UPPER ATMOSPHERE PHYSICS DATA OBTAINED AT SYOWA STATION IN 1998

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1. Introduction

This data book summarizes upper atmosphere physics data acquired by the 39th Japanese Antarctic Research Expedition (JARE-39) with the "Upper Atmosphere Physics Monitoring (UAPM) System" at Syowa Station in 1998. Observation items are as follows:

1) Geomagnetism :
- H-, D- and Z-components of magnetic variations
- Total force of the geomagnetic field
- H-, D- and Z-components of magnetic pulsations

2) ELF-VLF wave :
- Intensities at 0.35, 0.75, 1.2, 2, 4, 8, 30, 60 and 95 kHz
- Wide-band (0-10 kHz) signal of ELF-VLF emissions

3) Ionosphere :
- Cosmic noise absorption at 30 MHz observed with a broad-beam riometer

4) Aurora :
- All-sky imagers :
  CCD type : Panchromatic images recorded in a digital format
- Scanning photometers :
  Meridian-scanning record at the following three wavelengths
  557.7 nm (OI), 630.0 nm (OI) and 486.1 nm (H_β)

An outline of the observation system is given in Section 2. Section 3 describes specifications of the observation instruments and the data acquisition systems. Observation periods are also listed in Section 3. Format of the compiled digital data is shown in Section 4. Summary plots in the period of January 1-December 31, 1998 are given in Appendix.

All-sky imager observation data, magnetograms and summary plots of the monitoring data are available to users on request. The request should be addressed to:

World Data Center C2 for Aurora
National Institute of Polar Research
9-10, Kaga 1-chome, Itabashi-ku,
Tokyo 173-8515, Japan.

Digital and analog data described here are available to researchers who will do collaborative studies with the upper atmosphere physics group of NIPR. The request should be addressed to:

Upper Atmosphere Physics Research Division
National Institute of Polar Research
9-10, Kaga 1-chome, Itabashi-ku,
Tokyo 173-8515, Japan.

2. Upper Atmosphere Physics Monitoring (UAPM) System

A real-time digital data acquisition system for upper atmosphere physics observation was constructed at Syowa Station in January 1981 (Sato *et al.*, 1984). Data obtained from the system have been collected and published annually in the JARE Data Reports (Upper Atmosphere Physics) (Sato *et al.*, 1984, 1991 ; Fujii *et al.*, 1985, 1994; Sakurai *et al.*, 1985; Ono *et al.*, 1986, 1993; Yamagishi *et al.*, 1987; Kikuchi *et al*, 1988; Miyaoka *et al.*, 1990; Kadokura *et al.*, 1992; Yamazaki *et al.*, 1995; Tonegawa *et al.*, 1996; Obara *et al.*, 1996; Arisawa *et al.*, 1997; Kawana *et al.*, 1998; Takeuchi *et al.*, 1999). This report is the 18th of this series.

A block diagram of the system, including other ground observations, is shown in Fig. 1. The sensors for measuring weak natural electromagnetic waves such as ELF-VLF emissions, the three components of ULF magnetic pulsations and cosmic radio noise absorption (CNA) have been placed at a remote station on West Ongul Island, located about 5 km from Syowa Station in order to avoid man-made electromagnetic interference. Data of the magnetic pulsations and CNA are transmitted continuously to Syowa Station by a PCM telemeter in VHF band. Wide-band signals of ELF-VLF emissions are transmitted to Syowa Station through an FM telemeter in UHF band.

At the remote station, the electric power which drives all the instruments has been supplied by a solar battery system with maximum output power of 530 W since February 1985. An additional solar battery system with maximum power of 365 W was installed in January 1987 to reinforce the original battery system. The solar battery system consists of eighteen rechargeable car batteries (200 Ah each), five solar panels and three controllers in total. During winter when no sunlight is available, these batteries are charged manually about once a month by using a 10 kVA diesel-engine dynamo, which was installed in 1992 instead of the previous 16 kVA one.

The fluxgate and proton magnetometer sensors are placed at Syowa Station on East Ongul Island, about 150 m apart from the Data Processing Building. All the auroral photometric instruments are placed on the roof of the building, and the data acquisition facilities are installed inside the building. All the outputs obtained from the observation instruments except the auroral photometric ones are transferred to the matrix terminal board and then recorded with pen recorders, analog data recorders and a computer system. These data have been recorded simultaneously with two sets of the TEAC DR-200 digital data logger systems since January 1987 and with the Accurate Timing data Logging and Analysis support System (ATLAS) since February 1997. An 8 mm video tape recorder is used to record wide-band VLF emissions, and 24-hour data can be stored on one volume of 8 mm video tape.

Universal time (UT) is supplied from a precise time-keeping system. This system consists of a GPS satellite timing receiver, a quartz frequency standard with a stability of 2×10^{-11}/day, and time code generators. The time code generators supply the IRIG-A, -B and slow codes for analog data recorders and the 36-bit BCD code for the digital recording systems, respectively. The absolute accuracy of this system is estimated to be about 1 ms.

3. Specifications of Instruments

3.1. Geomagnetism

(1) *Magnetogram*

Magnetic variations were measured by a three-axis fluxgate magnetometer. Full scale ranges were +1250 to -3750 nT for H-component and ± 2500 nT for D- and Z- components, respectively, with the frequency response of DC–2 Hz and noise levels less than 0.5 nT. The magnetometer data were recorded in digital form at the sampling rate of 1 Hz. The H-component data were also recorded on a chart recorder and an R-950L long-term analog data recorder.

