Memoirs of the Kakioka Magnetic Observatory Vol. 24, No.1 1990

CHARACTERISTICS OF GEOMAGNETIC VARIATIONS ASSOCIATED WITH LOW LATITUDE AURORAS

Satoru TSUNOMURA, Tetsuya UWAI,
Yuji YAMADA, Kazumi HASEGAWA,
Fumio FUKUI, Shuichi TOYODOME and Masayuki KUWASHIMA

(Received October 11, 1990 ; Revised November 14, 1990)

Abstract

Characteristics of geomagnetic variations associated with low latitude auroras observed in the northern part of Japan at the times of large geomagnetic storms are examined on the basis of geomagnetic records in low latitude. There appeared two types of geomagnetic disturbances observed simultaneously with the auroral intensifications in the main phase of the storm. The first type is bay disturbance and the second, showing increases of H component in the wide longitudinal range simultaneously, may be attributed to the magnetospheric compression. The first type is same as the events analyzed by Tinsley et al. (1986) but the second is a newly found one. As an approach to clarify the mechanism for the first type, it is shown, using one second geomagnetic values, that the precipitation of low energy electrons would be generated when a Pi2 pulsation with short periods (less than ~40 seconds) occurs.

1. Introduction

There have been many researches about low latitude auroras observed at the times of large geomagnetic storms at various sites in low latitude. Spectroscopic features of low latitude auroras are basically different from those of high latitude auroras which are excited by keV electrons and it is thought that the source of low latitude auroras are different from those of stable auroral red (SAR) arcs (Tinsley et al., 1986). Tinsley et al. (1986) suggested that the primary source of vibrational excitation of the N_2^+ 1N (first negative) band of low latitude auroral emissions from equator to 40° dip latitude are due to the precipitations of the energetic neutral atoms. They also showed another contribution by low energy electrons to excite 630.0 nm [OI] emissions of aurora. Examining the magnetograms in high and low latitudes for low latitude auroral events, they pointed out that low latitude auroras are intensified when geomagnetic substorms occur at the main phases of large magnetic storms. As a possible mechanism to cause the enhancement of particle precipitations at very low latitudes associated with substorm occurrences, they proposed that the penetrations of substorm associated electric field driving the ions are not halted due to the lack of time for shielding current.

On October 21, 1989 and November 17, 1989, low latitude auroras were observed in Hokkaido, the northern part of Japan. From the positions of the auroras observed, it is deduced that the aurora on October 21, 1989 was located at about 45° to 50° geomagnetic latitude and at 150 to 500 km altitude for 630.0 nm [OI] emission (Kuwashima et al., 1990; Miyaoka et al., 1990). It is interesting to clarify the aurora associated geomagnetic variations observed in Japan on the basis of Tinsley et al's model. In this paper, we examine characteristics of geomagnetic variations associated with low latitude auroras in 1989 and those observed in the IGY period, using geomagnetic records of the observatories listed in Table 1.

Table 1 The dipole coordinates for the IGRF of 1985.0 at the magnetic observatories (after 'DATA CATALOGUE No.22' of World Data Center C2 for Geomagnetism).

Observatory	Geomagnetic		Altitude
	Latitude	Longitude	
Chichijima	17.8°	210.8°	154 m
Guam	4.6°	214.8°	150 m
Hermanus	-33.7°	82.7°	26 m
Honolulu	21.5°	268.6°	4 m
Kakioka	26.6°	207.8°	28 m
Kanoya	21.1°	199.9°	105 m
Memambetsu	34.6°	210.2°	39 m
San Juan	29.4°	5.2°	100 m

2. Geomagnetic variations associate with low latitude aurora

2.1 October 21, 1989 event

Fig.1, shows the plots of geomagnetic one minute values at Memambetsu, Kakioka and Kanoya on October 20 and 21, 1989. Shaded parts correspond to the appearances of the aurora observed at Moshiri in Hokkaido. Miyaoka et al. (1990) showed the photometer records of 557.7 and 630.0 nm wave lengths for the first one indicating the intensification of the aurora to the visible strength associated with the positive bay. The distinctive geomagnetic variations (shaded parts) may be related with the intensifications of the aurora. Variations of horizontal (H) component were positive for both, while those of declination (D) component were opposite each other. The forms and senses of variations are same as those of bay disturbance (Hatakeyama, 1938) at this local time. It is seen that the latitudinal variations of the magnitudes are not large, that is, the variations may not be strongly localized phenomena. From these features, it is deduced that the variations are bay disturbances related with polar magnetic substorms (Akasofu, 1977; §7.2.4). The Pi2 pulsations detected at the beginnings of them (Kuwashima et al., 1990) may indicate the onsets of the substorms (Saito et al., 1976).

