IMS requirements of the GOES weather satellite data collection system within NOAA. As such they assumed full responsibility for servicing their radio platforms and applied corrective actions through a remote command system in follow-up to a site status interrogation procedure. Aside from cooperation in communicating with the station sites there were no encumbrances to EPB.

Limited by budgetary restraints, flight schedules and available manpower, EPB attempted periodic servicing of the tape-loggers at the sites by a laboratory technician about twice a year. Resident station operators were employed under contract to attend to rudimentary functions which included changing the tapes and mailing them to Ottawa at intervals of one to three months. Instrumental breakdowns of any obvious nature were normally reported by the operators. But as most malfunctioning was registered only as erratics in the data with no on-site external symptoms apparent, such discoveries were made only after computer analysis and visual plot inspections were performed on the field tapes in Ottawa. The site operator could then be instructed over the telephone by an Ottawa lab technician regarding remedial action. Problems resolved in this manner usually involved replacement of existing components with tested circuit boards mailed to the stations. Success, however, could never be confirmed until further data were returned to Ottawa and processed.

Over the life of IMS a few logger units were exchanged with a spare unit kept in condition at Blackburn Laboratory as emergency standby for extreme cases.

EFFECTS OF SERVICING ROUTINES OR INSTRUMENTAL PERFORMANCE ON DATA RECOVERY

Lag time for corrective action to the EPB tape-loggers was cumbersome at best, given the chain of discovery, communication and material delivery requirements associated with remote site operations. Extensive "down" periods were sometimes caused when an entire unit was removed from service. Partial failure conditions involving malfunctioning in one or sometimes two magnetic channels were notably more frequent. Where problems could not be resolved by the station operator, the solution would normally be delayed until a technician's service trip could be arranged. In consideration of cost, such service often had to await the next scheduled general inspection tour of the entire line of stations.

When assessed overall, the tape-logger data gaps due to hardware failures were reduced during the later period of operations. This was partly attributable to the completion of the software editing package enabling quick identification of any problems contained in newly arrived data. As emphasis could be switched from development to application, and the processing of a sizeable raw data backlog commenced to move rapidly, the handling of current field data finally became a routine procedure. Also through instrumental improvements there was latterly much less protracted noise in the records, while virtually all noise in the form of spikes could be removed through the software.

Frequent repeating gaps, occurring in brief interruptive bursts the order of a few minutes, were a common fault in the satellite-relayed data. These often endured from hours to several days at a run. This characteristic was not observed in the data produced by the tape-loggers and continuity was generally assured whenever that system was operational (see Fig. 5). An advantage was hereby apparent with the tape-logger system inasmuch as it allowed for a fuller selection of unbroken sample events for analysis.

Dependent upon the DCPRS relay schedule for any given station, up to 12 minutes of data are consistently missing from the satellite record at the end of each UT day due to an error in the SELDADS raw-data processor. The first transmission of the day, conveying 12-minutes of data, had lost any values registered on the previous day - e.g. at Island Lake this amounted to 10 minutes, 17 seconds. With a single 1-minute average calculated from incomplete 10-second data, this resulted in an apparent loss of 9-10 minutes (see Part IV, page 36). The tape-logger data were unaffected at all stations.

RADIO TRANSMISSION INTERFERENCE

The development of EPB'S basic editing software was undertaken with the primary objective of processing the first year's tape data to a state of completion in view of the fact there were no satellite data for that period.

However, as attention finally turned by late 1978 to preliminary inspection of the more recent raw tape data (post Dec. 1977), a phenomenon of some concern presented itself; i.e. at least four of the six stations, which also possessed the SELDADS platform, displayed a continuum of square spikes superimposed on the natural magnetic data. Varying in magnitude up to 50 nT in the component being recorded and more readily recognizable during quieter periods, these pulses lasted about 2 minutes and were repeated at 12-minute intervals. Onsets were in direct correspondence with SEL's announced schedule of telemetered data transmission for each specified station in every case.

Subsequent examination of filmed magnetogram plots of the 10-second satellite data received from Boulder confirmed the impression that the satellite transmission was interfering with the data it was delivering. Furthermore the square spikes were propagated through the shared magnetometer and were found to be identical in the outputs of both the satellite system and the tape-logger system. After the automated processing at Boulder, the square pulses of the original 10-second data became broadened and flared into a series of approximately 3.5 minute bumps in the derived 1-minute files (see Fig. 4) generated for achiving. No editing procedures were available at SELDADS for removal of these effects.

COROLLARY

Concordant with the EPB program to acquire IMS data using the tape-loggers, was the undertaking to prepare these data in a form amenable to access and to assert reasonable quality control over the output. As raw data were received in Ottawa during the first year of operation, the great number of unanticipated hindrances emphasized the vital need for development of a coordinated software package to adequately organize and edit the large quantity of data, while maintaining flexibility to handle the problems as they appeared (see EDIT SOLUTION MEASURES, page 18).

The impact of the need to overcome the obstacles inherent with the tape-logger data was not felt in its fullest measure, however, until the aforementioned discovery in late 1978 of the satellite radio transmission interference. At all affected stations housing the satellite-logger relay platform, the data of both satellite and tape systems were equally contaminated by the transmission feedback through the magnetometer as already stated. Accordingly, further programming was then required to remove this type of spike from the tape data set, i.e. in addition to those types initiated within the tape-loggers themselves.

DEVELOPMENT OF SOFTWARE FOR EPB TAPE-LOGGER SYSTEM PART II

DATA ORGANIZATION

Format

Basic blocking format for recording the 10-second data was established in the tape-loggers prior to their deployment in Sept-Oct of 1976. Later adjustments allowed for the inclusion of auroral photometry data which supplemented the magnetic data at four of the stations.

10-Second Files

Relative values of the orthogonal components of the geomagnetic field were sampled simultaneously in nanotesla and registered on 7-track tape at 200 bpi in the sequence H,D,Z. Sampling was repeated at intervals of 10 seconds. At intervals of 20 minutes an IRG was introduced to define a record block consisting of 120 time samples. The first sample of each 20-minute record occurred at a time encoded from the built-in digital clock and written into an identification label entered at the head of that record. After converting field tapes to CDC binary in the initial read program BRAVO, a full 8-word label contained a 4-character alphameric name of the station followed by its numeric code combining latitude and east longitude. Next on the label was registered the time (UT) of the record's first sample entry giving the year, day of year, hour, minute and second in words 3 through 7. The number of channels concurrently containing data at a given station for that particular record was entered in word-8. Expressed by that number, a variable record length has been featured in the processed data sets of the 10-second files to provide for economic storage of auroral data for those stations which were equipped with photometers. This was executed as outlined in the following description.

Photometry inclusion

At the time of installation of the tape-loggers at the recording sites late in 1976, an NRC zenith-type photometer was included at each of stations Back, Gillam and Island Lake. Those three stations were altered to always record seven channels of data - three magnetic elements and four auroral emission bands (see contents, Table 1). The variable record format was introduced for the processed tape files in order to store the photometry portion of the data only during night-time hours, condensing storage space requirements and reducing cost. An argument based on season and station latitude specified the two diurnal limits for the data's inclusion. Inside those variable delimiters of no daylight the body of data on finished 10-second files remained at the full seven channels originally recorded at the sites and the photometry data with night-time constrasts were thereby retained. Outside the limits the data were restricted to the three magnetic components (H, D, Z) and the format reverted to the 3-word record length.

An Eather-Mende scanning photometer was incorporated into the recording system at Rankin Inlet when the SELDADS radio platforms were added to the Churchill Array in December 1977. Unlike the other three stations already monitoring four channels of auroral data, Rankin Inlet recorded one channel only and was altered to permanently record a total of four channels which included the three for the magnetic field elements. In the processed 10-second files for that station alone, a fixed record length of four channels (exclusive of time label) was maintained from the date of photometric introduction.

All the other stations of the array, which were recording magnetics only, remained fixed at three channels through all processing stages of 10-second files. They were unchanged in this regard for the entirety of the IMS.

An example of a Fortran read statement under format control is:

```
READ (1,100)STA,ICODE,IYR,IDY,IHR,MIN,ISEC,NC((ID(I,J),I=1,NC),J=1,120)

100 FORMAT(R4,I6,846I4)
```

TABLE 1

i.e.	Word	Abreviation	Item
	1	STA	4 character code name of station
	2	ICODE	combined latitude and east longitude
	3-5	IYR, IDY, IHR	year, day of year, hour (UT) (0-23)
	6-7	MIN, ISEC	minute (0-59), sec (0-59)
	8	NC	number of channels recorded
	9-368	ID	3 channel data i.e. H,D & Z (nanotesla)*
or	9-488	ID	4 channel data i.e. H,D,Z (nanotesla) & 4
or	9-848	ID	7 channel data i.e. H,D,Z (nanotesla) 3,5,H_B & BG

where for photometric data:

3 = 3914Å N_2 emission
4 = 4278Å N_2 emission
5 = 5577Å OI emission

H_B = H_β emission
BG = background

*Magnetics at station Pelly Bay are in the order -D, +H, +Z

1-Minute Files

Some of the other IMS arrays and the Canadian Magnetic Observatory network were recording only at a 1-minute interval. To allow direct interaction with such data files, a compatible 1-minute data set of all EPB's edited 10-second files was created through a process of 1-minute averaging. This was to be the version supplied eventually to the WDC-A databank.

In the creation of such 1-minute files the standard IAGA format was adopted for full conformity with observatory data. The files were organized in fixed records containing one hour of data, each with a header label containing the station identity (represented by combined colatitude and east longitude), year, day of year, and UT hour of commencement. The first sample of data was made to correspond to one minute <u>after</u> the hour. At all stations, four channels of data were constructed for each of the 60 1-minute samples, the first channel containing D, the second H, and the third Z. Whereas the Canadian Magnetic Observatories system normally enters F values in channel 4, the 1-minute versions of Churchill Array files for the IMS placed auroral data (emission 3 or 4) in that channel whenever they were present in the original 10-second files of the stations which were equipped with photometers. At the three stations intermittently possessing auroral data in channels 4 through 7, channels 5, 6 and 7 were ignored for the 1-minute files. Where no auroral data existed for a given station and time, channel 4 was simply occupied by 9999.

An example of a Fortran read statement under format control is:

```
READ (1,100)ICODE,IYR,IDY,IHR,((ID(I),IH(I),IZ(I),IA(I)),I=1,60)
100 FORMAT(244I6)
```

TABLE 2

i.e. Word	Abreviation	Item
1	ICODE	combined colatitude and east longitude
2-4	IYR,IDY,IHR	year, day of the year, hour (UT) (0-23)
5-244	ID,IH,IZ,IA	D,H,Z (nanotesla) & auroral channel

Throughout all data files for the entire array (both 10-second and 1-minute versions) invalid or missing data were represented by the entry of 9999.

With all values positive, all fields increase in the direction of numeric increase with a single exception, i.e. D component for Pelly Bay is inverted in the 10-second files only (1-minute files are normal).

Archiving

The final processed 10-second data files have been stored on 9-track tape at 1600 bpi in earlier phases of the project. When the 6250 bpi write density became available at the Computer Science Centre it was immediately adopted for intermediate stages in the processing as well as for final editions of all 10-second files. Derived 1-minute average files were stored on 9-track tape at 1600 bpi throughout the IMS period for consistency with their counterparts in most networks.

Implementation of a multifile tape-labelling system for the databank has made possible a substantial economic saving in building the finished tape library. Archive 10-second files in the databank were accommodated on 35 early IMS multifile tapes at 1600 bpi and 23 later tapes at 6250 bpi, containing about 2.5 billion characters of information. The 1-minute files were stored on 36 multifile tapes at 1600 bpi representing approximately an additional 400 million characters. Intermediate processing stages also employed the multifile system through which the utilization of tapes approached their full capacity and condensed by as much as a factor of 10 the number of tapes that would have been involved in a single file storage system.

EDIT SOLUTION MEASURES AND THEIR APPLICATIONS

Overview

Corrective measures pertained either to the need to establish the plausibility of a measured point in the context of neighbouring points, or to its place in time, and programs were structured to facilitate their application.