(2) *Total force of the geomagnetic field*

Due to the prolonged trouble with the proton magnetometer since January 1991, the total force observations were made only about once per month in 1996, using the other portable proton magnetometer, which was unable to be linked with the UAPM system. The results are listed in Table 1.

(3) *ULF magnetic pulsations*

The H-, D-, and Z-components of ULF magnetic pulsations are detected by three sets of search coil magnetometers. The search coil sensors have copper wires (0.4 mmϕ, 40000 turns each) wound around permalloy cores (1 cm in diameter × 100 cm in length). Measurable intensity range of the magnetometer is 0.001–5 nT/s and the frequency response is 0.001–3 Hz. The search coil magnetometers are installed at the remote station on West Ongul Island. The output signals transmitted by the PCM telemeter are recorded on a chart recorder and a digital data recorder. The sampling frequency of the digital data is 10 Hz and 1 Hz for each component.

(4) *Base line of the magnetic field and K-index*

Base line values of the magnetic field were observed about once or twice per month during a magnetically quiet day. K-indices are calculated for every 3-hour interval measuring the amplitudes of the H- and D-component magnetic fields from the quiet-day variations. The definition of the K-indices at Syowa Station is as follows:

K-index		Deviation	K-index		Deviation
0	:	0 – 25 nT	5	:	350 – 600 nT
1	:	25 – 50	6	:	600 – 1000
2	:	50 – 100	7	:	1000 – 1660
3	:	100 – 200	8	:	1660 – 2500
4	:	200 – 350	9	:	2500 and more

The ordinary magnetogram is also available on chart papers with a recording speed of 5 cm/hr. The sensitivity of each component on the chart papers is about 100 nT/cm. Table 2 gives the baseline values and K-indices at Syowa Station in February 1998 – January 1999. Inquiries or requests for the data copies of the magnetic field measurements should be addressed to World Data Center C2 for Aurora in NIPR.

3.2. ELF-VLF waves

The natural ELF-VLF wave receiving system at the remote station has consisted of a triangle-shaped three turn loop antenna (10 m in height, 20 m in the bottom side), a pre-amplifier and a main amplifier with gains of 60 and 40 dB, respectively. The ELF-VLF wave intensities at the frequency bands of 0.35, 0.75, 1.2, 2, 4, 8, 30, 60, 95 kHz were obtained from wide band waveforms using a 9-channel filter bank and detectors. The ELF-VLF emissions within the intensity range of 10^{-17} to 10^{-13} W/m^2 Hz were detectable with this system. These data were recorded continuously in digital form at the sampling rate of 1 or 10 Hz. Some of the wide-band ELF-VLF signals up to 10 kHz were recorded on 8 mm video tape recorders. The wide-band recording was executed during 900 - 1300 UT on Sunday - Friday.

3.3. Ionosphere

Cosmic noise absorption at 30 MHz was observed with a broad-beam riometer, which has been installed at the remote station on West Ongul Island since 1981. Its beam half-width is 60°. Used receiver is made by La Jolla Science, and bandwidth and time constant are 150 kHz and 0.25 s, respectively. The riometer data were recorded in digital form at the sampling rate of 1 Hz in the UAPM system.

Data of ionospheric vertical sounders, broad-beam riometers (20 and 30 MHz), HF field strength receivers (8 and 10 MHz) and the VHF auroral radar (50 and 112 MHz) were recorded with other observation systems at Syowa Station, and the observational results have been published in another JARE Data Report (Ionosphere). Inquiries and requests for the data copies are to be addressed to:

World Data Center C2 for Ionosphere
Communications Research Laboratory
Ministry of Posts and Telecommunications
2-1, Nukui-Kitamachi 4-chome, Koganei-shi,
Tokyo 184-8795, Japan.

3.4. Aurora

(1) *CCD all-sky imager*

All-sky observation of aurora was made by a CCD all-sky imager newly installed at Syowa Station by JARE39. Panchromatic auroral images are taken every twenty seconds with an exposure time of three to five seconds. Image data are saved in a DLT (digital linear tape). An observation list for the CCD all-sky imager is given in Table 3. Inquiries or requests for the all-sky data should be addressed to World Data Center C2 for Aurora in NIPR. Observation by the film-type all-sky camera which have been operated until the end of the 1997 season was terminated on April 8, 1998.

(2) *Meridian-scanning photometer*

Auroral emissions at the wavelengths of 557.7 nm (OI), 630.0 nm (OI) and 486.1 nm (Hβ) were observed by a meridian-scanning photometer installed in 1987. The interference filter for Hβ was tilted with 1 s period, measuring the Doppler effect of the auroral Hβ emission. The field of view of the photometer is 3° for OI 557.7 nm and 630.0 nm, and 5° for Hβ. A scan along a meridian from the poleward horizon to the equatorward horizon requires 30 s. Observations were carried out during 91 clear nights from March 17 until October 15 in 1998. Calibration using a standard light source was executed at every observation night. The meridian-scanning photometer data were recorded with a digital data logger (TEAC DR-200) at a sampling frequency of 10-25 Hz through a line-approximate logarithmic amplifier, and monitored with a pen-recorder (6 ch RECTI-GRAPH). Due to a trouble in the instrument, both scanning and tilting angle data were not recorded.

