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SOLAR-TERRESTRIAL EVENTS IN FEBRUARY–MARCH 1986

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Abstract

A brief summary of significant solar-terrestrial events occurring in February–March 1986 is presented. Unusually high solar-terrestrial activity was observed in early February 1986. A series of large solar flares took place within the active region of NOAA #4711 during the period 3–7 February 1986. A geomagnetic storm which took place at 13:12 UT on 6 February reached its maximum phase through 8–9 February. The minimum Dst of −312 nT was recorded on early 9 February. It took more than a month to show full recovery. This magnetic storm will be a good example to study various terrestrial events in association with high solar-flare activity. March 1986 was another important interval because extensive observations of comet Halley were performed. Large-scale solar wind structures in the minimum activity phase of the sun and their influences on plasma-tail activity of the comet will be of interest.

1. Overview of Solar-Terrestrial Activity in Early February 1986

A synoptic chart which contains inter-relating observational parameters of solar-terrestrial environment in February 1986 is given in Figure 1. The top panel shows the longitudes of solar flares measured from the solar central meridian (Solar-Geophysical Data, 1986). The size of each square is proportional to the importance of each flare; the largest square corresponds to a solar flare of a 3B class. Occurrence of type II (IV) radio burst is indicated by II (IV), on the top of this panel (Solar-Geophysical Data, 1986). It is seen that principal flare activity took place during the interval through 4 to 7 February and through 11 to 13 February. The former solar activity took place within the active region of NOAA #4711 whose central meridian passage (CMP) date was 5 February. Several large solar flares of 2B–3B classes took place within this active region, near the central meridian. The latter group of flare activity was observed within the active region of #4713 after its CMP on 9 February. The second panel shows the solar wind speed observed at

IMP–J. High-speed solar wind of faster than 700 km/s was observed during 9–10 February. Interplanetary shock waves are seen on 6 and 7 February, respectively. The third panel shows interplanetary magnetic observations. The fourth panel shows the daily variation of preliminary Dst values. The minimum value of Dst was −312 nT, which was obtained at 01:00 UT (hour:min) on 9 February. It is interesting to note that recovery of Dst was very slow. The bottom panel shows K_p indices, which remained very high ($K_p > 8$) for 18 hours through 8 February to 9 February. Small triangles indicate ssc of geomagnetic storms (Solar-Geophysical Data).

1.2 Solar Phenomena

The most significant solar activity occurred within the active region #4711, which appeared on the eastern solar limb on 30 January 1986. This active region exhibited remarkable activity in the interval from 3 to 7 February around its central meridian passage (CMP) on 5 February. Major solar flares during 3–7 February are listed in Table 1 (Garcia and Dryer, 1987).

Table 1. Major solar flares during 3–7 February 1986

Event	DATE (X–ray maximum)	Location (active region)	Classification (optical/X–ray)	Radio burst (metric sweep)
1	3 Feb. (20:49 UT)	S09 E26 (#4711)	1B/M2.3	Type II Type IV
2	4 Feb. (07:41 UT)	S03 E21 (#4711)	3B/X3.0	Type II
3	4 Feb. (10:29 UT)	S02 E68 (#4713)	1B/M6.4	
4	5 Feb. (12:55 UT)	S07 E06 (#4711)	2B/M3.0	Type IV
5	6 Feb. (06:25 UT)	S04 W06 (#4711)	3B/X1.7	Type II Type IV
6	7 Feb. (10:34 UT)	S10 W20 (#4711)	2B/M5.2	Type II Type IV

Flare No. 1 on 3 February showed enduring (about 120 min) flare activity. It is suggested that this flare would have been a more-or-less enduring energy source for an associated interplanetary disturbance (Garcia and Dryer, 1987). Flare No. 2 on 4 February is proved to be the largest of all six solar flares given in Table 1. It was an impulsive flare; the main hard X–ray burst lasted about 40 sec. Flare No. 3 took place within a different active region (#4713). It is suggested that this flare was triggered by the nearby 3B solar flare (No. 2). Flare No. 4 was a modest solar flare which took place near the central meridian of the sun. Flare No. 5 on 6 February was the only X–class flare (X1.7) other than Flare No. 2 (X3.0). Flare No. 6 on 7 February was a modest solar flare of an M5 class but showed exceptionally large emission measure for over one hour, indicating either a slow dissipative process or a low-level continuous energy source (Garcia and Dryer, 1987).

In addition to the active region #4711, the NOAA region #4713 also showed considerable flare activity after its CMP on 9 February. Several solar flares of larger than Importance 2 were reported on 10–14 February. Type II/IV radio bursts were observed on 10, 14 and 15 February, respectively. The solar-terrestrial events in February 1986 had a connection with the solar flare activity within above-mentioned two active regions of #4711 and #4713. Solar optical observations in early February 1986 are discussed by Hiei et al. in Paper 1 in this special issue.

1.3 Interplanetary Shock Waves

Solar wind plasma and interplanetary magnetic field data obtained at IMP–J during 6–10 February are shown in Figure 2. As noted in this figure, time coverage of solar wind observations by IMP–J was poor in February 1986. This makes it difficult to perform detailed study of interplanetary-magnetospheric relationship. Nevertheless, at least two interplaetary shock waves are seen in this figure. The first one was observed between 13:18:51 UT (hour:min:sec) and 13:22:56 UT on 6 February, and the second one was observed between 16:48:12 and 17:01:58 UT on 7 February. The hydrodynamic shock speed of the first shock wave is estimated to be 457 km/s, and 825 km/s for the second shock. Very high-speed solar wind of faster than 700 km/sec was observed after the appearance of the second shock wave at IMP–J until early 10 February. Interplanetary disturbances in early February 1986 were detected by Doppler scintillation observations of the Japanese Spacecraft Sakigake (Paper 5).

1.4 Cosmic Ray Observations

A synoptic chart showing solar flare activity (top panel), solar wind speed at IMP–8, the cosmic ray intensity at Alert, and K_p indices are shown in Figure 3. An extensive Forbush decrease of the neutron flux was initiated on 6 February, and reached the maximum extent on early 9 February. Another local minimum of the neutron flux was observed around 17 February. It is suggested that solar flares in association with type II/IV radio bursts, which took place within the active region #4713 near the western solar limb, were responsible for the decrease in cosmic ray intensity. An extensive discusssion on Nagoya meson observations in February 1986 is given by Fujii et al. (Paper 6).