These measures were:

1. Time domain control and identification

Establishing a continuously reliable time reference is axiomatic as the foundation of any data set whose purpose is to measure physical variations. While the tape-loggers were designed to register time from a field clock of normally high accuracy, limitations of the hardware system imposed difficulties whenever recording was interrupted by internal logger problems, manual intervention, or when inconstancies occurred in record lengths or in sampling intervals. Clocks could be either set incorrectly or their displayed digital advance found to be in error. On occasion time label codes could be misinterpreted.

Software developed to complement the existing hardware has removed ambiguities of the time domain.

2. Erratic data giving rise to "SPIKES"

Although secondary in precedence to the issue of timing, the high occurrence density of spikes in much of the tape-data demanded that means be devised to automatically identify and selectively remove them from the data files. Default in this regard would have resulted in a rejection of about 50% of all IMS Churchill Array data acquired via the tape-logger system.

Four different types of spike contamination were simultaneously monitored and removed at the edit phase of processing the 10-second files. This has prevented the effect of spike spreading that the averaging of unattended spike-ridden data would have otherwise imparted to the 1-minute files derived from them.

A computer data-edit package was created to respond practically to encountered deficiencies (see flow diagram Fig. 6). It consisted of two computer programs "DASHIFT and TAPEDIT" whose purpose and performance are described in the following section. Used in combination with a preliminary read program "BRAVO" and a plot routine "BPLOT", manipulation tasks of some complexity could be realized by following prescribed procedures. While retaining the necessary flexibility, total costs entailed were minimal when offset against the large volume of data processed.

General Discussion

1. Time

The self-contained EPB clock eliminated dependence on reception of radio time signals and the ability of operators to use them. Assuming the clock's initial setting to be correct, the header label would receive time to the nearest second at the first sample entry of any given record. Unless, however, the logger unit was commenced in operation at the instant of zero, 20 or 40 minutes within the standard hour frame, the record blocks were not organized to lend themselves readily to correct hourly alignment for graphical representation through a plot program. Of more pressing significance, the 1-minute data files ultimately derived from the 10-second processed tapes were required to square with an hourly reference grid in 1-hour records. All of this called for the body of 10-second data records to be initially adjusted by re-blocking, so as to start and end precisely within the standard hourly time-frame boundaries (if not already in that state when received from the stations).

In practice demands were more explicit. Many stations experienced occasional logger system hangups, and while the clocks would normally function through these off their independent power sources, eventual recovery of the logger would then cause a new time-referenced set of records commencing with the <u>chance</u> instant of onset and incrementing once again from that point by 20 minutes per block. Additional to the effect of hangups, other kinds of interruption, such as manual intervention by operators or inconstant record lengths, frequently imposed a mixture of time boundaries on different record groupings of the same raw tape file, all separated by time discontinuities.

Though relatively infrequent, the possibility of error in the setting of a clock by the attending operator superimposed a further degree of complexity on the resolution of any re-blocking problem. However, to reduce package procedure to systematic routine, the clock was at first assumed to be accurate. Time labels were accepted as valid with respect to the record blocks they introduced and the problem then concerned a method of initially re-blocking the data to revert to the standard hourly time frame as seen by the clock.

Two stages were hereby conceivable in the total task of re-blocking affected records, each stage defining time boundaries by different criteria.

stage 1 - shifting of data relative to time displayed on clock and entered on label

stage 2 - shifting of resultant data relative to correct time if clock set in error

Program "DASHIFT"

To meet such requirements computer program DASHIFT was developed. Its design purpose and continuing main function was to physically shift the position of portions of data-points sequentially from record to record by amounts which correctly represented the departures of actual record onsets from a new set of hourly boundaries. In its application a reconstituted file of records was returned aligned to a time reference frame that commenced on the exact hour, or 20 or 40 minute boundaries within the hour. This was accomplished by calculating a shifting intercept for each input record. Based on the total elapsed time in seconds between the label read off the old record and the previous 20 minute boundary, a proportionality was defined for shifting the contents of that record forward (to the right in a magnetogram plot) and replacing the early portion so vacated with the equivalent latter portion of the previous record. The time on the label was dropped back to the start boundary belonging to the new merged record.

With 3, 4 or 7 channels of data possible in any given record, total data entries might amount to 360, 480 or 840 data points. The minimum shift of 10-seconds for these formats would result in contiguous record segments consisting of point combinations of 3-357, 4-476 or 7-833 respectively. All other shifts must be exercised with each segment a multiple of the number of channels in the records involved, in order to recognize each time sampling as an integral grouping.

In this respect a particular obstacle was presented when data of the stations incorporating the zenith photometers came to be shifted. Twice daily as provided (see Format) the format of BRAVO tapes for those stations switched, first from 7 to 3 channels of data and again from 3 back to 7, at the start of the unshifted records. Exceptional provision was required in sensing and reorganizing these two shifted records per day which merged portions of adjacent old records whose number of channels differed. To prevent infusion of photometry data into the magnetics stream at such junctures of conflict, all channels greater than 3 in the sample were discarded and the array spacing altered to the 3-channel format for that entire merged record. For simplicity and perfect equivalence of shifting response in the variable format mode, it would have served better to select a multiple for the larger recording format upon the installation of the photometers (e.g. 3 or 6 photo for 3 mag/instead of the 4 photo for 3 mag as adopted). Complementary segments from each of the old records would then have packed exactly into the new 3 channel array dimension without the possibility of overlap in a single sample.

Application of DASHIFT (stage 1) shifted a complete file of BRAVO data into hourly alignment on a record-to-record basis, automatically overcoming all restart discrepancies within that file as imposed by hangups. If the time labels as registered on the field tapes were an accurate image of the clock and the clock was initially set correctly within any 20-minute record while also functioning with the correct rate of advance, the file was then ready for the major and final processing step - program TAPEDIT.

Improper functioning of the clocks was encountered only in a period after day 299 in 1977 for the balance of that year when an electronic aberration resulted in a general gain effect. The matter of incorrect clock-setting was not uncommon when restarts were required, however, mainly due to a limited familiarity of most site operators with time-check procedure. An intermediate step of prime importance was therefore mandatory with all data processed through the level of DASHIFT, i.e. for any given file, magnetogram plots were run for the first and last few days. By visually correlating events and detail in the plots of the data with the concurrent data of the time-controlled Canadian Magnetic Observatories network (mainly Fort Churchill), any consistent residual time discrepancy to the 20-minute block boundary was revealed. An erroneous clock-setting could in this way be discovered and carefully measured. If such were the case, the resultant data could again be run through DASHIFT (stage 2) to create a third file which was shifted not as before through reference to time labels, but rather by a forcing parameter reflecting the observed one or more time discrepancies.

The technique, which consigned block boundaries to correct time at the 20-minute frame, operated as a forward time shift - i.e. data were shifted only to the right relative to the hour grid of a magnetogram. For a slow clock-setting this in itself provided full solution. If on the other hand the clock was determined to be set fast at the true 20-minute record frame, the data were shifted still farther forward by the complement of 20 minutes so that the clock appeared to be fast by one complete record - i.e. data were then positioned correctly relative to each record frame but each record label indicated a start time 20 minutes in advance of what it should have been. It then remained simply to roll back all time labels by 20 minutes. To apply this correction, a facility in TAPEDIT dealt exclusively with segmental revisions to the time labels (see page 25).

In addition to its major purpose, DASHIFT was designed to manage several useful functions in manipulation or testing. While introducing dummies for records recognized as missing, it also provided means for synthesizing an entire time-label track where such was lacking on the field tapes. Its most complex application entailed a reconstituting of the digital record to compensate the sampling interval controlled by a gaining clock of fixed rate. Only in late 1977 was this latter facility required.

Program "TAPEDIT"

Following the commencement of the IMS, a need was soon recognized for a pilot program to organize the incoming data after the initial read/conversion program BRAVO, and to adjust them with various corrections. This led to development of a specialized program which it was intended at the time would lead directly from BRAVO to the archival form of the IMS Churchill Array tape-data. Computer program TAPEDIT was spawned initially as a basic organizer and calling master which directed data to a set of subroutines on cue as requirement arose. The purpose of the original program was to service the data of particular events of interest to "in-house" analysis. Variability in errors and the profusion of their possibilities when monitoring all of the data on the grand scale, however, soon set the stage for a sizeable evolution of the basic program. While retaining the central approach, it was eventually expanded heavily into automated response together with a broadened capacity for controlled flexibility and added functions. The intention of the design was to deal practically with the fuller complexity of problems which had been gradually revealed.

TAPEDIT in its upgraded version was written to receive the output of DASHIFT in all cases where block shifting was required. If such was not necessary the output of the front-line program BRAVO was accepted.

The first pass of a data file through TAPEDIT produced an archival tape of all the 10-second data together with a listing specifying type, particulars and location of error occurrences remedied within the data. All record labels were also listed against the first few samples of edited output. Corrective processing addressed both problem domains outlined in the overview - i.e. time and spike removal.

Time Label Revision

Unlike DASHIFT, the type of time correction in TAPEDIT concerned only revisions to the record header labels. Action asserted at this stage was controlled under input command since intercomparison and the establishing of tie-points with the Canadian Magnetic Observatories network was the guide by which label revisions were determined. The time label track could be advanced forward or dropped backward in time by any 20-minute increment or multiple thereof (all 20-minute records previously adjusted for boundary). Card instruction specified the full extent of the increment in DAYS, HOURS, and MINUTES. Most essentially the instructions could be commenced, changed, reversed, ceased or recommenced at any record to bring a fragmented file into complete synchronization with the known observatory station control.

Minor isolated or spot hindrances were also correctable:

a) A specific element or elements of the time label on rare occasion could fail to increment normally with advancing time. Compensation was automatic.

b) Sporadic error in one or more time label elements in specific records could be spotted prior to TAPEDIT. Correction was by assignment.

c) Overlapped (long/short) or noisy records could be identified when entering TAPEDIT and removed entirely from the output file.

2. Spike Removal

The occurrence of sometimes abundant data erratics, presented perhaps the largest single hurdle of the software development effort. A final edition of TAPEDIT's subroutine DESPIKE incorporated four different spike-monitoring and removal procedures operating simultaneously while guarding against injury or bias to any of the valid data. Inaction on the removal of spikes, while detrimental to the 10-second files, would have magnified in consequence when final 1-minute average files were derived - in cases even eliminating recognition of the spikes through coalescence.

- Random Spikes (Type 1, 2)

At the 10-second recording rate there was little difficulty applying a simple point-to-point difference check to spot and remove single-point spikes. However since much of the transient contamination was of a duration greater than the digital recording interval, many spikes involved a number of points. By limiting the scanning duration to about 40 seconds in monitoring such multiple-point spikes, and weighing a set of ambient criteria, useful recovery of most contaminated data was achieved. (see Fig. 2)

- Clock Spikes (Type 3)

A third type of spike of longer duration and low magnitude was sometimes triggered in the data through the clock when registering the hour. Suppression of hour spikes was activated automatically in those files and channels displaying them. (see Fig. 4)

- Radio Transmission Spikes (Type 4)

The most troublesome aspect of spike-removal software construction presented itself in the wake of discovering the broad spikes superimposed on the data recorded at those sites housing satellite relay platforms whenever radio transmissions were in progress (see PART I, page 11). Solution to this unexpected development was essential if salvage was to be realized for any of the affected data recorded under either tape-logger or satellite systems on the Churchill Array.

A method was designed to address each station on the basis of its own scheduled time for signal transmission to the satellite. The input to TAPEDIT was searched through a mask defining the windows within which the ~110-second square radio-spike could possibly occur for the station under examination. Applicable sensing criteria would then lock on to the spike in the event of its occurrence, replacing its span with a slope joining the flanking points after finding the spike's termination.

The 12-minute recurrence of signal set a pattern (time of onset after the hour differing for each station) which completed its cycle in three 20-minute records. For protection from possible record gaps, synchronizing the advance of the mask routine was controlled by the time labels. It was necessary to program for the possibility of a spike initiated in one record not reaching completion until the following record. (see Figs. 3 & 4)

To permit all four spike types to be monitored in a single pass, sensing and removal procedures were coordinated, i.e. when monitoring was initiated for one type of spike, this did not inhibit the sensing of another type occurring within the given scan envelope.