4. Compiled Digital Data Format

(1) *Magnetic Tape*

Data have been digitally recorded continuously since 1981. A similar recording system has been used in Iceland for the geomagnetic conjugate observations. The specifications of the compiled digital tapes are as follows:

Tracks : 9

Record density	:	6250 BPI
Record format	:	FB
Block length	:	28848 bytes
Logical record length	:	48 bytes
Label	:	Non-label
Filing	:	Multi-file (1 file/day)

24 kinds of upper atmospheric data are recorded every 1 s in the following sequence:

Word No.	Observation item	Word No.	Observation item
1	H-component of geomagnetic field	13	VLF 8 kHz
2	D-component of geomagnetic field	14	VLF 30 kHz
3	Z-component of geomagnetic field	15	VLF 60 kHz
4	H-component of ULF waves	16	VLF 95 kHz
5	D-component of ULF waves	17	NA
6	Z-component of ULF waves	18	NA
7	CNA (30 MHz)	19	NA
8	VLF 350 Hz	20	NA
9	VLF 750 Hz	21	NA
10	VLF 1.2 kHz	22	NA
11	VLF 2 kHz	23	NA
12	VLF 4 kHz	24	NA

Words 17-24 are dummy words. Each word, 12 bit A/D converted value, is recorded in the 2 byte binary form of signed 2's complement. A set of these 24 words makes a logical record of 48 bytes; the 10-min data make a block of 28848 bytes. A file contains one day of data (144 blocks) and a volume contains one month of data (28-31 files), as shown in Fig. 2. At the beginning of each block, the starting time of the observation period is written in the following format (48 bytes):

Sequence	Item	
1	Year	(2 bytes)
2	Total day	(2 bytes)
3	Hour	(2 bytes)
4	Minute	(2 bytes)
5	Station code	(4 bytes)
6	Space	(36 bytes)

The magnetic field data recorded on a compiled tape can be transformed to physical quantities by the following relations:

H-component of the geomagnetic field variation (nT) = DATA*2500/2048 – 1250
D- and Z-component of the geomagnetic field variation (nT) = DATA*2500/2048
H-component of ULF waves (nT/s) = DATA/141
D-component of ULF waves (nT/s) = DATA/158
Z-component of ULF waves (nT/s) = DATA/316

For CNA and VLF data, individual calibration values are required to obtain physical values from the recorded data. Inquiries on these calibration values should be addressed to the Upper Atmosphere Physics Research Division of NIPR. For more detailed information on the compiled data, see Uchida *et al.* (1988). These compiled data are also recorded on an Optical Disk (OD) at the sampling rate of 0.5 Hz together with the data from three Icelandic stations for conjugate studies. One volume of the OD can store the data obtained at the four stations during one year. Softwares to handle the OD data are also available to researchers. Details of the OD conjugate data base are described in Yamagishi (1990).

A computer system of the Information Science Center is available to collaborative researchers of NIPR. The center has also been providing various kinds of software such as tape-to-tape copy, displays and spectrum analysis program to the researchers.

(2) *Magnetic Optical Disc*

MO media has been added since 1998 recorded by ATLAS (AT compatible computer with QNX operating system). This system has GPS clock and 16bit strait binary A/D converter (from –10V to 10V). Data in MO are written by Common Data Format (CDF) based on NASA NSSDC (see [1] or [2] for more detail of CDF). Each record has one time stamp and 16 kinds of data. Variable names of CDF for each data are follows;

EPOCH: Time stamp (unit: CDF Epoch)
MGFH: H component of flux gate magnet meter
MGFD: D component of flux gate magnet meter
MGFZ: Z component of flux gate magnet meter
ULFH: H component of induction coil
ULFD: D component of induction coil
ULFZ: Z component of induction coil
CAN: CNA
VLF350: Intensity of natural VLF wave at 350Hz
VLF750: Intensity of natural VLF wave at 750Hz
VLF1.2k: Intensity of natural VLF wave at 1.2kHz
VLF2.0k: Intensity of natural VLF wave at 2.0kHz
VLF4.0k: Intensity of natural VLF wave at 4.0kHz
VLF8.0k: Intensity of natural VLF wave at 8.0kHz

VLF30k: Intensity of natural VLF wave at 30kHz

VLF60k: Intensity of natural VLF wave at 60kHz

VLF95k: Intensity of natural VLF wave at 95kHz.

Each CDF valuable has 5 attributes. The names of attributes and characteristics are follows;

Attributes (based on CDF standard attribute name)

VALIDMIN: Minimum valid value of raw AD data (usually, 0).

VALIDMAX: Maximum valid value of raw AD data (usually, 65534)

SCALEMIN: Minimum value as unit for VALIDMIN

SCALEMAX: Maximum value as unit for VALIDMAX

UNIT: Unit (ex. nT, V/mHz, dB: written by characters)

Using these valuables, user can convert from A/D value to physical value following relation.

(Physical value) = SCALEMIN +

(SCALEMAX-SCALEMIN)/(VALIDMAX-VALIDMIN)*

((Variable data)-VALIDMIN)

[1] CDF User's Guide (Version2.6) NASA/GSFC/NSSDC,

[2] http://nssdc.gsfc.nasa.gov/cdf/cdf_home.html

Acknowledgments

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Ono, T., Tsunomura, S., Ejiri, M., Fujii, R. and Sato, N. (1986): Upper atmosphere physics data, Syowa Station, 1984. JARE Data Rep., **118** (Upper Atmos. Phys. 4), 271p.