1.5 Geomagnetic Activity

The daily plot of the H component of the geomagnetic field (1-minute averages) at Kakioka is shown in Figure 4 for the period from 5 to 11 February (STE Data Book, 1988). An ssc of geomagnetic storm was observed at Kakioka at 13:12 UT on 6 February, and high geomagnetic activity remained until 10:00 UT on 10 February. The largest depression of the geomagnetic H component (−310 nT) appeared on early 9 February. Provisional plots of the H component (1-minute averages) of 9 geomagnetic observatories are shown in Figures 5a, b for 8 and 9 February. According to Allen (1986), maximum change in the H component at College, Alaska was −6110 nT. The minimum Dst of −312 nT was observed during the first hour of 9 Feb (Figure 1).

It is suggested that the magnetic storms in early February 1986 resulted from interplanetary disturbances produced by a series of solar flares given in Table 1 (Garcia and Dryer, 1987). Another interesting feature which appears in world-wide magnetograms is a sudden impulse (SI) which took place at 17:48 UT on 9 February. This event is reported as an SC at Guam and Kerguelen (Solar-Geophysical Data, 1986). Onsets of SSC's of geomagnetic storms reported in Solar- Geophysical Data are given in Table 2. An overview of world-wide geomagnetic observations is given by Kamide in Paper 7.

Table 2. Principal ssc's observed in February 1986 (Solar-Geophysical Data, 1986)

	DATE	TIME(UT)
YEAR	MONTH/DAY	HOUR:MIN
1986	2/06	06:18
1986	2/06	13:11-13:13
1986	2/07	15:21
1986	2/08	20:13
1986	2/09	17:48
1986	2/21	08:14

The geo-stationary spacecraft GOES–5 was located at the longitude of 74° W. The H, V and D components of the geomagnetic field at the spacecraft on 6–9 February are shown in Figure 6. The sharp decrease in the H component indicates magnetopause crossing at the geosynchronous orbit (6.6 Re). Parameters of geosynchronous magnetopause crossings are given in Table 3 (Rufenach et al., 1989). An extensive discussion on the relationship between solar wind parameters and the geomagnetic activity is given by Nagano in Paper 8.

Table 3. Geosynchronous magnetopause crossing in February 1986

Satellite	Year	Date	Crossing (UT)	Time (LT)	Hmin (nT)	Duration (h:min)
GOES-5	1986	2/7	16:20	11:38	-132	0:23
GOES-6	1986	2/7	16:35	09:13	-115	0:17
GOES-6	1986	2/7	21:35	14:13	-111	0:08
GOES-5	1986	2/8	15:28	10:28	-125	1:19
GOES-5	1986	2/8	16:50	11:50	3	0:07
GOES-5	1986	2/8	20:50	15:50	-132	2:09
GOES-6	1986	2/8	14:15	07:01	5	0:03
GOES-6	1986	2/8	15:50	08:22	-85	0:43
GOES-6	1986	2/8	20:15	13:01	-175	2:42
GOES-5	1986	2/9	17:50	12:56	-28	0:02
GOES-6	1986	2/9	17:50	10:22	3	0:01

1.6 Solar Energetic-Particle Events and Ionospheric Disturbances

Figure 7 shows the solar X–ray activity (GOES–5), the energetic proton flux of 6–10 MeV (GOES–6), the diurnal phase variation (saw-tooth like curve) and phase deviation from the average diurnal variation of the radio paths between INUBO, Japan and N. DAKOTA (13.6 kHz) and NORWAY (13.6 kHz) signals observed at INUBO, Japan in the period from 3 to 12 February (STE Data Book, 1988). Also shown in this figure are K_p indices. The NORWAY–INUBO path traverses the polar cap region of the corrected geomagnetic latitude of $< 68^\circ$ N, while the N. DAKOTA–INUBO path traverses the auroral zone of $< 63^\circ$ N. An increase in the flux of solar energetic protons of $>$ 10 MeV took place at 08:25 UT on 6 February, corresponding to a 3B/X1.7 solar flare which took place in #4711 at S04 W06, 06:18 UT on 6 February. The time-variation of the phase deviation for the NORWAY–INUBO path on 6 February shows a rough coincidence with the time-variation in the solar energetic proton, while no appreciable phase deviation is seen for the N. DAKOTA–INUBO path. This suggest that the equatorward border of the solar proton precipitation was located between 63° N and 68° N on this date.

Another strong solar proton event took place at about 12:00 UT on 7 February, immediately after a 2B/M5.2 solar flare which took place within #4711 at S10 W20, 09:48 UT on 7 February. In this case, the phase deviation was observed for both the NORWAY and N. DAKOTA path, and the largest phase deviation for the N. DAKOTA path was observed when the highest K_p indices were obtained on late 8 February. It is suggested that a development of strong ring currents during the high geomagnetic activity and the resulting decrease in the geomagnetic field strength caused an equatorward shift of the low latitude edge of the proton precipitation region.

1.7 Ionospheric Activity

Very disturbed condition of ionosphere was observed in association with solar-terrestrial events in early February 1986. According to HF Doppler (HFD) measurements using the Communications Research Laboratory HFD network in Japan, very distinct travelling ionospheric disturbances (TID's) were observed in association with the high geomagnetic activity on 6–9 February (Ogawa et al., Paper 11). Sinusoidal HFD oscillations which were detected in association with an SI of geomagnetic field at 17:48 UT on 9 February have been attributed to global compressional oscillations of the magnetosphere (Yumoto et al., Paper 11, Tsunomura et al., Paper 13).

2. Overview of Solar-Terrestrial Events in March 1986

A sinoptic chart showing solar-terrestrial activity in March 1986 is given in Figure 8. The format is the same as in Figure 1. It is intersting to note that encounters of Giotto passed near the comet Halley's nucleus on March 14, and the Japanese spacecraft Suisei encountered the comet on March 8. The level of solar-terrestrial activity in March was generally moderate. Solar flare activity was seen in early March within the active region NOAA #4717. A disturbance in the plasma tail of comet Halley was observed during 12–14 March (Oki et al., Paper 19). It is suggested that the tail event took place in association with the passage of the heliospheric neutral sheet at the comet. It is interesting to note that the recurrence of solar wind streams disappeared through March–April 1986 (Abe et al., Paper 4).