3. One-Minute File Process

Subroutine MINUTE generated a file of 1-minute averages from each of the fully edited 10-second files. To reduce handling and computer time it was executed immediately upon successful completion of a 10-second archival file by rewinding the latter for input and entering a second pass of TAPEDIT.

In producing the 1-minute files (see Format) the 10-second data input were shifted so that the first averaged entry in each 60-minute record was centered on 1-minute after the hour, conforming with IAGA format.

Criteria adopted by SELDADS were recognized:

- Fewer than 3 available valid 10-second points out of the possible 6 resulted in a rejection of the average.
- If a single 1-minute average was missing, the mean of the adjacent minute values was accepted.

Nulled signal records were sensed and filled with 9999.

The 20-minute input records were organized and merged into 60-minute blocks with reference to the contained time label as safeguard against gaps consisting of missing records. Incomplete data from the input file were blank-filled for the balance of each 1-hour block on output. Absences of data for one whole hour in the input were not compensated as 9999 fill in the 1-minute output file; i.e. gaps amounting to one complete record hour or greater were not represented in the 1-minute tapes as dummy records.

ARCHIVAL FILES PART III

DATA COVERAGE

Temporal coverage of fully processed data for the Churchill Array acquired via the tape-logger system is represented in bar graphs (Figure 7) for each year of the program (1976-1980). Periods for which recording was inoperative at any given station or for which valid results were not obtained, are without graphic entry. Gaps in the data of less than one calendar day are not indicated in the graphs though coverage is usually continuous. For simplicity of presentation the graphs are referred to a 5-day grid and a 30-day month. The sixth division for months other than thirty days may be read in proportion to the days remaining past day 25.

Data are stored in the EPB databank in both the 10-second and the 1-minute average interval form (see Format). Only the 1-minute version of all the archival files has been entered in the WDC-A databank at Boulder.

DATA QUALITY

The processing system has removed most random spikes of types 1 and 2, replacing them with mean values of flanking points as encountered. However some assumptions have necessarily resulted in the retention of a small percentage of spikes (<5%) whose defining parameters were always weighted for the defence of valid data.

Spikes of these two random types were removed only when conforming to constant requisites in the 10-second data.

- Single points contrasting 15 nT or greater with the background were recognized and acted upon as spikes.

- Multiple points (or clusters) contrasting 120 nT or greater with the background were further assessed before possible removal as spikes. A maximum cluster of 4 points (40 seconds) were permitted in this category.

In rare instances, broader transients may therefore remain. Where this occurs it is commonly in association with other digital difficulties (such as A to D converter malfunctions) resulting in data of relatively inferior quality. Alteration of general recognition parameters might further improve such isolated cases with the attendant risks of a corresponding easing of safeguard criteria.

A data quality condition of a totally different nature, and of major significance to potential use of those data affected, made its first appearance at stations Island Lake and Gillam in November 1978. Artificial interference (probably introduced by a thermostatically switched hut heater) superimposed a quasi-cyclic pattern on the Z field as recorded. The fluctuation at Island Lake approximated a 10-minute cycle with an amplitude of 10nT. At Gillam the cycle was close to 30 minutes with an amplitude of about 30 nT. Varying in its intensity, the characteristic then persisted at Island Lake until the close of IMS and occurred intermittently at Gillam. Owing to its non-mathematical variation no compensatory adjustment could be applied with justifiable argument and this singular inferiority of those affected Z channels has been so designated in graphs 1978 thru 1980.

Base level shifts in the recorded data were generally rare but where exceptions occurred no measure was taken to adjust the differences. Nearly all occurrences of this effect were encountered at stations Fort Severn or Gillam. The Gillam recording station was situated in a zone affected by the earth return route of Manitoba Hydro's local DC transformer facility. During much of 1979-80 significant variations in the DC line voltage to Winnipeg resulted in a more frequent incidence of the variometer level shift or stepping effect. Users of Gillam data should be wary of this uncompensated condition.

Fort Severn was the most difficult station to process for the time domain. The archival files are often fragmental. Single records of total noise may be found interspersed with the valid data but are always obvious. During the period from December 1977 to April 1978 channels H & Z were prone to intermittently drift off scale.

DATA AVAILABILITY

IMS tape-logger data from the eight stations of the Churchill Array are available from the Earth Physics Branch upon request. All requests will be filled on a cost recovery basis.

Magnetics may be obtained on digital tape written as CDC binary, BCD or EBCDIC. Selected data may be copied from either the 10-second or the 1-minute averaged data sets.

Auroral photometry digital data copied from all channels are also available with any 10-second set requests for stations Island Lake, Gillam, Back or Rankin Inlet. The first emission band (N_2) is included with sections copied from the 1-minute set for those stations.

Analogue plots in the form of standard magnetograms for 1 day at 20 mm/hr may be supplied from any of the EPB files. Auroral data traces may be included if desired.

The 1-minute averaged EPB data set will also be available for copy from WDC-A, Boulder, in addition to SELDADS satellite-relayed 1-minute averaged data set from the six linked stations. As noted earlier in this report, however, the satellite relayed data contain interference pulses which may limit their usefulness in some applications.

A COMPARISON OF DATA RETRIEVAL EFFICIENCIES AT AN IMS STATION PART IV

RESOURCES AND OPERATIONAL COSTS

Cost of Station Equipment

Excluding the cost of the magnetometer and photometer the cost of both the satellite transmission system and the tape data-logger system roughly balanced out at about $10,000 each. The cost of the tape deck was slightly higher than the satellite radio but the radio interface /controller/A to D converter was more expensive than its equivalent for the digital tape-logger. Other equipment such as clock, regulated power supply and standby power were the same for both systems.

Cost of Data Transmission

As the IMS program was scientific in nature and of limited duration, it was allowed to use, at no charge, the highly sophisticated Geostationary Operational Environmental Satellite (GOES) developed jointly by National Oceanic and Atmospheric Administration (NOAA) and National Aeronautics and Space Administration (NASA), both of the United States. In Canada, no such national satellite was available to the scientific community at that time. Cost of data transmission by using the tape-loggers was $20.00 Canadian for a 730 m magnetic tape and $4.50 per shipment via registered mail.

Cost of Software Development

In any new system relying heavily on computers for control and processing, a great proportion of the development cost lies in the writing of computer programs. The system development for the acquisition of data brought to Boulder via SMS-GOES (satellite data) required four person-years for providing the necessary programs (Hornbach, personal communication, 1979). In comparison, approximately three person-years were spent in software development for the tape system, most of it taking place concurrently with data production.

Operational Resource Requirement

Data collection by SELDADS at the time of IMS required a data network consisting of the radio transmitter, the SMS-GOES satellite, a receiving station at Wallops Island, a land line to Boulder and a retrieval system consisting of a dedicated mini-computer and disc storage at SELDADS. Identification of errors and archiving of the collected data required about one-half a person-year. Routine checks of the data tapes by a computer other than the dedicated mini required an additional three to four hundred dollars per year. In essence, the system was largely automated and required only a small amount of human intervention.

Data collection by the medium of magnetic tape required a tape-logger, a postal service, and a method of batch processing the tapes at the receiving site in Ottawa. One person was dedicated to the regular processing of data on a large computer. Computer costs in 1979 totalled $9,500.00 for eight stations of which $4,500.00 was spent on rental and maintenance of the working files which had been placed on magnetic tape.

Resources required for the technical maintenance of the equipment at the remote sites cannot be compared. Problems arose in shipping equipment across the Canadian/U.S. border delaying the replacements of the satellite transmitter. In other cases service trips were simply cancelled as funds were diverted to other higher priority purposes. In addition, after having exhausted alternative methods of equipment repair, the one technician charged with the servicing of the network would make emergency trips only if both the satellite radio and the tape-logger were inoperative.

DATA SELECTION

The 10-second data set from the tape-logger route and the satellite transmission route were both routinely summarized to produce 1-minute averages on every minute. To compare the percentages of missing data from each system it was decided to concentrate on the 1-minute data for the following reasons:

- easy access to data files
- relatively low cost of processing

Both 1-minute data sets from the satellite/radio route and the tape-logger contained only those records in which resided some significant data. That is, if 10-second data did not exist for intervals of one or more hours then the corresponding records did not exist in the 1-minute data sets. There were, therefore, discontinuities in the 1-minute data coverage.

In order to compare the two fully operational systems, a station and data interval were chosen when both types of data acquisition systems were working. Instrument logs and summaries of data quality from the editing procedures were examined for the tape-loggers. Instrument logs and the automated reports on the operational status of the satellite radios at each station as provided by the central data processor at Boulder (platform status reports) were examined for the data routed via the satellite. On this basis, the data interval selected for comparison was provided by Island Lake during the period from 29 March, 1978 to 30 September, 1978.

DISCUSSION ON MISSING DATA

Error Rate

Computer programs were written to tally the number of missing values in the "satellite" data. A test interval stretching from the 29 March, 1978 to 30 September, 1978 from Island Lake was chosen as it had a relatively uninterrupted run of both types of data at that time. Approximately 154 days were counted in the satellite data. The average rate of missing data was found to be around 5%. However, if one exceptionally bad period is removed from the tally process, the percentage drops to 4%. A detailed accounting is given in Table 3.

TABLE 3

One-Minute Data Set Received via

the SMS-GOES Satellite for

Island Lake for

29 March, 1978 to 30 September, 1978

Period of Data File	Component D		Component H		Component Z	
	Missing Minutes	Total Minutes	Missing Minutes	Total Minutes	Missing Minutes	Total Minutes
29/3 to 18/4	2987	30180	2891	28860	2963	28800
19/4 to 9/5	1281	30180	1268	30240	1289	30240
10/5 to 30/5	1210	28740	1208	28800	1207	28800
1/6 to 20/6	894	25860	897	25920	976	25920
1/6 to 11/7	856	25860	861	25920	900	25920
Duplicates 1/6 to 4/6 only						
12/7 to 22/8	2350	60480	2349	60480	2449	60480
23/8 to 30/9	2298	46500	2221	44640	2279	42780
% Missing	4.8		4.8		5.0	

TABLE 4

One-Minute Data Set Received via

the Tape-Logger for

Island Lake for

29 March, 1978 to 30 September, 1978

Period of Data File	Component D		Component H		Component Z	
	Missing Minutes	Total Minutes	Missing Minutes	Total Minutes	Missing Minutes	Total Minutes
1/4 to 30/4	60	43260	60	43260	60	43260
1/5 to 31/5	148	44220	68	44220	228	44220
1/7 to 5/8	51	53100	51	53100	51	53100
6/8 to 31/8	21	36340	21	36240	70	36240
1/9 to 3/10	49	47280	49	47280	249	47280
% Missing	0.2		0.1		0.3	

The same computer program, with a few changes to accommodate the difference in tape format, was run on the "tape" minute data. The interval at Island Lake was chosen to coincide with the interval selected for the "satellite" data. The average rate of missing data was found to be less than 0.5%. A detailed accounting is given in Table 4.

Distribution of Missing Data

An attempt was made to analyze the distribution of missing data in order to pinpoint a probable cause. A computer program was written to compile the number of missing minutes per hour into a table. Tables A(1), A(2) and A(3) in the Appendix are the results of running the compilation. Except for the consistency of the 9-10 missing minutes at the end of each day for the satellite data, there does not appear to be any pattern to the distribution of missing values. To make sure that there were no cyclic patterns with periods longer than a week, the percentage of missing data as noted by the satellite platform status reports from Boulder were plotted in Figure 8 along with the International Disturbed Days. Again, there is no apparent cyclic behaviour or correlation between missing data and magnetic activity.

With the aid of Table A(4) in the Appendix a few representative days using the "satellite" data set were plotted. Figure 9(a) contains reconstituted magnetograms at 10 nT/mm from Island Lake. Figure 9(b) is a magnetogram from the "tape" data set to cover the missing period in day 206 (July 25, 1978) from the "satellite" data set. It is evident that no unusual magnetic or instrumental events are associated with the data breaks.