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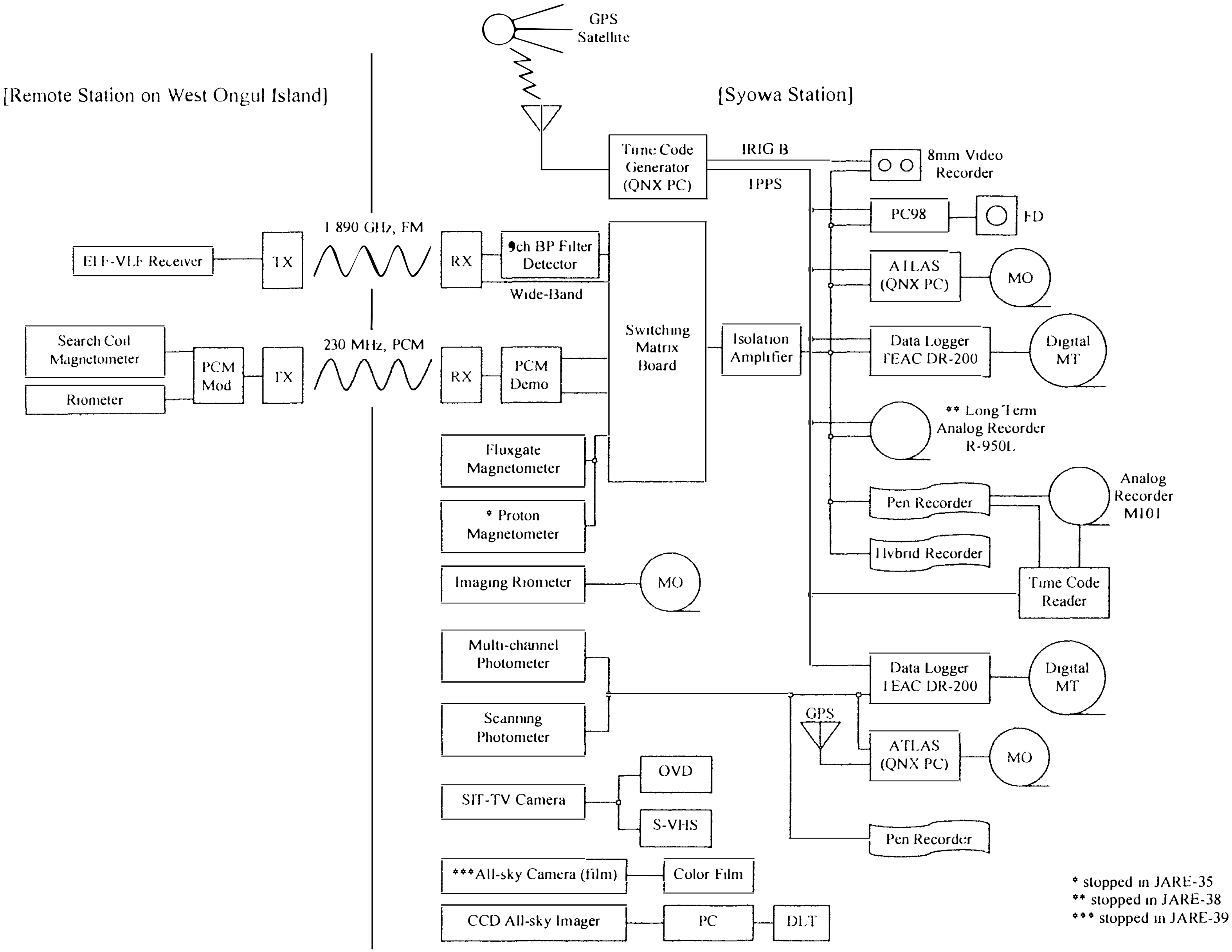

Fig. 1. Block diagram of the "Upper Atmosphere Physics" monitoring system at Syowa Station in 1998.