3. Concluding Remarks

The solar activity and related terrestrial effects on 4–10 February 1986 would be very interesting for the solar-terrestrial research community to promote coordinated data analysis. Although extensive ground-based observations are available, the insufficient coverage of solar wind and interplanetary magnetic field data for the period in question is the most important discouraging factor. Nevertheless, this interval will be worth performing a detailed analysis to study solar-terrestrial phenomena in association with major solar-flare activity because interplanetary observations for a part of interesting events are available. The data and papers contained in this special issue will stimulate further creative research works and will promote construction of a comprehensive data base.

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Data	Data Source
IMP-J solar wind plasma data	H. S. Bridge, Massachusetts Institute of Technology
IMP-J interplanetary magnetic data	R. P. Lepping WDC-A for Rockets and Satellites
Geomagnetic observations	M. Kuwashima, Kakioka Geomagnetic Observatory
	J.H. Allen, WDC-A for Solar Terrestrial Physics

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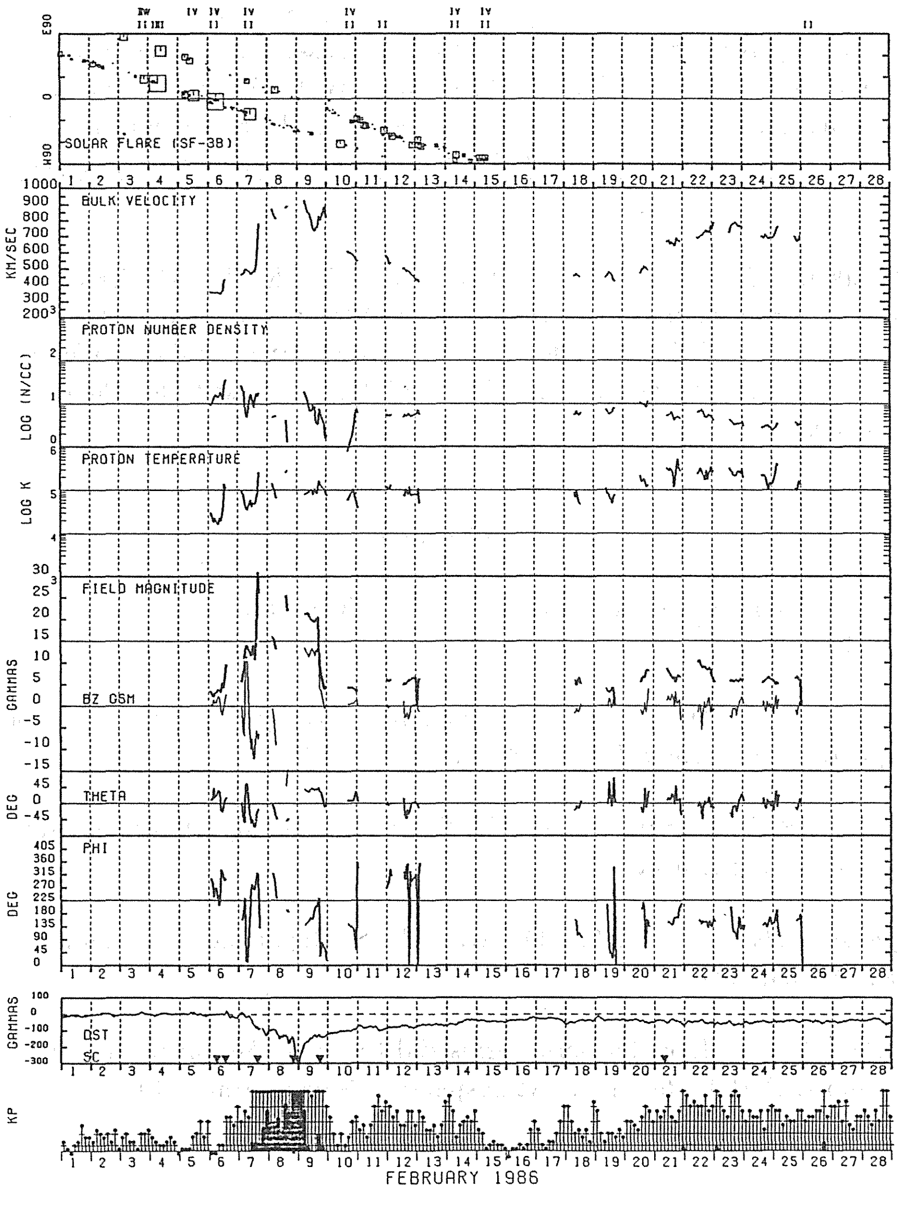

Fig. 1. A synoptic chart for solar-terrestrial events in February 1986. The top panel shows the longitudes of solar flares measured from the solar central meridian. The size of each square is proportional to the importance of each flare; the largest square corresponds to a solar flare of a 3B class. Occurrence of type II (IV) radio bursts is indicated by II (IV), respectively, on the top of this panel. The second panel shows the solar wind speed observed at IMP–J. The third panel show interplanetary magnetic observations at IMP–J. The fourth panel shows the daily variation of Dst values. The bottom panel shows K_p indices. Small triangles indicate ssc of geomagnetic storms.