Re-examining Figure 8, the visual average of the percentage of missing data as indicated by the platform status report does not agree with the percentage of missing data as indicated by a tally of the data set from the 1-minute satellite tapes. Therefore, a more detailed compilation of missing data from the satellite (Table A(4)) was made for comparison to the platform status reports. Inconsistencies are apparent. It is evident that platform status messages tend to indicate a lesser amount of missing data than a detailed tally of the final 1-minute "satellite" data set.

A platform message consists of 12 minutes of real-time data or 0.8% of the "satellite" data set for one day. Therefore, even if the percentages of missing platform messages are truncated (they apparently are from 7 July to 17 September, 1978), it still does not explain the discrepancy between platform messages and the data tally. Furthermore, although the platform messages and station logs do not show any instrumental malfunction, the following days are missing from the final 1-minute "satellite" data set:

March	29	Z Component only
April	4	Z Component only
May	10,17	D. H, Z Components
June	1,2,3,4,5,6,28,29,30	D, H, Z Components
September	6,7,8,9,10,11,12	D, H, Z Components

A review of the literature [3, 4, 5] does not reveal the source of these errors. However, the data linkage from Island Lake to Boulder, Colorado has many places where errors could be injected into the data.

CONCLUSION

If the cost of the satellite, ground receiving station and data collecting platform/radio are included in the cost of the "satellite" data set, then certainly the "tape" data set is produced at less cost. If only the cost of the data collecting platform/radio is compared to the tape-logger, then costs of data production are comparable. In the latter case, the cost of dedicated mini-computer(s) for the processing of "satellite" data is balanced by the cost of tape processing and the person-years associated with it. If the amount of missing data is taken into account then the "tape" data is a more effective method of data collection. If data quality is taken into account, then the tape-logger method is definitely more effective. However, immediacy of data and uniformity of data format over a very diverse (international) network of variation stations are strong arguments for a SMS-GOES type data routing.

Increased automatic control over the production of data relieves the investigator of much of the drudgery of editing data. This works well when instrumentation is stable and error free or when technical assistance is immediate. However, it appears that digital instrumentation has the unfortunate characteristic of developing long periods of marginal operation before complete breakdown. It is during these periods that automatic onsite data processing is more likely to become a hindrance than an asset. Data which may be amenable to intelligent manipulation may be irretrievably lost when processed in real-time. A promising compromise would be real-time or semi real-time data transmission associated with an onsite mass storage device. Then, whenever automatic processing fails, special processing may be performed on the "original" data set.

ACKNOWLEDGEMENT

Consultations with Dr. J.K. Walker are gratefully acknowledged. His efforts included the planning and supervision of hardware installation at the sites and the initial management of station operations. Station servicing and maintenance of the tape-loggers and peripheral equipment were capably administered by Mr. R. Groulx throughout the recording period.

References

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2. Currie, B.W. (1976) editor "Canadian-Based Activities, International Magnetospheric Study 1976-1979" National Research Council of Canada.
3. Williams, D.J. (1976) "SELDADS: An Operational Real-Time Solar Terrestrial Environment Monitoring System" NOAA Tech. Report ERL 37.
4. "Geostationary Operational Environment Satellite/Data Collection System" NOAA Technical Report NESS 78; July, 1979.
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A P P E N D I X

TABLE A(1)

Hourly Totals of Missing Values
In the IMS One-Minute Data
Set Received Via SMS-GOES Satellite
For Island Lake, 23 August, 1978 to 30 September, 1978

D Component

Day	Mth	0-1	1-2	2-3	3-4	4-5	5-6	6-7	7-8	8-9	9-10	10-11	11-12	12-13	13-14	14-15	15-16	16-17	17-18	18-19	19-20	20-21	21-22	22-23	23-24
		Hours in U.T.																							
23	8	0	12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
24	8	0	13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	11	0	0	0	0	0
25	8	0	0	0	0	0	0	0	0	0	0	0	0	4	11	12	10	12	11	10	1	0	1	0	0
26	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
27	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	9
28	8	0	0	0	0	0	0	0	0	0	0	0	0	9	2	0	0	0	2	2	0	11	11	0	9
29	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	9
30	8	11	10	12	11	18	12	10	5	0	1	11	12	12	9	11	0	0	0	0	1	1	0	0	9
31	8	0	11	0	0	0	0	0	7	0	0	0	0	11	0	0	0	8	0	0	5	0	0	0	9
1	9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	0	0	0	0	0
2	9	11	13	12	9	12	10	12	11	29	12	10	14	10	10	12	11	11	10	20	18	15	18	12	33
3	9	0	21	9	0	12	0	0	0	0	0	20	0	0	0	0	0	0	0	0	0	0	0	0	8
4	9	0	0	0	12	0	0	0	0	0	0	0	0	0	0	14	0	0	1	0	0	0	0	0	9
5	9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	9
13	9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	11	0	0	0	0	0	9
14	9	0	0	0	0	0	0	0	0	0	0	0	0	0	15	0	0	0	0	0	0	0	0	0	9
15	9	11	11	10	13	10	12	11	8	11	12	11	8	11	12	12	10	11	11	10	12	9	11	10	17
16	9	9	0	17	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	9
17	9	0	0	0	0	0	6	0	0	0	0	0	0	0	0	0	0	0	0	4	0	0	0	0	9
18	9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	11	0	0	0	9
19	9	0	0	8	13	13	7	12	10	12	10	11	15	11	20	13	11	8	10	12	11	2	0	0	8
20	9	12	8	2	9	13	10	12	10	11	9	10	18	15	12	10	18	11	9	13	9	10	9	6	9
21	9	0	0	0	0	0	0	0	0	0	0	0	20	20	0	0	0	0	0	0	0	0	0	0	9
22	9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	9
23	9	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	1	9
24	9	12	10	12	10	11	12	11	12	11	13	11	12	10	10	23	0	0	0	0	0	0	0	0	9
25	9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	9
26	9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	9
28	9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	9
29	9	0	0	0	0	0	0	0	0	0	4	23	11	16	25	11	10	11	8	0	0	0	0	4	9
30	9	0	0	0	0	0	0	0	0	0	21	2	0	4	0	0	0	0	2	0	0	0	0	9	60

TABLE A(2) H Component

Day	Mth	0-1	1-2	2-3	3-4	4-5	5-6	6-7	7-8	8-9	9-10	10-11	11-12	12-13	13-14	14-15	15-16	16-17	17-18	18-19	19-20	20-21	21-22	22-23	23-24
		Hours in U.T.																							
23	8	0	12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
24	8	0	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	11	0	0	0	0	0
25	8	0	0	0	0	0	0	0	0	0	0	0	0	4	11	12	10	12	11	10	1	0	1	0	0
26	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
27	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	9
28	8	0	0	0	0	0	0	0	0	0	0	0	0	9	2	0	0	0	2	2	0	11	11	0	9
29	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	9
30	8	11	10	12	11	18	12	10	5	0	1	11	12	12	9	11	0	0	0	0	1	1	0	0	9
31	8	0	11	0	0	0	0	0	7	0	0	0	0	11	0	0	0	8	0	0	5	0	0	0	9
1	9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	8	0	0	0	0	0
2	9	10	13	12	9	12	10	12	11	29	12	10	14	10	10	12	11	11	10	19	18	15	10	19	33
3	9	0	22	8	0	6	0	0	0	0	0	20	0	0	0	0	0	0	0	0	0	0	0	0	8
4	9	0	0	0	12	0	0	0	0	0	0	0	0	0	0	14	0	0	1	0	0	0	0	0	9
5	9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	9
13	9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	11	0	0	0	0	0	9
14	9	0	0	0	0	0	0	0	0	0	0	0	0	0	15	0	0	0	0	0	0	0	0	0	9
15	9	10	11	10	13	10	12	11	8	11	12	11	8	11	12	12	10	11	11	10	12	9	11	10	17
16	9	3	0	17	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	9
17	9	0	0	0	0	0	6	0	0	0	0	0	0	0	0	0	0	0	0	4	0	0	0	0	9
18	9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	11	0	0	0	9
19	9	0	0	8	13	13	7	12	10	12	10	11	15	11	20	13	11	8	10	12	11	2	0	0	8
20	9	11	8	2	9	13	10	12	10	11	9	10	18	15	12	10	18	11	9	13	9	10	9	6	9
21	9	0	0	0	0	0	0	0	0	0	0	0	20	20	0	0	0	0	0	0	0	0	0	0	9
22	9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	9
23	9	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	1	9
24	9	10	10	12	10	11	12	11	12	11	13	11	12	10	10	23	0	0	0	0	0	0	0	0	9
25	9	0	0	0	0	0	11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	9
26	9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	9
28	9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	9
29	9	0	0	0	0	0	0	0	0	0	4	23	11	16	25	11	10	11	8	0	0	0	0	4	9
30	9	0	0	0	0	0	0	0	0	0	21	2	0	4	0	0	0	0	2	0	0	0	0	9	60

TABLE A(3)

Z Component

Day	Mth	Hours in U.T.																							
		0-1	1-2	2-3	3-4	4-5	5-6	6-7	7-8	8-9	9-10	10-11	11-12	12-13	13-14	14-15	15-16	16-17	17-18	18-19	19-20	20-21	21-22	22-23	23-24
23	8	0	12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
24	8	0	9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	12	0	0	0	0	0
25	8	0	0	0	0	0	0	0	0	0	0	0	0	4	11	12	10	12	11	10	1	0	1	0	0
26	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
27	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10
28	8	0	0	0	0	0	0	0	0	0	0	0	20	10	2	0	0	0	4	2	0	12	12	0	10
29	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10
30	8	11	10	12	11	19	12	10	5	0	1	11	12	12	9	12	0	0	0	0	1	1	0	0	10
31	8	0	12	0	0	0	0	0	7	0	0	0	0	12	0	0	0	9	0	0	6	0	0	0	10
1	9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	8	0	0	0	0	0
2	9	20	13	12	9	12	10	12	11	29	12	10	14	10	10	12	11	11	11	20	18	15	10	19	39
3	9	0	20	10	0	9	0	0	0	0	0	20	1	1	0	0	0	0	0	0	0	0	0	0	9
4	9	0	0	0	12	0	1	0	0	0	0	0	0	1	0	14	0	0	2	0	0	0	0	0	10
5	9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10
13	9	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	12	0	0	0	0	0	10
14	9	11	0	0	0	0	0	0	0	0	0	0	0	0	16	0	0	0	0	0	0	0	0	0	10
15	9	9	11	10	13	10	12	11	8	11	12	11	8	11	12	12	10	11	11	10	12	9	11	10	18
16	9	0	0	17	10	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	10
17	9	0	0	0	0	0	7	0	0	0	0	0	0	0	0	1	0	0	0	6	0	0	0	0	10
18	9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0	0	12	0	1	0	10
19	9	12	0	8	13	13	7	12	10	12	10	11	15	11	20	13	11	8	10	12	11	2	0	0	9
20	9	0	8	2	9	13	10	12	10	11	9	10	18	15	12	10	18	11	9	13	9	10	9	6	11
21	9	0	0	0	0	0	0	0	0	0	0	0	20	20	0	0	0	0	0	0	0	0	0	0	10
22	9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10
23	9	12	0	0	0	0	1	0	0	0	0	1	2	0	0	1	0	0	0	0	0	0	0	2	10
24	9	0	10	12	10	11	12	11	12	11	13	11	12	10	10	23	0	0	0	0	0	0	1	0	10
25	9	0	0	0	1	0	12	0	1	0	0	1	0	0	0	2	0	0	0	0	0	0	0	0	10
26	9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	10
28	9	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10
29	9	0	0	0	0	0	0	0	0	0	4	24	13	16	28	12	10	11	8	0	0	0	0	4	12