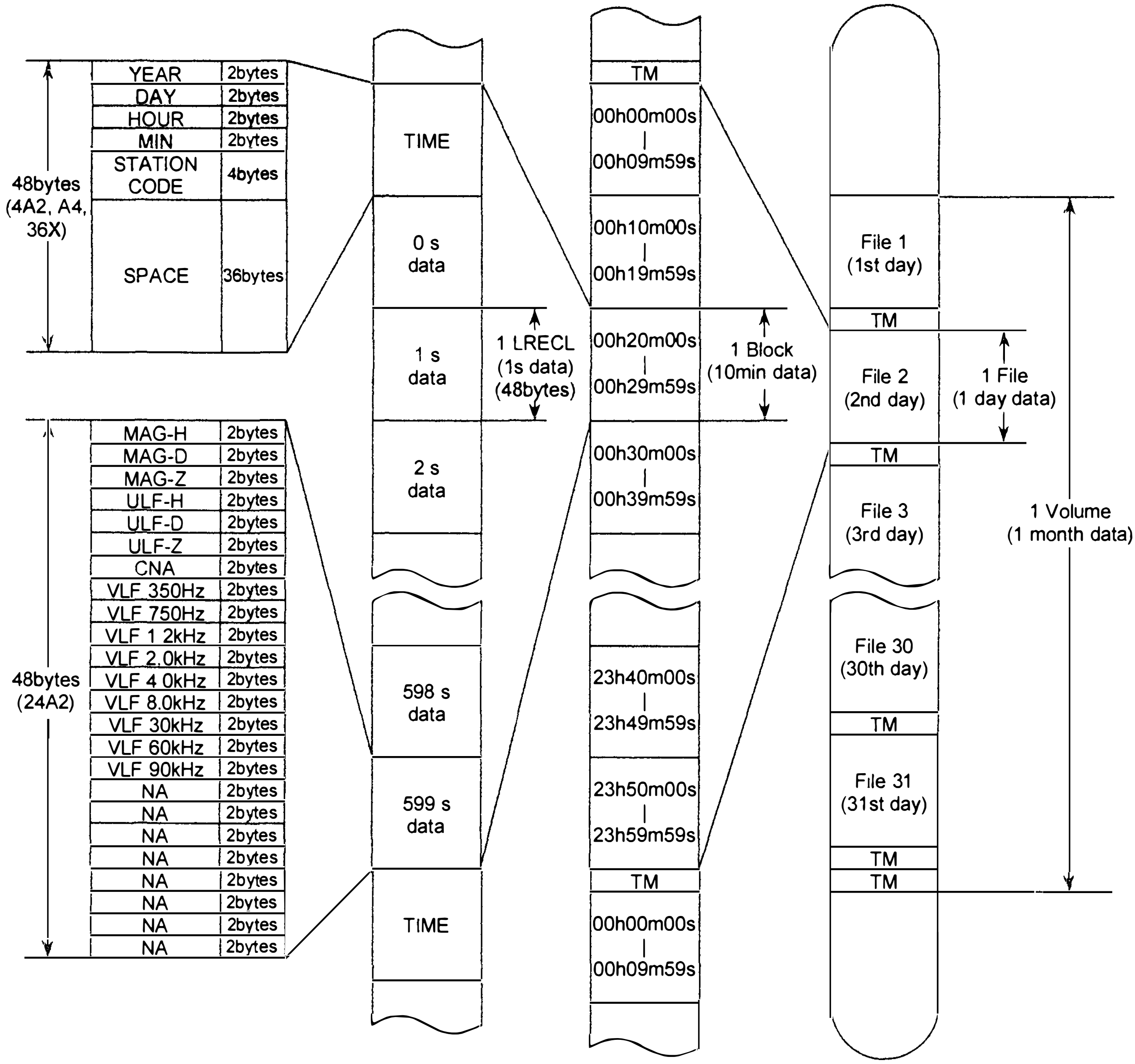

Fig. 2. The structure of the compiled digital tape format for Syowa Station in 1998.

Table 1. Baseline values of the geomagnetic field at Syowa Station in February 1998–January 1999.

DATE	TIME hh:mm	DECLINATION (deg:min)	TIME hh:mm	DIP ANGLE (deg:min)	TOTAL (nT)	HOLIZONTAL (nT)	VERTICAL (nT)
1998 2/25	14:20	-48:09.07	14:41	-63:53.43	43503.2	19145.3	-39063.9
	14:23	-48:09.19	14:46	-63:53.46	43502.9	19144.8	-39063.8
	14:27	-48:09.22	14:49	-63:53.36	43502.4	19145.7	-39062.8
	14:29	-48:09.13	14:52	-63:53.36	43502.5	19145.8	-39062.9
mean	14:24	-48:09.15	14:47	-63:53.40	43502.8	19145.4	-39068.3
1998 3/ 9	13:52	-48:08.45	14:22	-63:52.22	43500.8	19157.9	-39055.0
	13:56	-48:07.85	14:26	-63:52.16	43500.1	19158.3	-39054.1
	14:00	-48:07.53	14:29	-63.52.06	43502.4	19160.5	-39055.5
	14:03	-48:07.83	14:32	-63:52.11	43503.6	19160.4	-39056.9
mean	13:57	-48:07.91	14:27	-63:52.14	43501.8	19159.3	-39055.4
1998 4/ 6	12:50	-48·10.28	13:11	-63:52.08	43494.5	19156.7	-39048.6
	12:54	-48:10.63	13:14	-63·52.14	43493.0	19155.4	-39047.6
	12:57	-48:10.37	13:17	-63:52.16	43491.6	19154.6	-39046.4
	13:00	-48:10.08	13:19	-63:52.09	43492.0	19155.5	-39046.4
mean	12:55	-48:10.34	13:15	-63:52.12	43492.9	19155.6	-39047.3
1998 5/15	11:13	-48:14.05	11:36	-63:51.54	43494.6	19163.0	-39045.6
	11:16	-48:14.13	11:40	-63:51.55	43495.2	19163.1	-39046.3
	11:19	-48:14.14	11:43	-63:51.50	43495.0	19163.6	-39045.8
	11:23	-48:13.99	11:45	-63·51.47	43495.0	19164.0	-39045.6
mean	11:18	-48:14.08	11:41	-63·51.51	43494.9	19163.4	-39045.8
1998 6/15	10:57	-48:10.14	11:19	-63:50.81	43476.8	19163.3	-39025 6
	11.01	-48:10.14	11:22	-63.50.74	43477.3	19164.3	-39025.6
	11:04	-48:10.55	11:25	-63:50.82	43480.6	19165.0	-39029.0
	11:07	-48:10.47	11:28	-63:50.53	43484.3	19169.9	-39030.7
mean	11:02	-48:10.32	11:23	-63:50.72	43480.1	19165.6	-39027.7