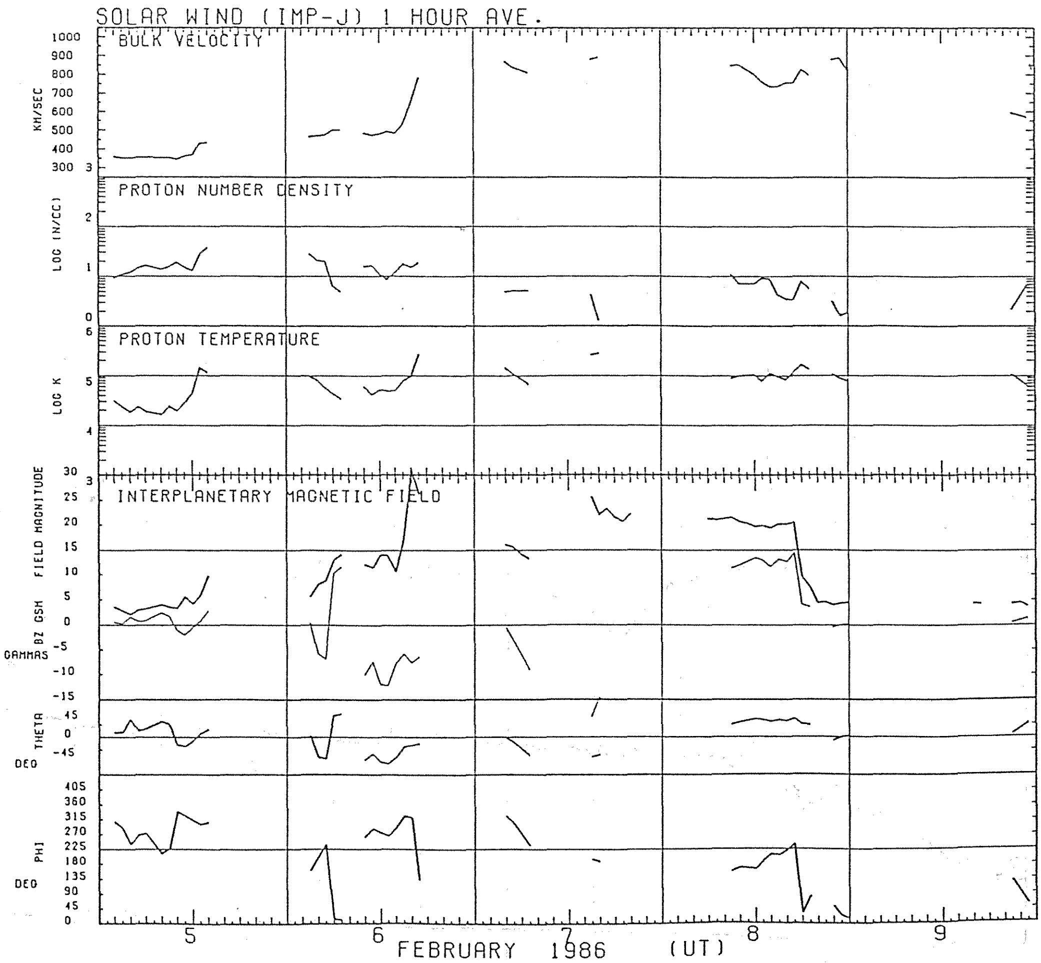

Fig. 2. Solar wind parameters (plasma and interplanetary magnetic field) observed at IMP–J during 5–9 February 1986.

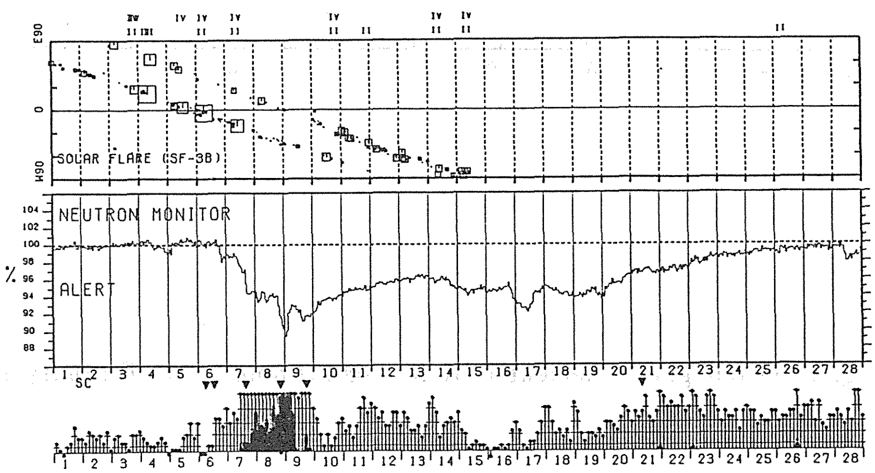

Fig. 3. Solar flare data, the neutron intensity at Alert, and K_p indices in February 1986.