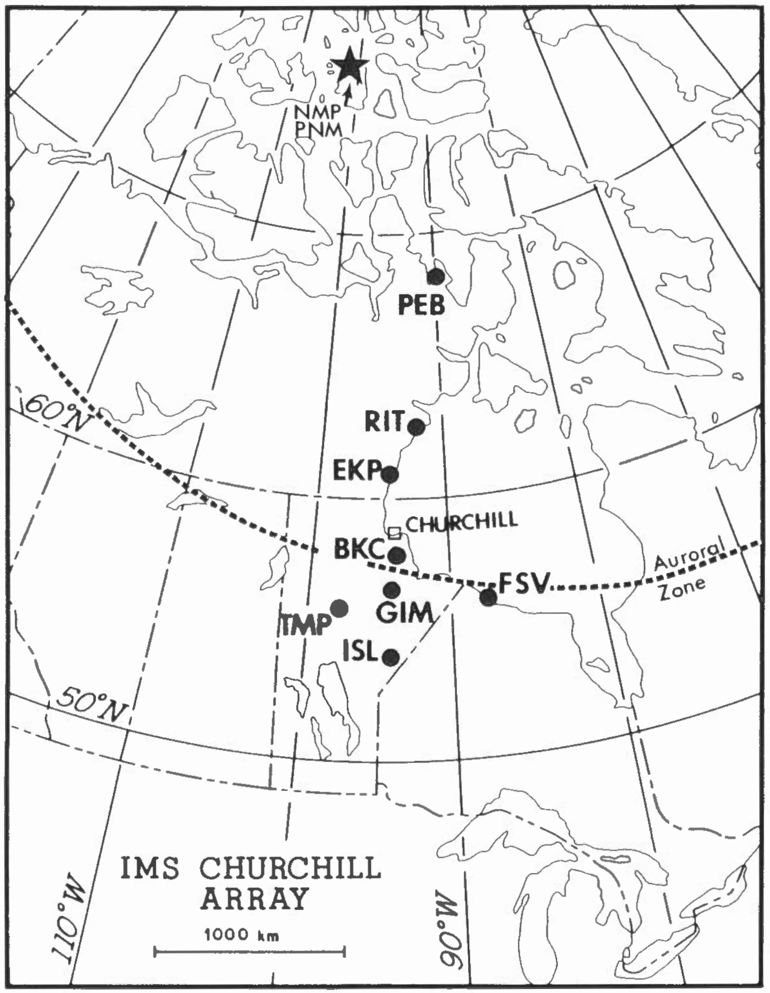
TABLE A(4) - Comparison of Missing Data from IMS Minute Tapes to Missing Platform Messages, 12 July, 1978 to 21 August, 1978.

DAY	MONTH		NO. OF MISSING MINUTES			TOTAL NO. OF MINUTES	%	% OF MISSING PLATFORM MESSAGES
			Z	D	H			
12	7		37	23	18	78	1.8	0
13	7	D	34	31	32	97	2.2	2
14	7	D	284	265	253	802	18.6	0
15	7		10	9	9	28	0.6	0
16	7		32	30	30	92	2.1	0
17	7		9	8	8	25	0.6	0
18	7	D	10	9	9	28	0.6	0
19	7		29	25	25	79	1.8	1
20	7		32	30	30	92	2.1	1
21	7		12	11	11	34	0.8	0
22	7		14	12	12	38	.9	0
23	7		276	243	233	752	17.4	0
24	7		91	89	89	269	6.2	1
25	7		251	248	248	747	17.3	17
26	7		10	9	9	27	0.6	0
27	7	Q	14	12	12	38	.9	0
28	7		17	16	16	49	1.1	0
29	7	Q	231	220	230	681	15.8	1
30	7	Q	32	20	29	81	1.9	1
31	7	Q	23	21	21	65	1.5	0
1	8	Q	10	9	9	28	0.6	0
2	8		31	28	28	87	2.0	1
3	8		40	35	35	110	2.5	0
4	8	D	21	9	19	49	1.1	0
5	8		10	26	9	45	1.0	0
6	8		27	24	26	77	1.8	1
7	8		259	235	254	748	17.3	1
8	8		186	174	185	545	12.6	0
9	8		20	19	19	58	1.3	0
10	8		15	13	13	41	0.9	0
11	8		10	9	9	28	0.6	0
12	8		11	9	9	29	0.7	0
13	8		38	33	34	105	2.4	2
14	8		24	22	22	68	1.5	-
15	8	Q	42	38	38	118	2.7	2
16	8		47	52	42	141	3.3	10
17	8		49	30	30	109	2.5	1
18	8		19	17	17	83	1.2	0
19	8		22	21	21	64	1.5	0
20	8	Q	10	9	9	28	0.6	0
21	8		10	9	9	28	0.6	0

Mean % of missing minutes from minute Tape = 4%.
Mean % of missing platform messages = 1%.

Q - International Quiet Days, D - International Disturbed Days.

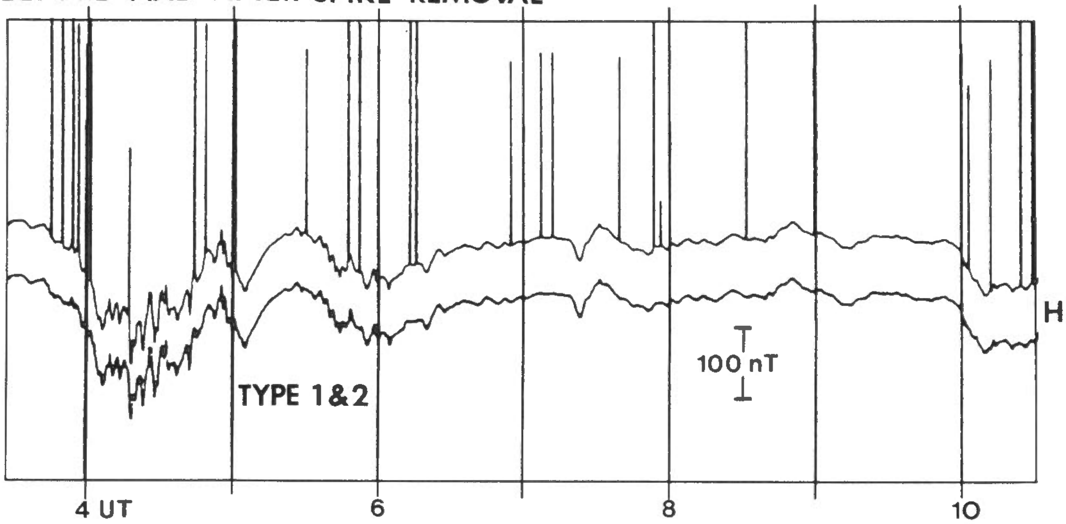
Fig. 1



IAGA CODE	STATION	GEOGRAPHICAL COORDINATES	
		LAT N	LONG W
PEB	PELLY BAY	68.5°	89.8°
RIT	RANKIN INLET	62.6°	91.9°
EKP	ESKIMO POINT	61.1°	94.1°
BKC	BACK	57.7°	94.2°
GIM	GILLAM	56.4°	94.7°
FSV	FORT SEVERN	56.0	87.6°
TMP	THOMPSON	55.7°	97.9°
ISL	ISLAND LAKE	53.9°	94.7°

Fig. 2

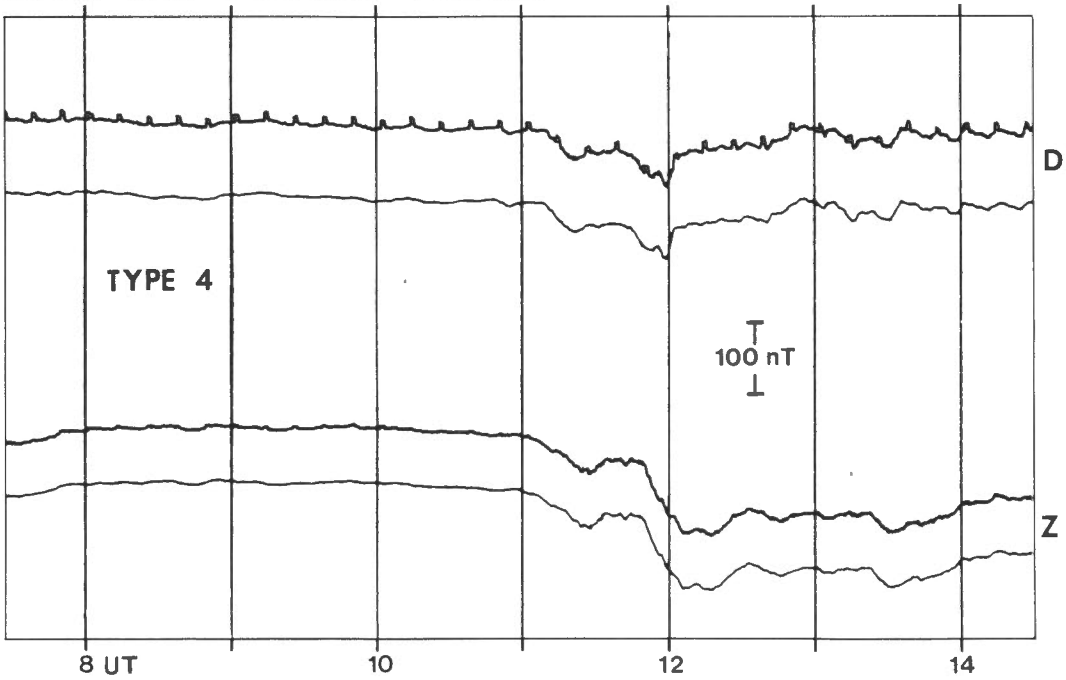
TAPE LOGGER 10-SECOND DATA
BEFORE AND AFTER SPIKE REMOVAL



BACK 29, MAY, 1979

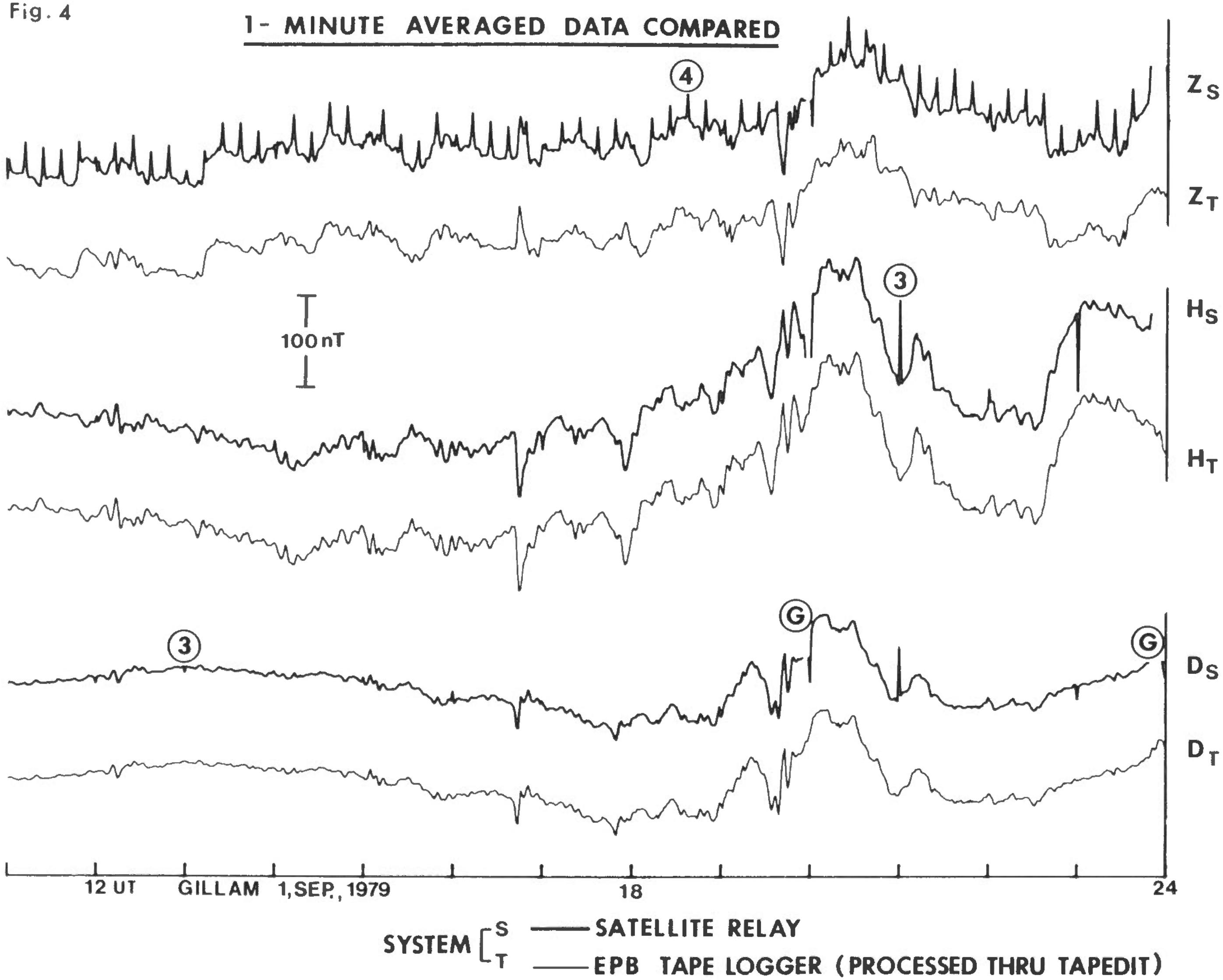
Fig. 3

TAPE LOGGER 10-SECOND DATA
BEFORE AND AFTER SPIKE REMOVAL



ISLAND LAKE 23, MAR, 1978

Fig. 4



Magnetogram sample illustrating some of the described characteristic differences between archival data sets of the two recording systems.