1998 7/ 9	10:41	-48:14.03	10:58	-63:49.99	43475.2	19172.0	-39019.6
	10:44	-48:13.86	11:01	-63:49.67	43479.2	19177.4	-39021.4
	10:46	-48:14.18	11:04	-63:49.50	43482.8	19180.9	-39023.6
	10:49	-48:14.63	11:07	-63:49.93	43478.0	19174.0	-39021.8
mean	10:45	-48:14.18	11:02	-63:49.77	43477.7	19176.1	-39021.6
1998 8/11	10:58	-48:13.76	11:20	-63:51.60	43468.7	19150.8	-39022.8
	11:01	-48:13.89	11:23	-63.51.59	43469.0	19151.1	-39023.0
	11:04	-48:14.38	11:26	-63:51 63	43469.4	19150.8	-39023.5
	11:08	-48:14.51	11:30	-63:51.55	43469.7	19151.8	-39023.4
mean	11:02	-48:14.14	11:25	-63:51.59	43469.3	19151.1	-39023.1
1998 9/30	11:32	-48·15.98	11:51	-63:51.48	43470.7	19153.1	-39023.9
	11:35	-48:15.70	11:53	-63:51.32	43471.8	19155.3	-39024.0
	11:37	-48:15.60	11:57	-63:51.39	43473.7	19155.4	-39026.1
	11:40	-48·15.57	11:59	-63:51.34	43475.5	19156.8	-39027.4
mean	11:36	-48:15.71	11:55	-63:51.39	43473.1	19155.1	-39025.3
1998 10/30	13:43	-48:15.13	14:05	-63:50.89	43472.8	19160.7	-39022.5
	13:48	-48.15.16	14:10	-63:50.98	43472.0	19159.4	-39022.2
	13:52	-48:15.95	14:15	-63:50.96	43472.1	19159.6	-39022 2
	13:56	-48·15.80	14·21	-63·50.98	43472.8	19159.7	-39023 0
mean	13.49	-48:15.51	14:13	-63:50.95	43472.5	19159.8	-39022.5
1998 12/ 3	10:08	-48:20.31	10:31	-63:51.32	43442.4	19142.5	-38997.5
	10:12	-48:19 82	10:44	-63:51 47	43442.2	19140.7	-38998.2
	10:16	-48.19.59	10·47	-63:51.47	43444.2	19141.5	-39000 0
	10:19	-48:19.14	10:50	-63:51.56	43446 5	19141.5	-39002.5
mean	10:13	-48:19.71	10:43	-63:51.45	43444.1	19141.5	-38999.6
1999 1/30	11·47	-48:13 87	12:48	-63·50.55	43440.9	19150.5	-38991.9
	12:05	-48:11 21	12:55	-63:50.50	43439.8	19150.6	-38990.6
	12:10	-48:12.00	13·03	-63:50.42	43442.2	19152.6	-38992 4
	12:15	-48:14.61	13:08	-63:50.27	43444.1	19155.1	-38993.3
mean	12:04	-48:12.92	12:58	-63:50.43	43442.1	19152.2	-38992.0