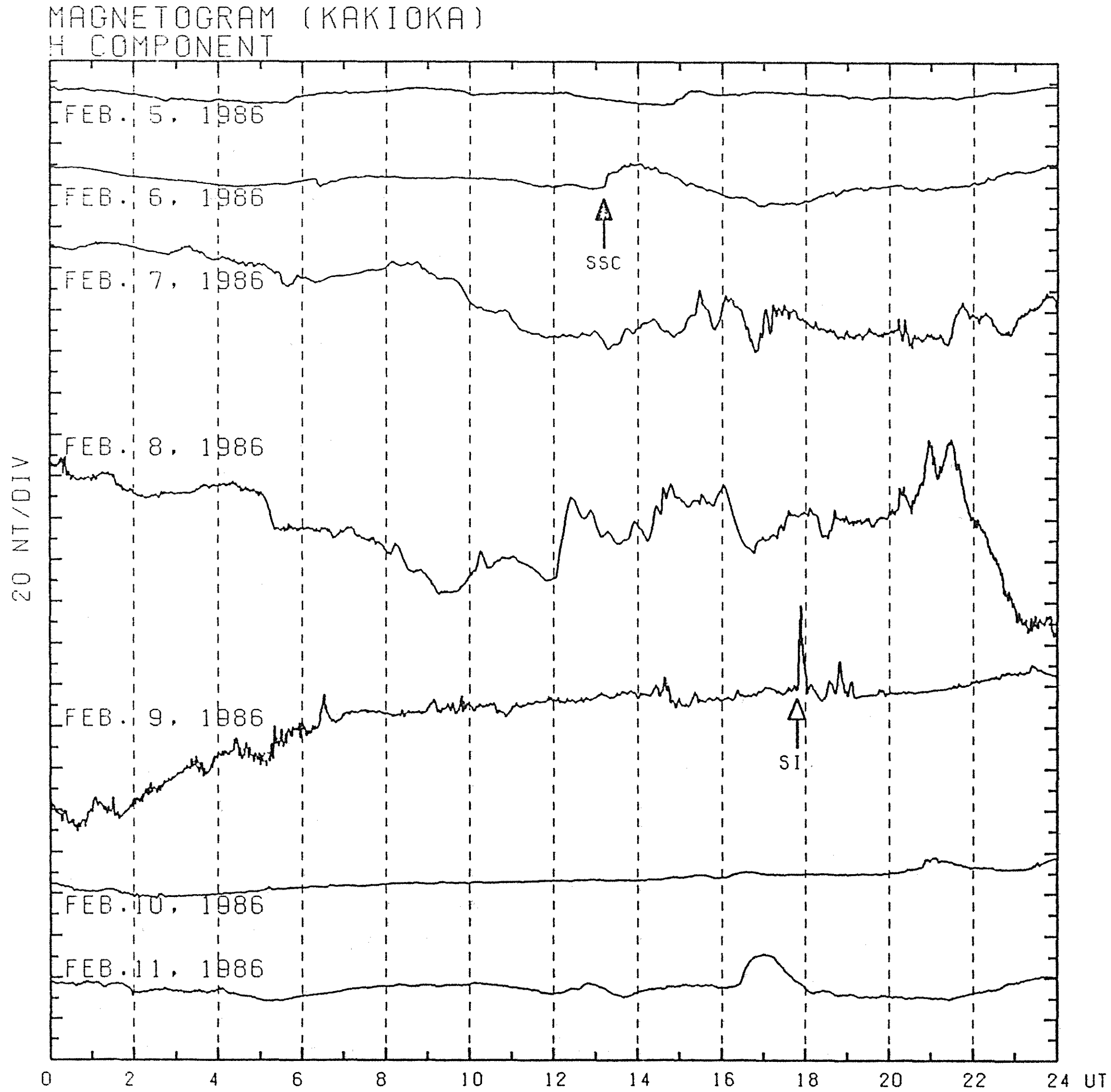

Fig. 4. Geomagnetic element H at Kakioka through 5–11 February 1986.

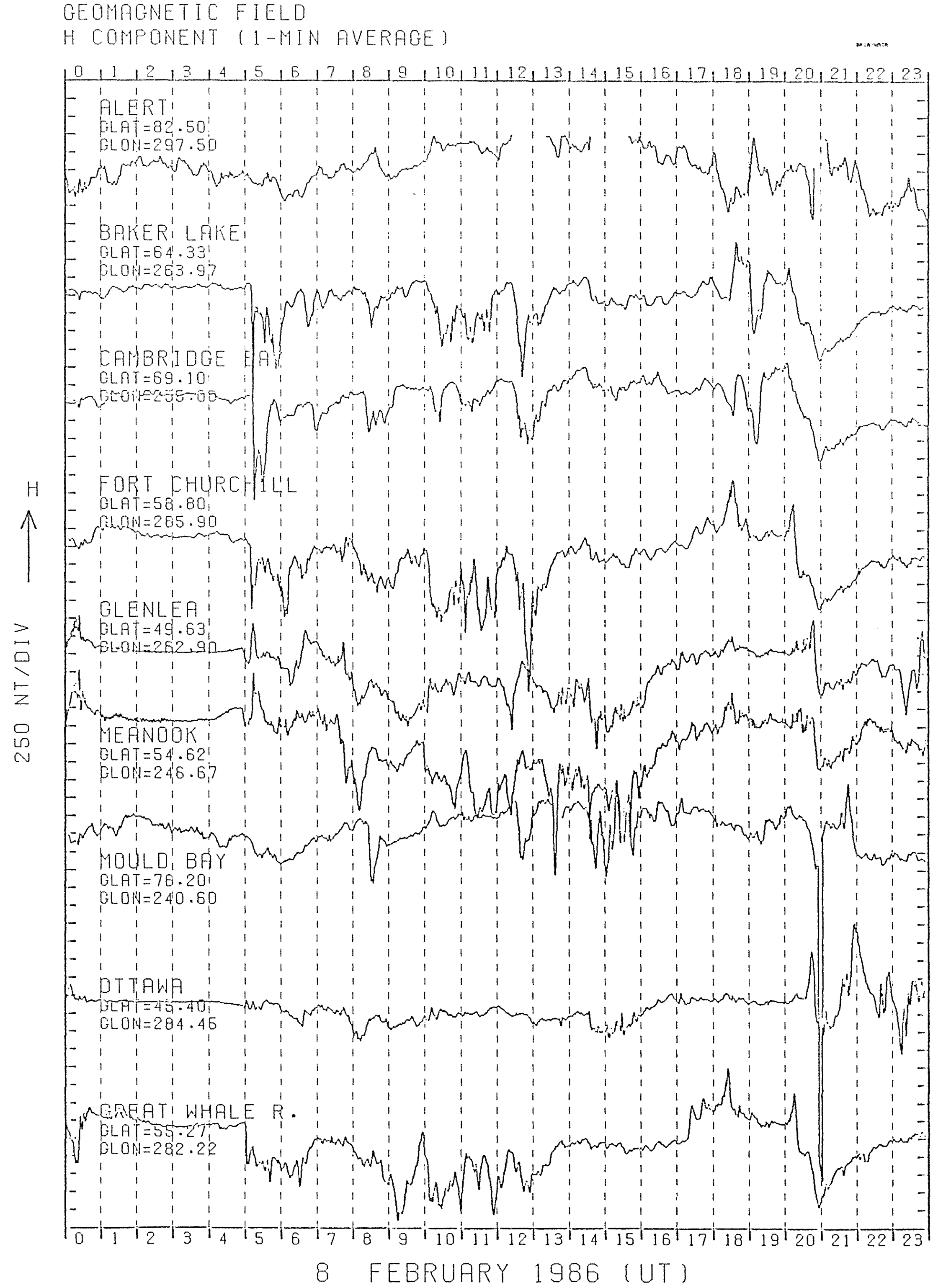

Fig. 5a. Geomagnetic element H at 9 stations on 8 February 1986.