(3) Clock-initiated hour spikes.

(4) Radio transmission spikes showing flared effect of automatic averaging.

(G) Gaps interspersed in the data.

Fig. 5

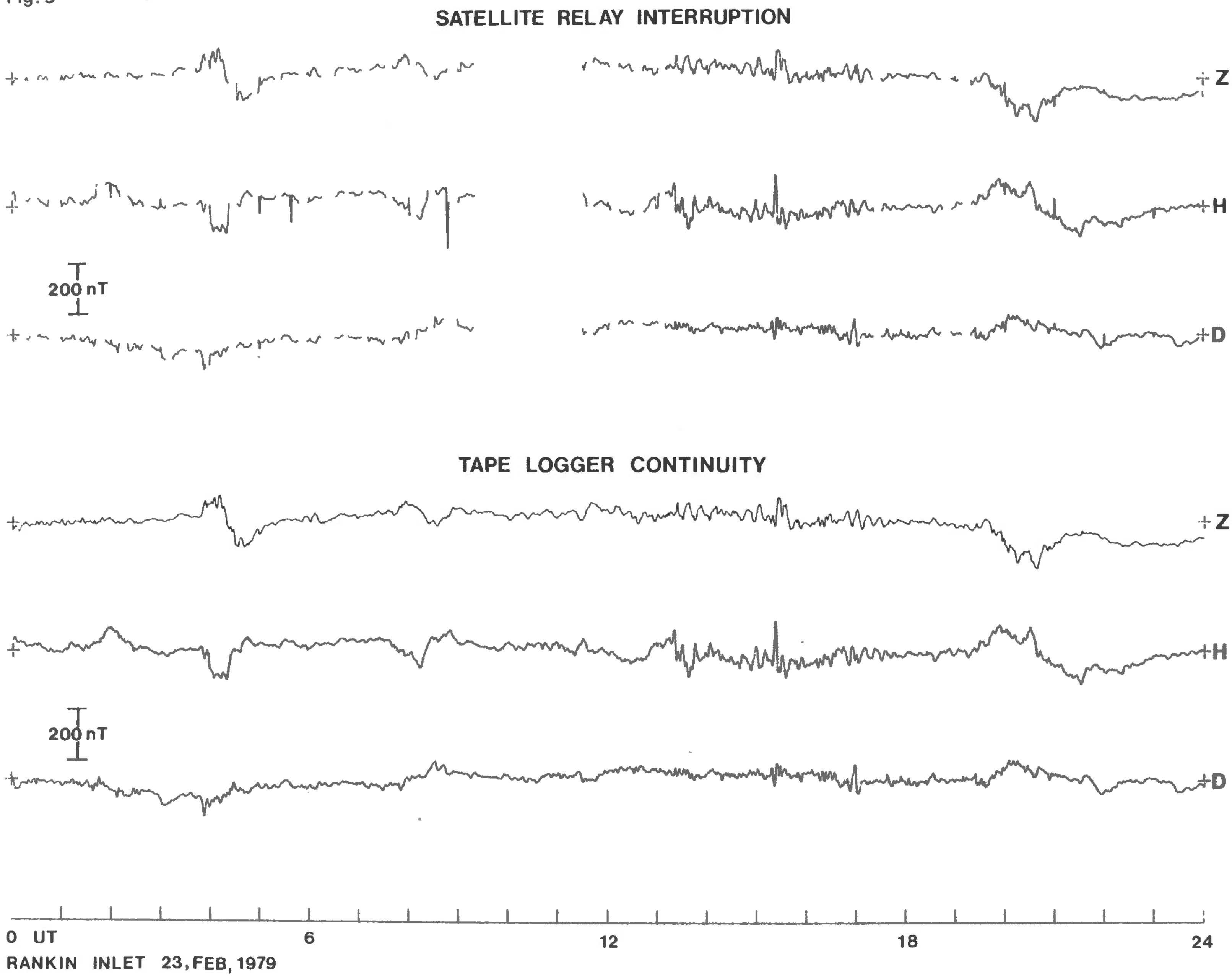
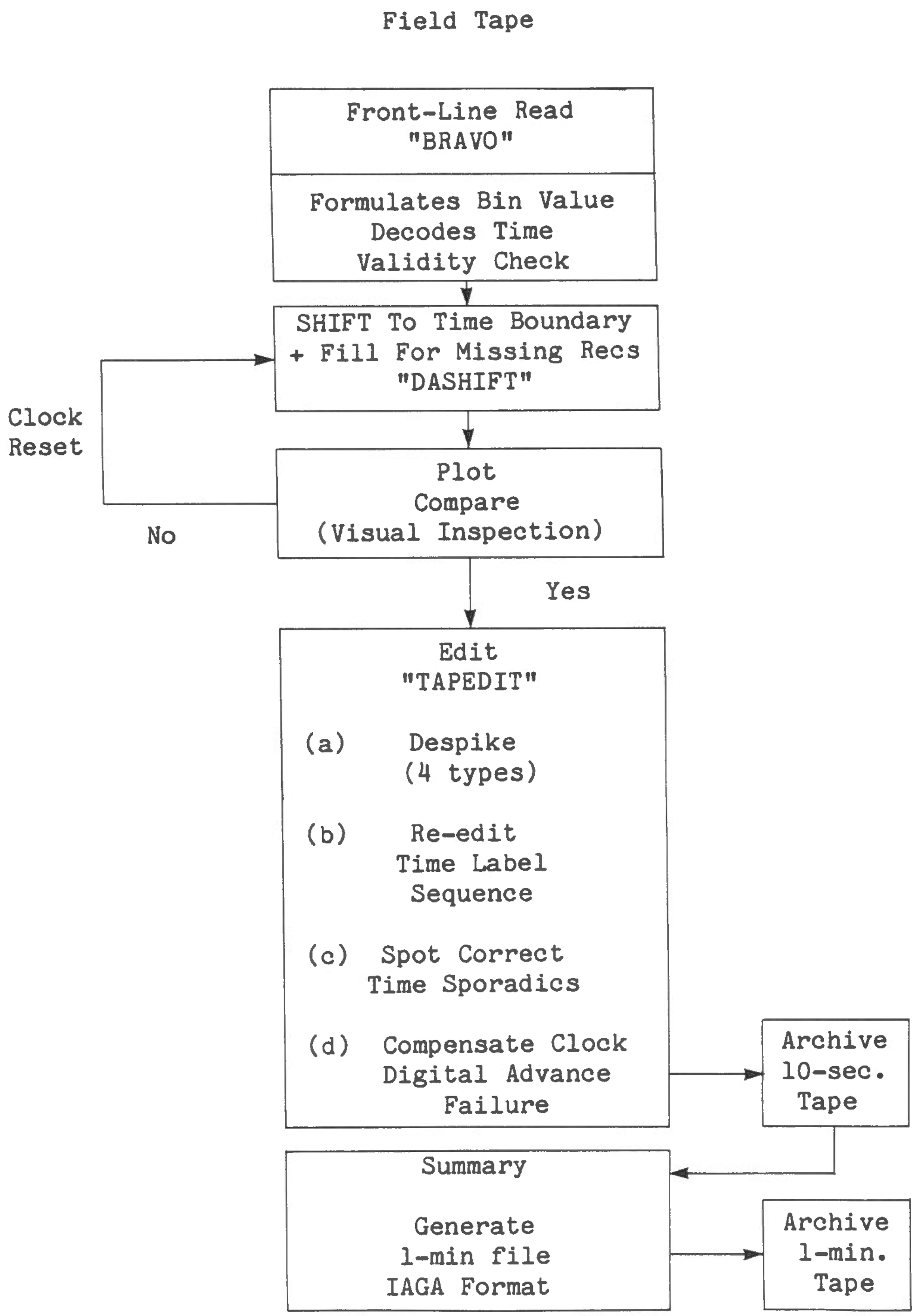