On the basis of optical observations and the particle data of DMSP satellite, Miyaoka et al. (1990) pointed out that low energy electrons (less than 300 eV) played a dominant role to excite the aurora, the major emission of which is 630.0 nm [OI] with the maximum brightness ~90kR (Miyaoka et al., private communication). Thus, the precipitations of low

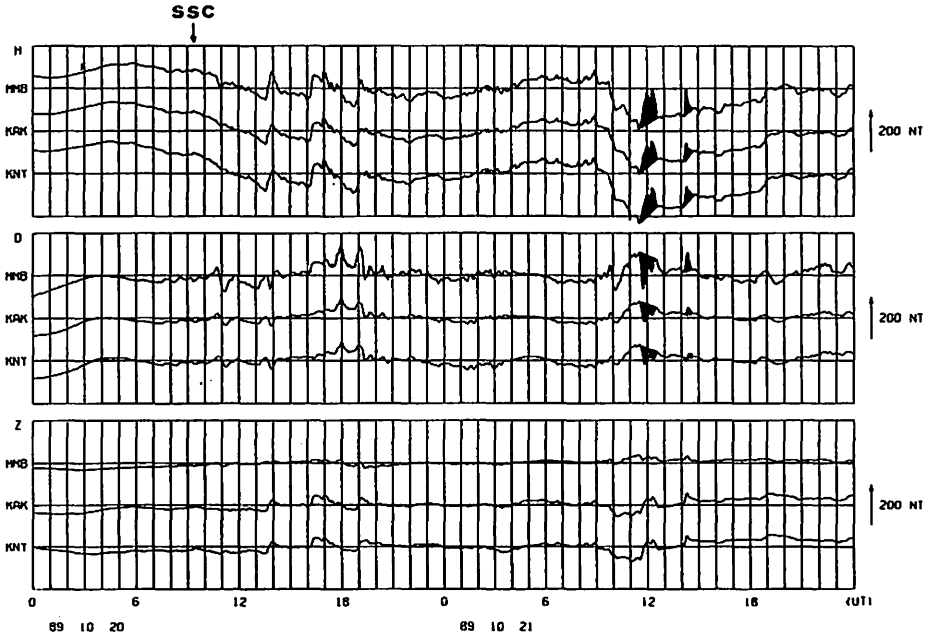

Figure 1 Geomagnetic variations at Memambetsu, kakioka and Kanoya on October 20 and 21, 1989. The arrows of H, D and Z components indicate geomagnetically northward, westward and vertically downward, respectively. Aurora were observed at the shaded periods.

energy electrons must be related with the bay disturbances.

As the first step, it is discussed that the auroral oval was shifted to lower latitude side than its usual position from the fact that the main period of a Pi2 pulsation observed at about 10 minutes after the onset of the bay disturbance was significantly shorter than those usually observed (Kuwashima et al., 1990). On the basis of DMSP particle data, Miyaoka et al. (1990) showed a model that the equatorward boundary of the auroral oval was near 50° geomagnetic latitude at this time. The equatorward shift of the auroral oval may be related with the geomagnetic condition (Stringer and Belon, 1967). In this case, the H component at Kakioka reached the minimum value at 1132 UT (the storm range was 307 nT) before the aurora was observed (1140 UT and 1430 UT).

The amplitude of the first bay disturbance was about 200 nT at Kakioka, that is, larger than the largest one tabulated in the series of 'REPORT OF THE GEOMAGNETIC AND GEOELECTRIC OBSERVATIONS (RAPID VARIATIONS)' (Okamoto and Fujita, 1987). The relationship between the largeness of the bay and the brightness of the aurora may be an interesting problem to be analyzed in future.

2.2 November 17, 1989 event

Geomagnetic variations at Memambetsu, Kakioka and Kanoya on November 17 and 18, 1989 are shown in Fig. 2. The shaded parts (from ~1640 UT to ~1700 UT) in the figure correspond to the appearance of the aurora detected by the observer's watchings (Hasegawa, 1990).