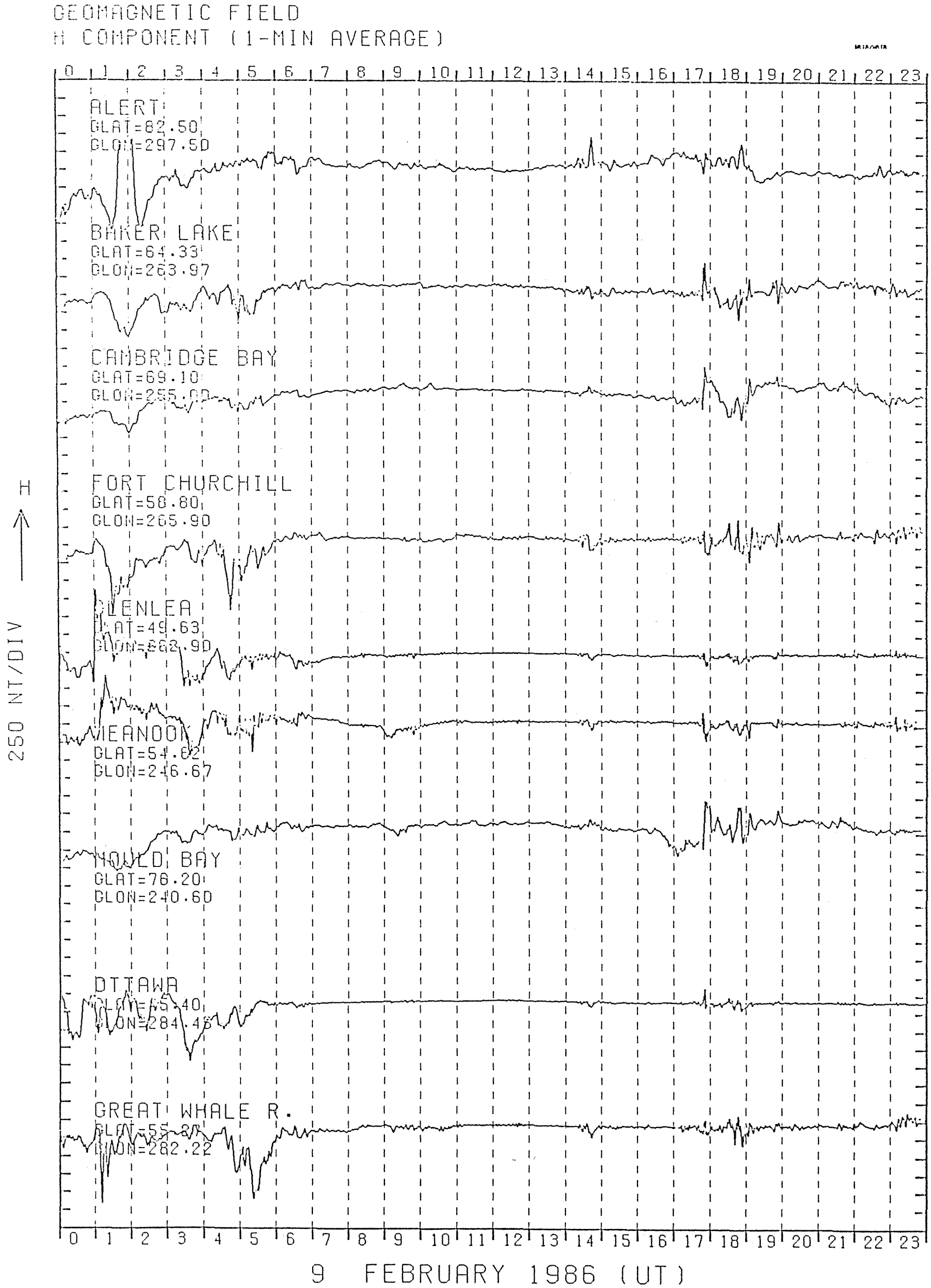

Fig. 5b. Geomagnetic element H at 9 stations on 9 February 1986.

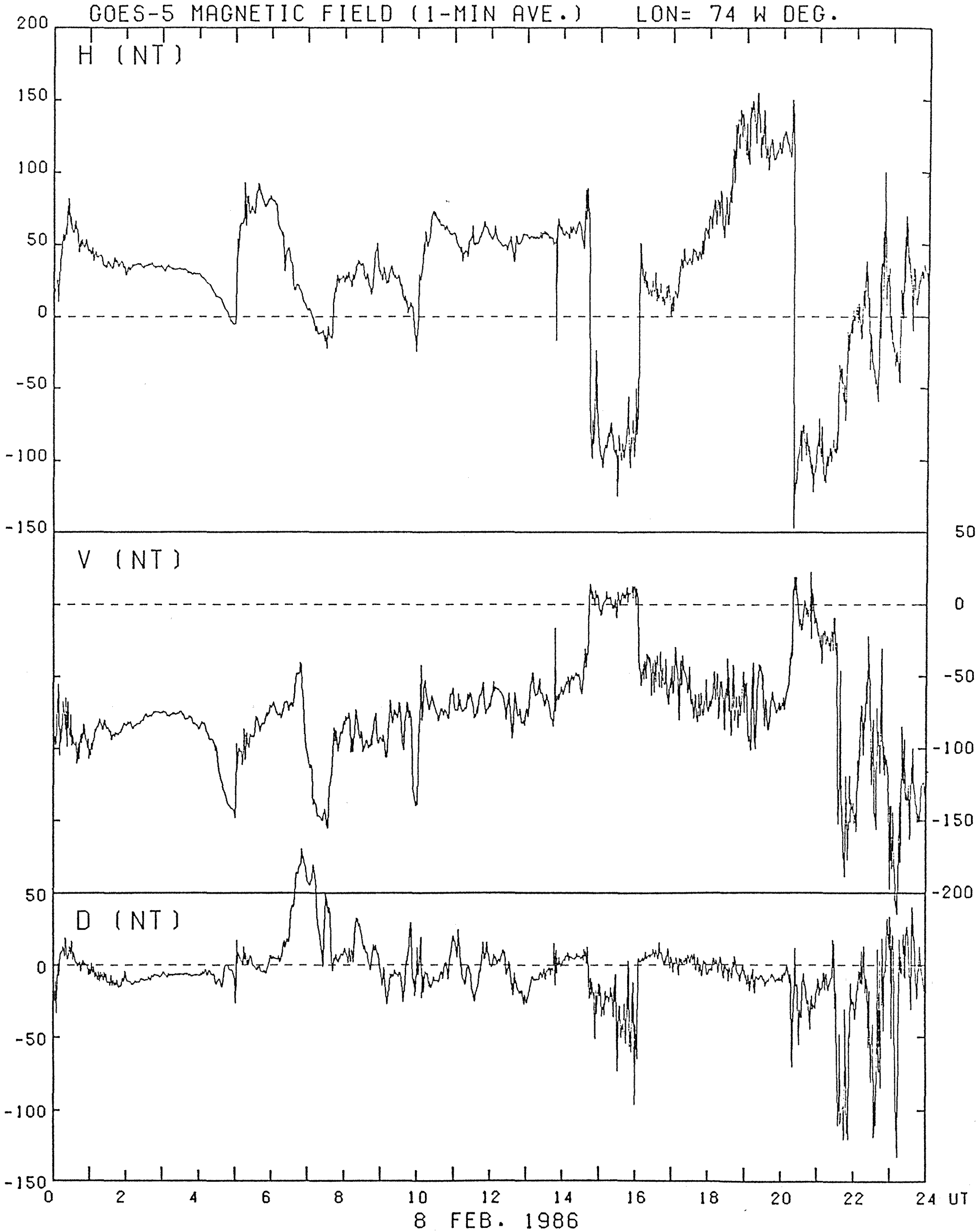

Fig. 6a. Geomagnetic field at GOES 5 on 8 February 1986.