SATELLITE RELAY INTERRUPTION
Z
H
200 nT
D
TAPE LOGGER CONTINUITY
Z
H
200 nT
D
0 UT
6
12
18
24
RANKIN INLET 23, FEB, 1979

Fig. 6

SOFTWARE SCHEMATIC
FOR
IMS VARIOMETER TAPE DATA



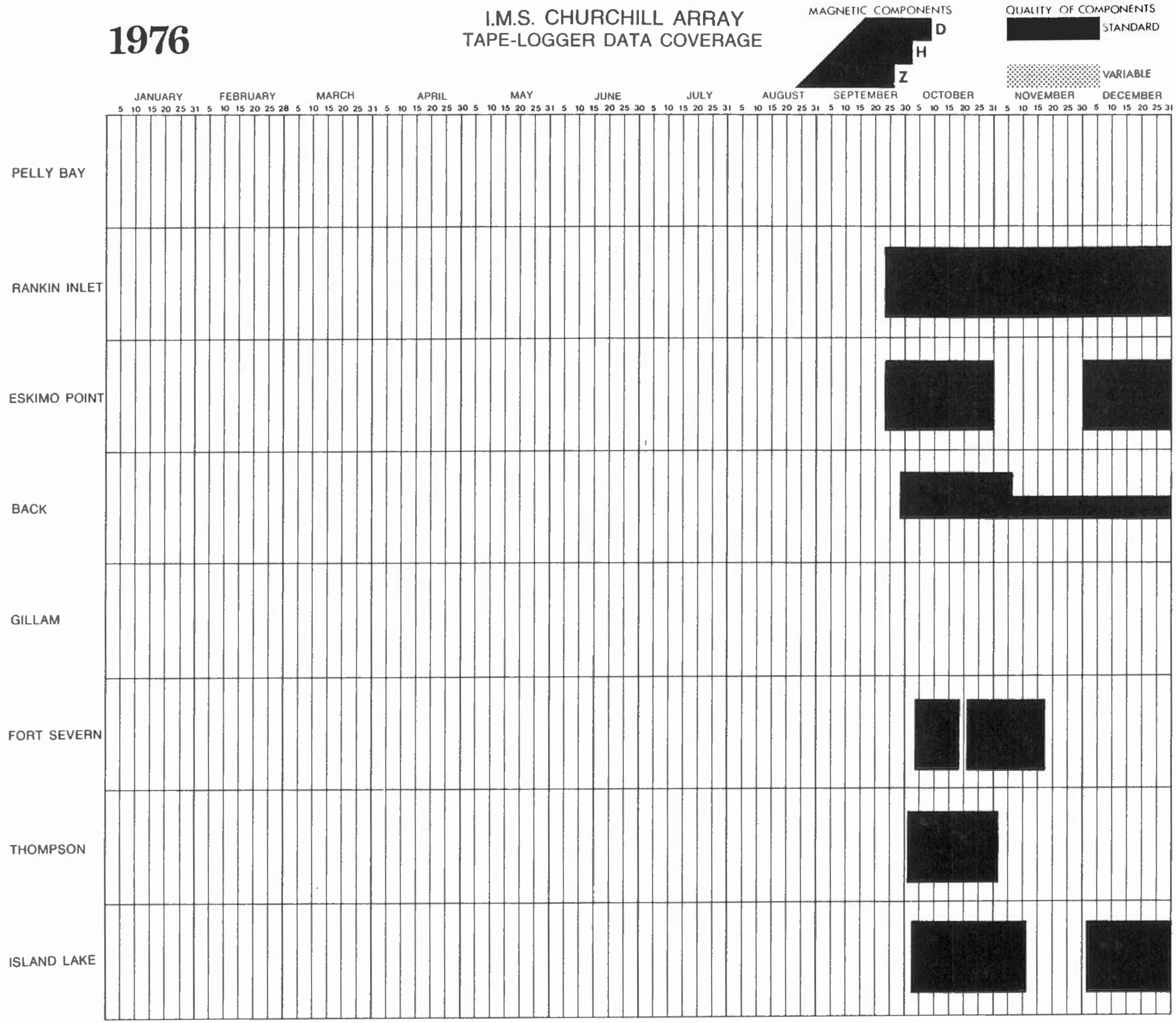

1976
I.M.S. CHURCHILL ARRAY
TAPE-LOGGER DATA COVERAGE
MAGNETIC COMPONENTS
D
H
Z
QUALITY OF COMPONENTS
STANDARD
VARIABLE
JANUARY
FEBRUARY
MARCH
APRIL
MAY
JUNE
JULY
AUGUST
SEPTEMBER
OCTOBER
NOVEMBER
DECEMBER
PELLY BAY
RANKIN INLET
ESKIMO POINT
BACK
GILLAM
FORT SEVERN
THOMPSON
ISLAND LAKE

FIGURE 7 (a)


1977
I.M.S. CHURCHILL ARRAY
TAPE-LOGGER DATA COVERAGE
MAGNETIC COMPONENTS
D
H
Z
QUALITY OF COMPONENTS
STANDARD
VARIABLE
JANUARY
FEBRUARY
MARCH
APRIL
MAY
JUNE
JULY
AUGUST
SEPTEMBER
OCTOBER
NOVEMBER
DECEMBER
PELLY BAY
RANKIN INLET
ESKIMO POINT
BACK
GILLAM
FORT SEVERN
THOMPSON
ISLAND LAKE

FIGURE 7 (b)

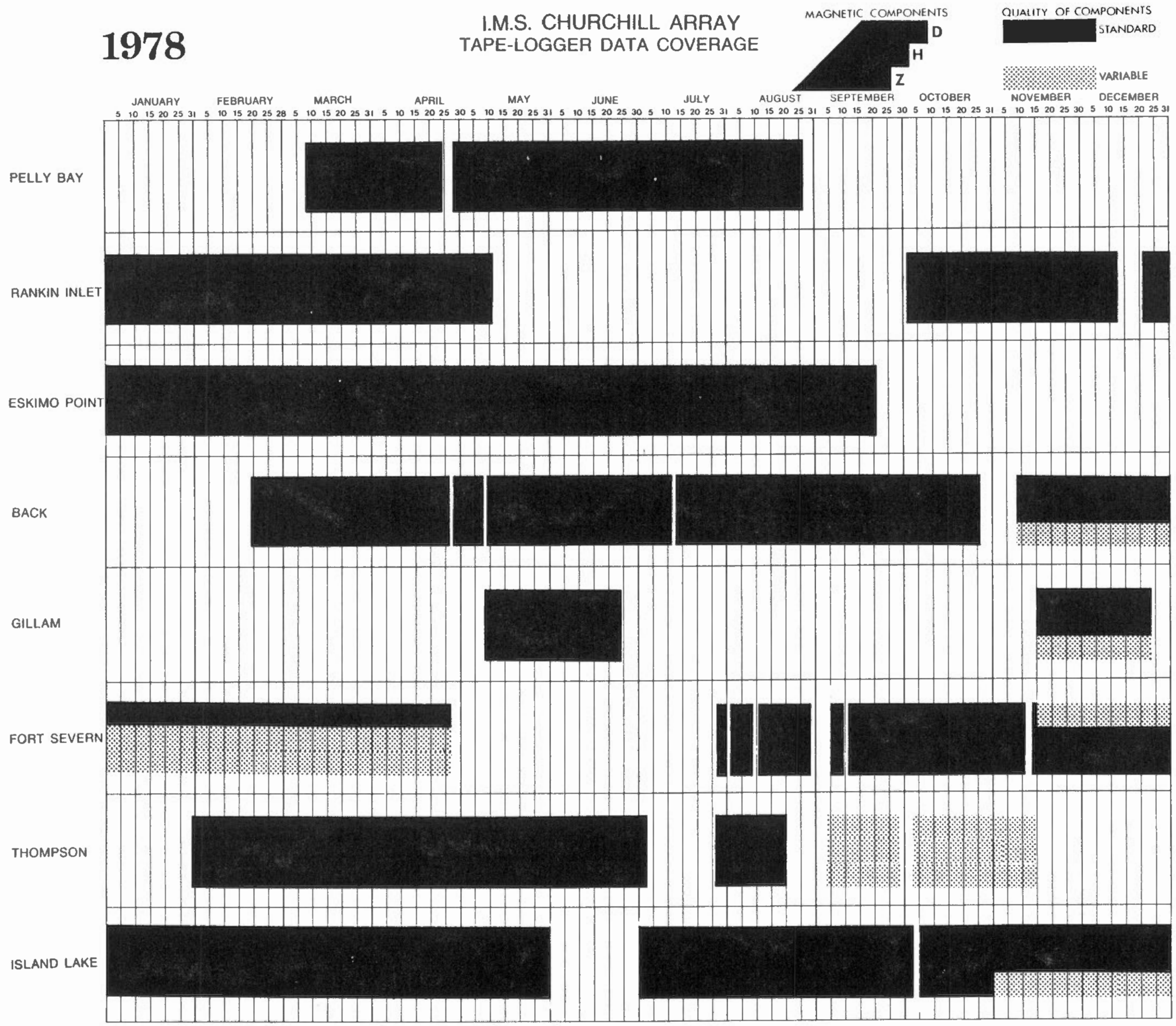

1978
I.M.S. CHURCHILL ARRAY
TAPE-LOGGER DATA COVERAGE
MAGNETIC COMPONENTS
D
H
Z
QUALITY OF COMPONENTS
STANDARD
VARIABLE
JANUARY
FEBRUARY
MARCH
APRIL
MAY
JUNE
JULY
AUGUST
SEPTEMBER
OCTOBER
NOVEMBER
DECEMBER
PELLY BAY
RANKIN INLET
ESKIMO POINT
BACK
GILLAM
FORT SEVERN
THOMPSON
ISLAND LAKE

FIGURE 7 (c)

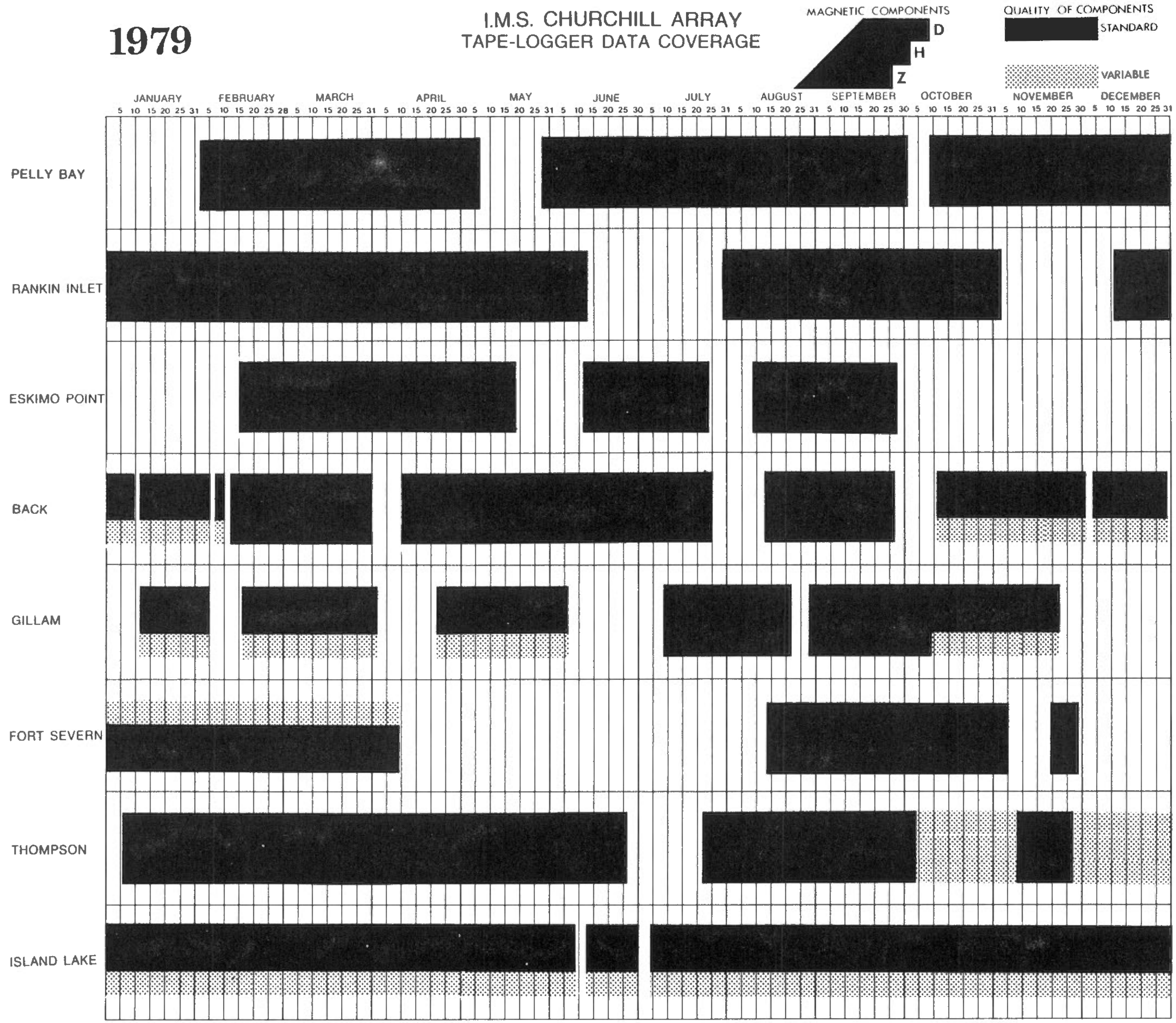

1979
I.M.S. CHURCHILL ARRAY
TAPE-LOGGER DATA COVERAGE
MAGNETIC COMPONENTS
D
H
Z
QUALITY OF COMPONENTS
STANDARD
VARIABLE
JANUARY
FEBRUARY
MARCH
APRIL
MAY
JUNE
JULY
AUGUST
SEPTEMBER
OCTOBER
NOVEMBER
DECEMBER
PELLY BAY
RANKIN INLET
ESKIMO POINT
BACK
GILLAM
FORT SEVERN
THOMPSON
ISLAND LAKE

FIGURE 7 (d)