It can be seen that the aurora appearred in accordance with the geomagnetic disturbance. The sense of the variation suggests that the disturbance is a bay. The magnetic

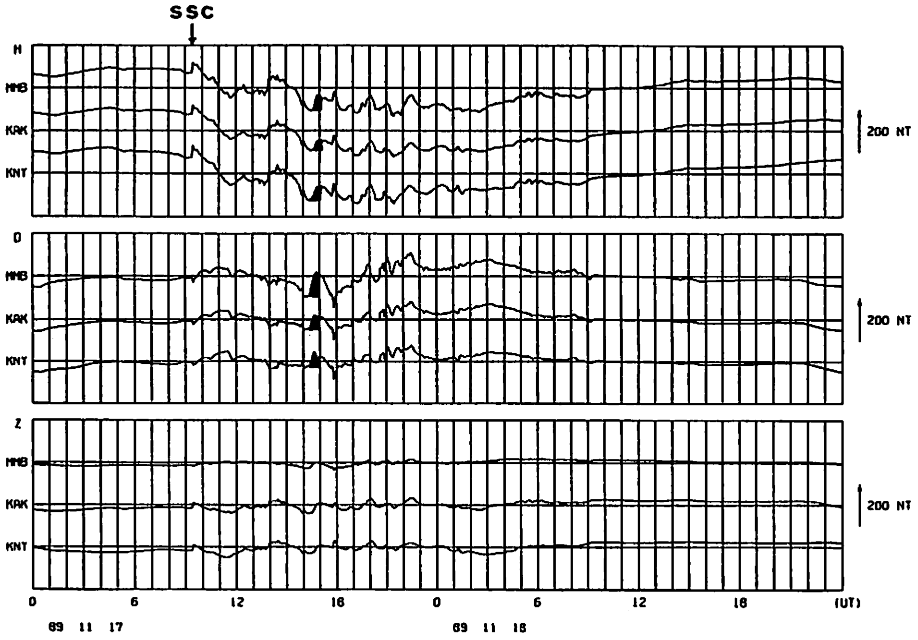

Figure 2 Same as Figure 1 on November 17 and 18, 1989.

storm developed (the H component at Kakioka decreased~200 nT from the night time quiet level) before the appearance of aurora. The geomagnetic condition at the appearance of the aurora was same as that of Oct. 21, 1989 event, that is, a bay disturbance occurred at the main phase of the magnetic storm which had already developed. In this case, the amplitude of the bay was not so large as that of Oct. 21, 1989 event (less than 100 nT in H component at Kakioka).

2.3 February. 18, 1958 event

Analogue records of variometers at Memambetsu, Kakioka and Kanoya on February 11, 1958 are shown in Fig. 3. In this case, the magnitude of storm was significantly larger (the H component at Kakioka reached the minimum value at about 11.3 UT and the storm range was 548 nT) than those of the previous events. The thick arrows roughly indicate the appearance of the aurora ('REPORT OF THE AURORAS OBSERVED AT MEMAMBETSU THROUGH 1958 AND 1960', 1969).

At Memambetsu, the aurora appearred near the northern horizon at about 0920 UT (1820 JST) and optical observations were started from the evening hours when there remained the influence of twilight. The aurora gradually decreased and faded out at about 1330 UT (2230 JST) due to the cloud (Nagamine, private communication), therefore, the aurora might have been excited for longer period than the reported one. The maximum intensity of 630.0 nm emission was 145 kR at the zenith distance 75° at the period from 0955 to 1030 UT (1855 to 1930 JST). On the basis of the model of Tinsley et al. (1986), the aurora was thought to be excited by low energy electrons because the emission rate of 630.0 nm [OI] was much larger than those of 427.8 nm or 391.4 nm of N_2^+ 1N band (about 100 times). From the pattern of development of auroral blackout, Nagai (1964) inferred that the auroral zone was shifted equatorward (near Kamchatka) at the main phase of the storm from its usual position.

It is reported that the auroral intensity increased at two intervals during the observation; the first was from 1030 to 1050 UT with the intensity up to2+ (the maximum value in this event) and the latter from 1210 to 1230 UT with the intensity nearly 2 ('REPORT OF THE AURORAS OBSERVED AT MEMAMBETSU THROUGH 1958 AND 1960', 1969). Additionally, before the first intensification of the aurora, there might have occurred a brief one from about 0950to 1000 UT recognized by the watchings (Nagamine, private communication) . The geomagnetic variations corresponding to these intensity variations of the aurora were shown by the shaded parts in Fig. 3. Amplitudes of them are all not so large as that of the bay disturbances observed at Oct. 21, 1989.