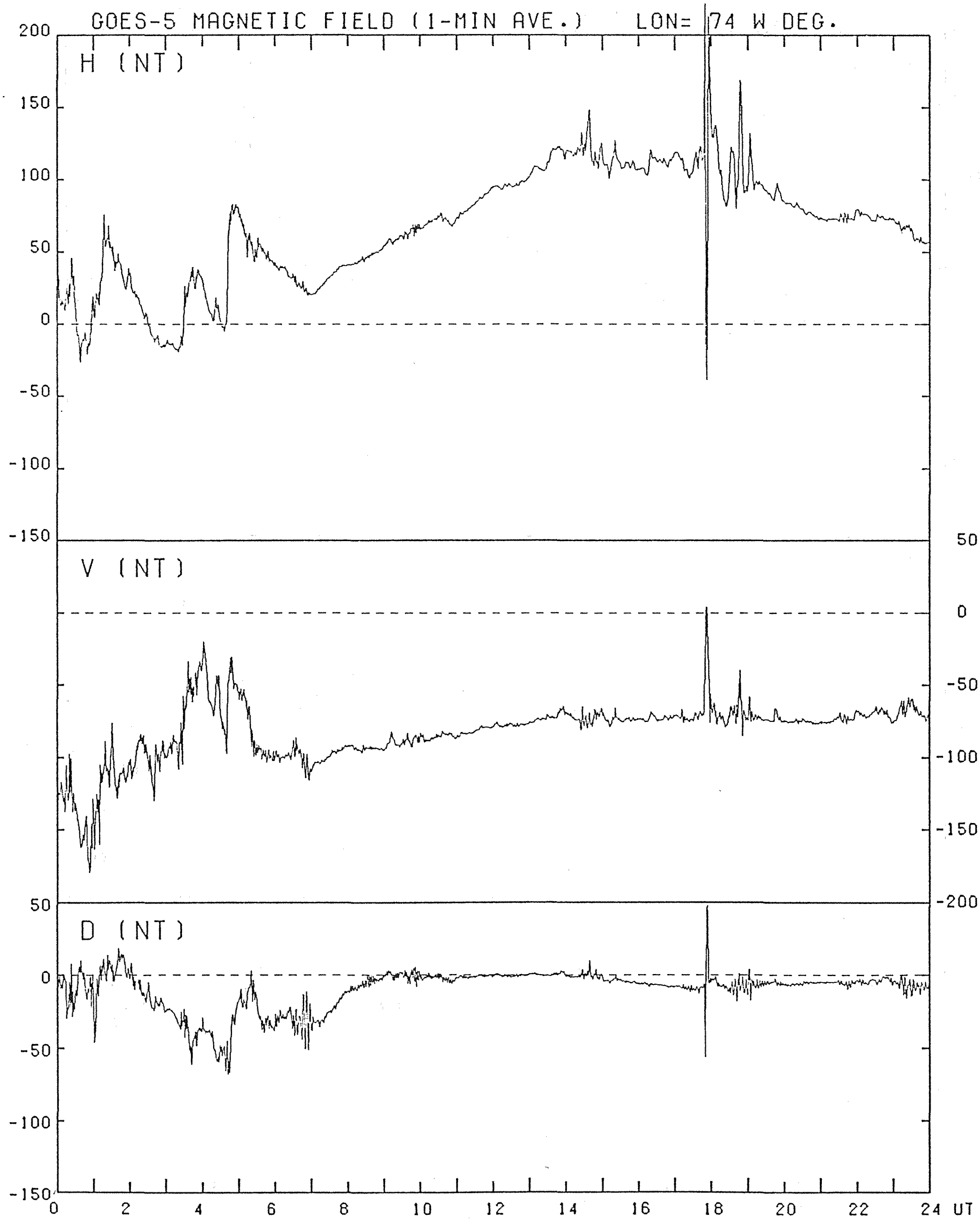

Fig. 6b Geomagnetic field at GOES 5 on 9 February 1986.