Table 2. K-indices at Syowa Station in February 1998–January 1999.

	FEBRUARY	MARCH	APRIL	MAY	JUNE	JULY	AUGUST	SEPTEMBER	OCTOBER	NOVEMBER	DECEMBER	JANUARY
1	2323 2124	4412 2466	3410 0000	2231 0114	2200 1002	1101 0024	1121 2343	6621 2325	6553 3443	3311 1122	5422 4222	1322 3133
2	2111 1101	5033 2354	0101 0004	4655 5445	3201 2103	4232 1003	2121 1111	4012 1334	6342 4576	4222 1132	3221 1232	3222 2221
3	0111 2233	5211 0023	4221 1221	5464 4367	2112 2135	4311 1015	1112 1122	5311 1201	5543 2112	2212 1235	2121 3432	2221 2212
4	5322 2220	3411 2433	5531 1102	7965 4324	5432 2103	5433 2234	3432 1133	4411 1001	3111 1105	4122 2323	3222 3343	2442 2333
5	1211 1112	4122 1002	3211 0110	6853 4443	3421 3225	5532 1133	3222 2222	1011 0024	4111 0112	4212 3344	3452 3342	4552 1213
6	3311 0100	1211 1103	2101 1122	1211 2214	4202 3454	6653 4321	4565 4238	4311 0002	1111 0223	5553 4445	2222 3332	3221 3333
7	1111 0113	3321 0000	1110 0134	5423 3325	6563 2125	3312 1100	6653 2223	3311 1233	5422 3565	4333 4454	4221 2223	3222 3333
8	3311 1145	2111 0000	4411 0023	6544 3455	5332 2233	0210 0001	4422 2221	5521 0133	5332 2344	5883 3323	4311 1213	4533 4444
9	3422 2233	0111 1001	3421 1234	4552 2344	2133 2221	1011 2355	1111 1111	5312 1022	3542 4345	4775 4554	3221 3411	5542 2223
10	5321 1115	1233 3586	4332 1555	4233 3133	3123 3234	3200 0111	5432 2236	5410 0010	4432 1123	3222 1111	2111 2334	3223 1124
11	4522 3465	5443 2316	5521 1245	5433 2255	4221 1000	1210 2245	5111 1225	1110 1114	5321 1133	1112 1123	4664 4433	4200 1222
12	4322 2244	4542 2324	4442 1010	5554 2233	1431 1112	3222 1100	3321 1115	4222 3333	4311 2223	2221 1123	4422 1222	3021 2234
13	4222 1233	4422 2334	1100 0024	4221 1024	1210 0023	2210 1124	4322 1111	3321 1112	4312 1123	6655 4666	1211 0132	5432 3546
14	3122 1125	4122 2244	3521 2212	2111 0012	4643 2101	1000 0000	1122 2231	2010 1133	2311 0110	4445 4444	3222 2213	3344 4435
15	4422 0000	5653 2215	2101 0003	3000 1133	0332 1212	0000 0003	1111 1243	3411 1221	2221 1211	4323 3353	3321 1124	4533 3342
16	2211 0111	5442 2333	2222 1013	1111 1245	1221 1313	5545 3445	2211 0100	2111 1113	2211 1123	3321 1214	4432 2311	4322 2214
17	2111 3365	4421 1105	1423 3332	6321 0115	3220 0000	5432 3222	0111 0010	5511 0003	3332 2323	5321 1112	0111 0000	5321 1121
18	7543 3342	3311 0013	2122 2000	4111 3336	0001 1003	3111 1123	1111 1112	4313 3456	3322 2225	4222 3122	1112 2102	1121 1343
19	1122 1255	3111 1014	0000 0133	4412 1110	3233 2122	2232 1112	2111 1246	3321 1125	5755 4453	4322 2222	2212 3323	4222 1022
20	5322 1136	5222 1434	1432 3115	1011 1344	1532 2236	4211 1113	5223 3444	4211 0014	3323 2356	1222 2133	3333 3332	3111 2443
21	5311 0123	3323 4553	3412 2223	5442 2356	5544 3044	1543 2133	5100 0004	4542 2110	6543 2352	3322 2313	2111 1121	2412 3111
22	4422 2131	3333 3331	2311 1233	6222 1112	6421 1254	3211 2225	2234 3355	2221 1133	4332 3455	3321 2220	3111 1232	2121 4563
23	3321 2253	4311 0013	4431 0054	4531 2145	3321 0025	4565 3456	5443 3332	3421 2235	3422 3455	4331 2433	3112 4333	3433 2455
24	3311 1112	1121 1266	5663 3326	4353 2324	4533 3444	4444 3455	3422 2136	4552 2357	4522 1335	3322 3343	3422 2112	4552 2434
25	1111 0122	4311 4333	6643 3464	1032 2345	4211 0214	4453 2223	5422 1134	7695 5423	5531 2332	2322 2435	4444 2333	5531 1222
26	1111 0102	2211 2433	7553 4446	4311 1235	6654 3342	3321 1111	3454 4456	2222 3455	1222 1114	3332 3434	3532 3234	3202 2014
27	1121 1133	4522 3255	5533 2233	3411 1223	2211 1101	1112 2112	7664 3575	5322 3212	3111 2215	5432 3111	3111 1101	4422 3332
28	3331 3436	3432 3126	5422 1243	2310 0012	1111 1001	2121 1225	5553 3535	1221 1133	4321 1224	4421 1222	2321 2454	2232 2233
29		6522 1546	3211 1014	4421 2533	2000 0001	3411 1123	5643 2364	1421 1143	5332 2325	4422 2132	3333 4365	3322 2223
30		3232 2236	3002 1344	6642 2223	1110 1000	3211 1223	5543 2354	3311 1235	3321 1112	2343 2455	3331 1122	3212 1111
31		5542 1002		3211 1001		5554 4332	4343 3234		2212 1131		3311 2221	2211 1110

Table 3. Observation periods of a CCD all-sky imager at Syowa Station in 1998.

DATE	Hours (UT)									K-Index	
	h	m	s	h	m	s	h	m	s		
Apr. 1	21	30	00	~ 23	10	00				3410	0000
Apr. 2							18	10	00	0101	0004
Apr. 3	~ 00	50	00							4221	1221
Apr. 5							17	45	00	3211	0110
Apr. 6	~ 01	08	00				17	08	00	2101	1122
Apr. 7	~ 01	20	00							1110	0134
Apr. 8							17	30	00	4411	0023
Apr. 9	~ 00	53	00				20	27	00	3421	1234
Apr. 10	~ 01	20	00							4332	1555
Apr. 16							17	59	00	2222	1013
Apr. 17	~ 00	47	00							1423	3332
Apr. 22							17	09	00	2311	1233
Apr. 23	~ 00	04	00	17	25	00	~ 19	16	00	4431	0054
Apr. 24							16	20	00	5663	3326
Apr. 25	~ 03	00	00	16	19	00	~ 21	52	00	6643	3464
Apr. 26				19	38	00	~ 22	24	00	7553	4446
Apr. 29							16	26	00	3211	1014
Apr. 30	~ 02	30	00				17	15	00	3002	1344
May 1	~ 00	52	00							2231	0114
May 6							23	11	00	1211	2214
May 7	~ 03	00	00				16	05	00	5423	3325
May 8	~ 03	12	00	16	04	00	~ 20	33	00	6544	3455
May 10							22	43	00	4233	3133
May 11	~ 03	01	00	14	59	00	~ 16	54	00	5433	2255
May 12							16	09	00	5554	2233
May 13	~ 01	28	00				16	40	00	4221	1024
May 14	~ 03	10	00	17	02	00	~ 21	37	00	2111	0012
May 16							18	08	00	1111	1245
May 17	~ 03	01	00				15	18	00	6321	0115
May 18	~ 03	21	00				20	23	00	4111	3336
May 19	~ 03	30	00				15	13	00	4412	1110
May 20	~ 03	28	00				14	58	00	1011	1344
May 21	~ 03	30	00				14	54	00	5442	2356
May 22	~ 01	35	00							6222	1112
May 23							18	20	00	4531	2145
May 24	~ 03	32	00							4353	2324
May 27				17	58	00	~ 23	30	00	3411	1223
May 29				16	24	00	~ 17	39	00	4421	2533
May 31							14	50	00	3211	1001
Jun. 1	~ 03	36	00				23	14	00	2200	1002
Jun. 2	~ 00	13	00							3201	2103
Jun. 6							14	57	00	4202	3454
Jun. 7	~ 03	59	00							6563	2125
Jun. 8							18	23	00	5332	2233
Jun 9	~ 04	00	00	14	37	00	19	27	00	2133	2221
Jun. 12							14	45	00	1431	1112
Jun. 13	~ 04	00	00				14	36	00	1210	0023