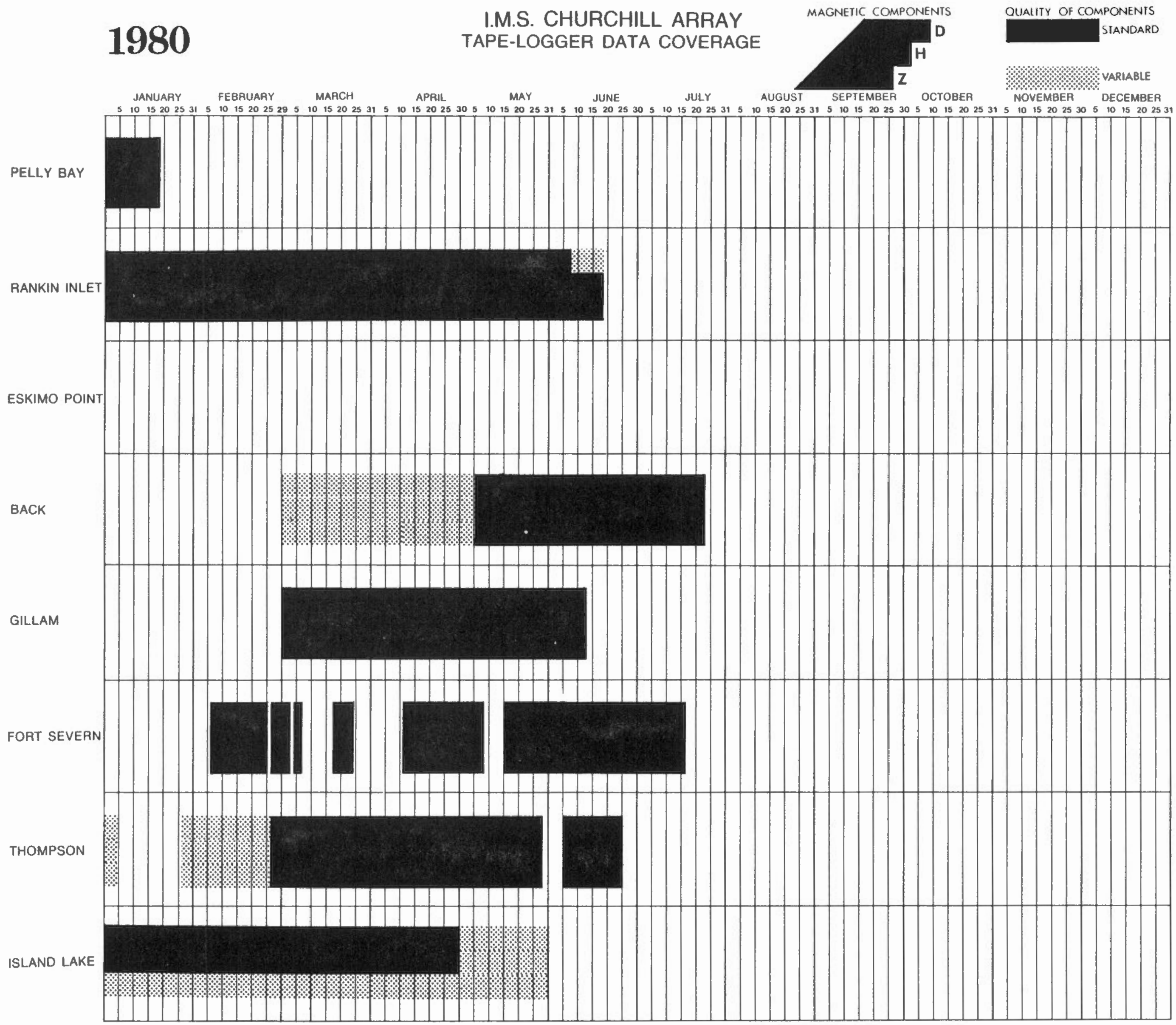

1980
I.M.S. CHURCHILL ARRAY
TAPE-LOGGER DATA COVERAGE
MAGNETIC COMPONENTS
D
H
Z
QUALITY OF COMPONENTS
STANDARD
VARIABLE
JANUARY
FEBRUARY
MARCH
APRIL
MAY
JUNE
JULY
AUGUST
SEPTEMBER
OCTOBER
NOVEMBER
DECEMBER
PELLY BAY
RANKIN INLET
ESKIMO POINT
BACK
GILLAM
FORT SEVERN
THOMPSON
ISLAND LAKE

FIGURE 7 (e)

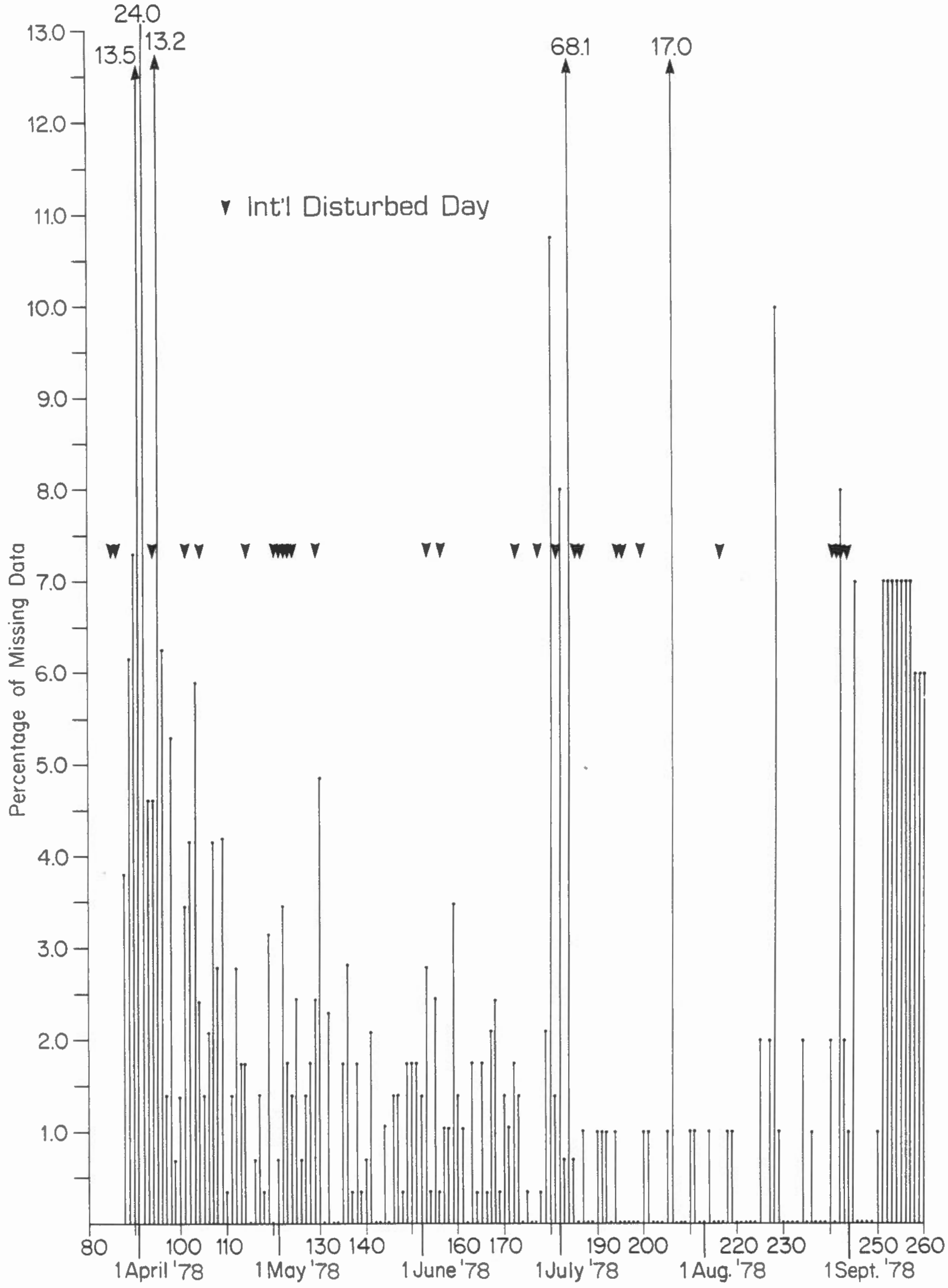


FIGURE 8

Percentage of missing IMS Minute-Data Routed via Satellite for 29 March, 1978 to 17 September, 1978.

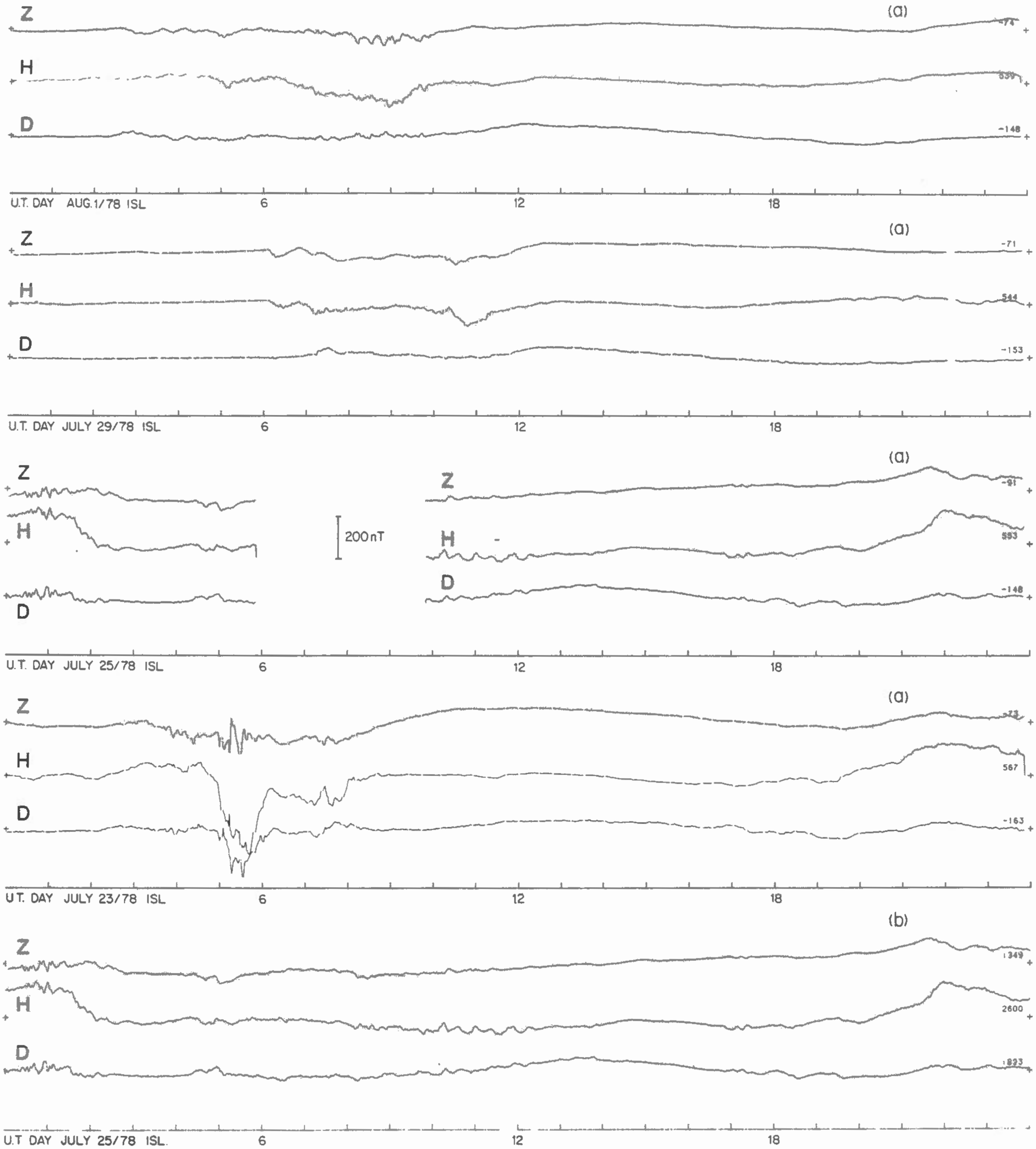


FIGURE 9 (a)

Reconstituted Magnetograms from Digital Minute-Data for Island Lake, 1978; Data Routed via SMS-GOES Satellite.

FIGURE 9 (b)

Reconstituted Magnetogram from Digital Minute-Data for Island Lake, 1978; Data Routed via Tape-Logger.