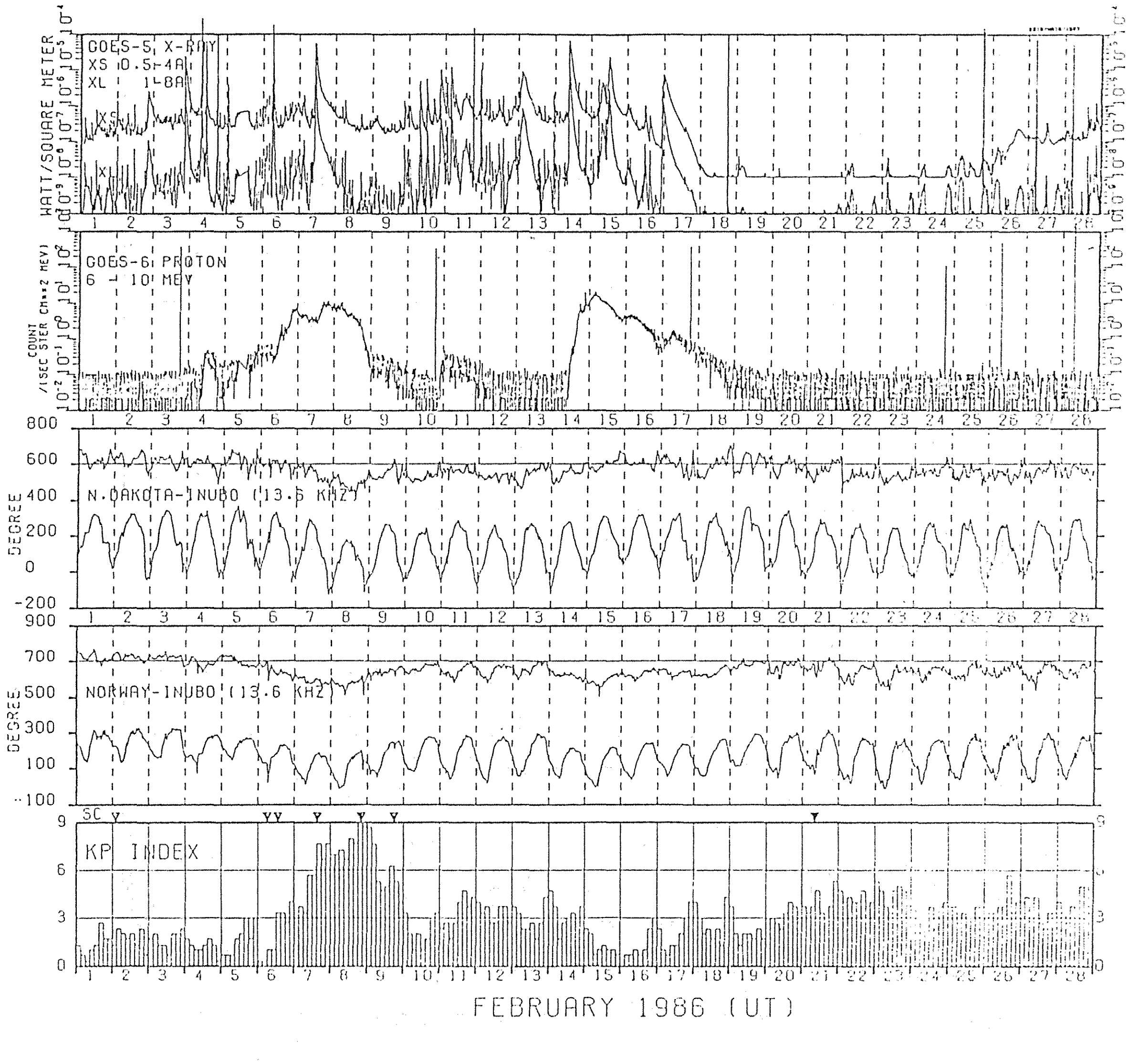

Fig. 7. A synoptic chart showing solar X–ray (GOES–5), proton (GOES–6), propagation characteristics of Omega NORTH DAKOTA and NORWAY observed at INUBO, Japan (phase deviation from the monthly average and the diurnal phase variation) in February 1986 (STE Data Book, 1988).

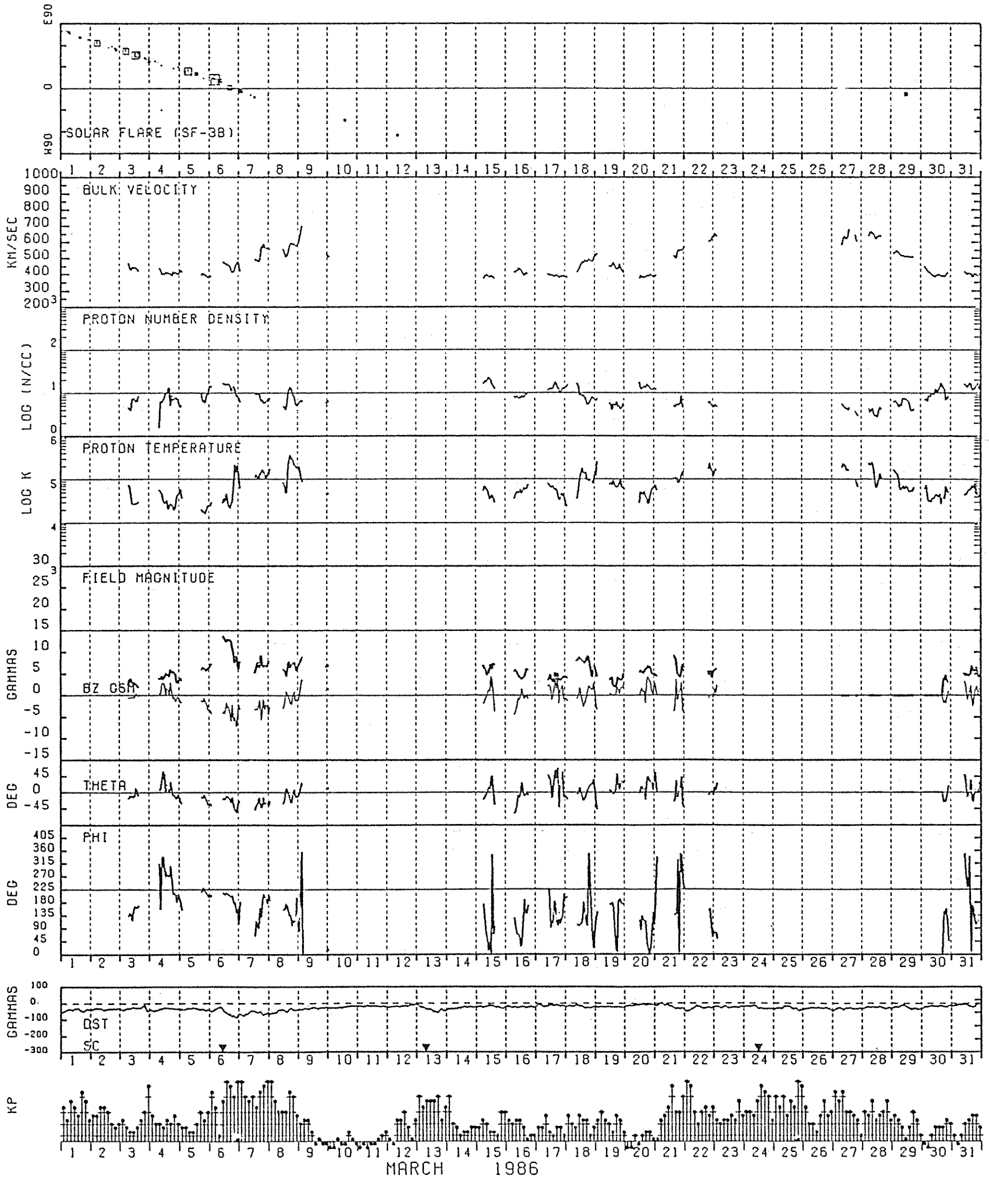

Fig. 8. A synoptic chart for solar-terrestrial events in March 1986. The format is the same as that in Figure 1.