DATE	Hours (UT)									K-Index	
	h	m	s	h	m	s	h	m	s		
Jun. 14	~ 04	00	00				14	37	00	4643	2101
Jun. 15	~ 04	03	00	14	40	00	~ 22	56	00	0332	1212
Jun. 17				15	00	00	~ 23	29	00	3220	0000
Jun. 19							18	36	00	3233	2122
Jun. 20	~ 04	25	00				14	33	00	1532	2236
Jun. 21	~ 03	25	00				15	33	00	5544	3044
Jun. 22	~ 03	58	00				19	01	00	6421	1254
Jun. 23	~ 03	41	00	14	41	00	~ 20	13	00	3321	0025
Jun. 24							14	40	00	4533	3444
Jun. 25	~ 03	23	00				14	38	00	4211	0214
Jun. 26	~ 04	07	00				14	30	00	6654	3342
Jun. 27	~ 04	05	00				14	42	00	2211	1101
Jun. 28	~ 04	18	00				14	40	00	1111	1001
Jun. 29	~ 00	25	00							2000	0001
Jul. 7							19	53	00	3312	1100
Jul. 8	~ 03	54	00				14	21	00	0210	0001
Jul. 9	~ 03	52	00	19	35	00	~ 20	01	00	1011	2355
Jul. 10				18	01	00	~ 20	07	00	3200	0111
Jul. 13	00	28	00	~ 03	30	00	20	24	00	2210	1124
Jul. 14	~ 03	51	00				14	45	00	1000	0000
Jul. 15	~ 03	50	00				14	50	00	0000	0003
Jul. 16	~ 03	57	00				15	02	00	5545	3445
Jul. 17	~ 01	36	00							5432	3222
Jul. 19							15	01	00	2232	1112
Jul. 20	~ 03	23	00				16	10	00	4211	1113
Jul. 21	~ 00	05	00	16	09	00	~ 21	21	00	1543	2133
Jul. 25							16	15	00	4453	2223
Jul. 26	~ 03	35	00	16	16	00	~ 18	43	00	3321	1111
Jul. 27							16	17	00	1112	2112
Jul. 28	~ 02	43	00				17	56	00	2121	1225
Jul. 29	~ 03	14	00							3411	1123
Jul. 30							23	05	00	3211	1223
Jul. 31	~ 01	51	00							5554	4332
Aug. 1							20	00	00	1121	2343
Aug. 2	~ 03	07	00				18	29	00	2121	1111
Aug. 3	~ 03	15	00				18	31	00	1112	1122
Aug. 4	~ 03	26	00				18	56	00	3432	1133
Aug. 5	~ 03	17	00							3222	2222
Aug. 8							16	26	00	4422	2221
Aug. 9	~ 02	56	00				16	27	00	1111	1111
Aug. 10	~ 02	53	00				16	30	00	5432	2236
Aug. 11	~ 03	31	00				16	31	00	5111	1225
Aug. 12	~ 03	27	00				18	11	00	3321	1115
Aug. 13	~ 02	50	00							4322	1111
Aug. 14							17	02	00	1122	2231
Aug. 15	~ 02	46	00				16	22	00	1111	1243
Aug. 16	~ 02	26	00				16	22	00	2211	0100
Aug. 17	~ 02	38	00				16	18	00	0111	0010
Aug. 18	~ 02	33	00				16	43	00	1111	1112

DATE	Hours (UT)									K-Index	
	h	m	s	h	m	s	h	m	s		
Aug. 19	~ 02	37	00				16	27	00	2111	1246
Aug. 20	~ 02	31	00				16	20	00	5223	3444
Aug. 21	~ 01	53	00				16	29	00	5100	0004
Aug. 22	~ 02	32	00				16	09	00	2234	3355
Aug. 23	~ 02	29	00							5443	3332
Aug. 24							16	50	00	3422	2136
Aug. 25	~ 03	16	00				17	15	00	5422	1134
Aug. 26	~ 01	57	00				16	24	00	3454	4456
Aug. 27	~ 02	02	00				18	17	00	7664	3575
Aug. 28	~ 02	45	00				16	53	00	5553	3535
Aug. 29	~ 01	37	00							5643	2364
Sep. 1							20	49	00	6621	2325
Sep. 2	~ 02	04	00				19	05	00	4012	1334
Sep. 3	~ 02	13	00							5311	1201
Sep. 9							18	01	00	5312	1022
Sep. 10	~ 01	37	00				17	04	00	5410	0010
Sep. 11	~ 01	29	00				17	01	00	1110	1114
Sep. 12	~ 01	31	00							4222	3333
Sep. 13				18	22	00	~ 20	33	00	3321	1112
Sep. 23							18	28	00	3421	2235
Sep. 24	~ 00	18	00	18	00	00	~ 23	14	00	4552	2357
Sep. 25							18	00	00	7695	5423
Sep. 26	~ 00	37	00							2222	3455
Oct. 3				19	45	00	~ 22	30	00	5543	2112