Corresponding variations at low latitude observatories in other local times are shown in Fig. 4. The variation was not so clear at Honolulu (premidnight) and were in the oposite sense (decrease of H component) at Hermanus (late morning) and San Juan (early morning) for the two events from 0940 to 1100 UT. From the local time dependence of the sense, it is deduced that they were a series of bay disturbances. Geomagnetic condition being quite disturbed, it is difficult to find out the corresponding negativebays in high latitudes.

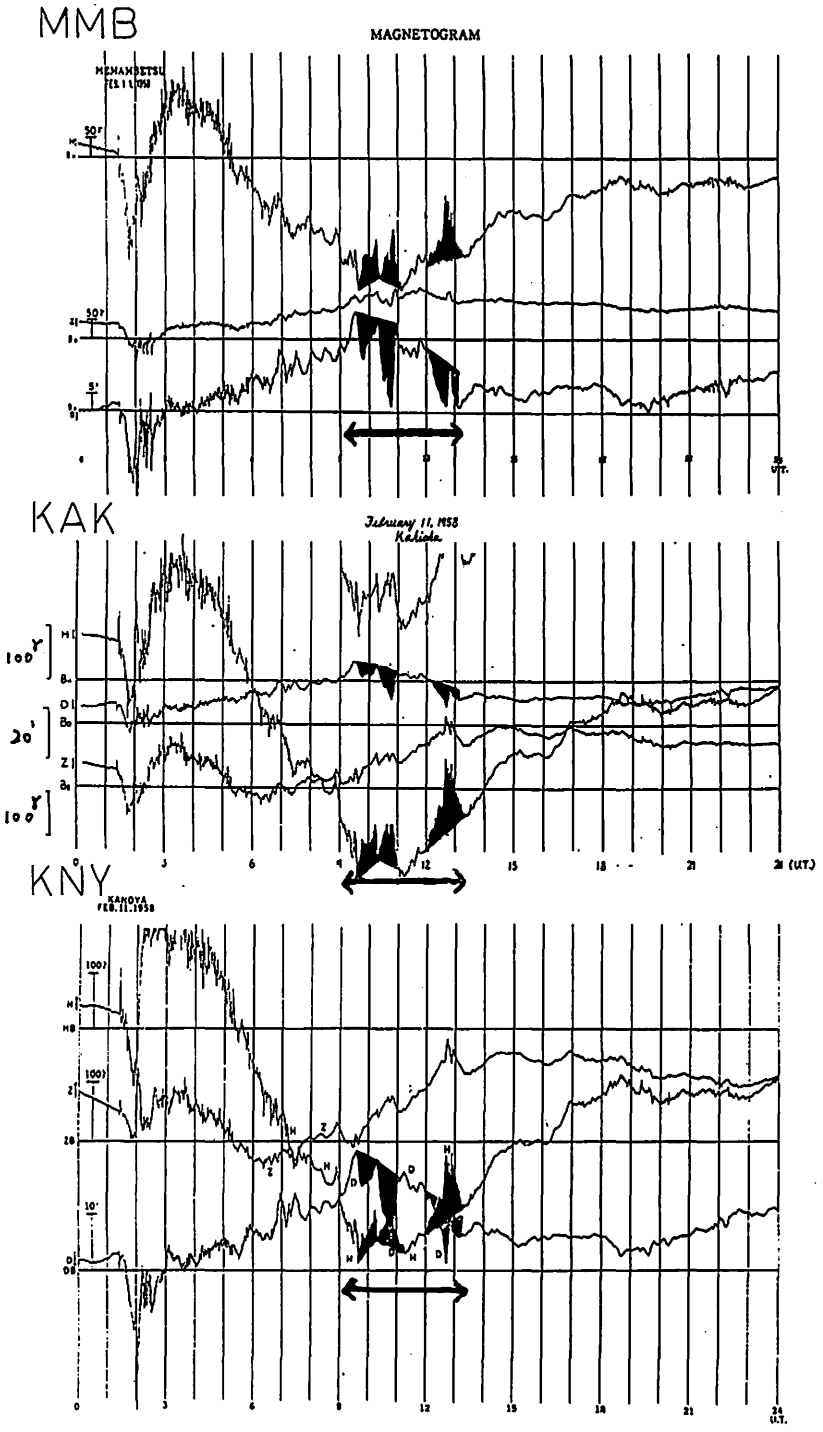

Figure 3 Same as Figure 1 on February 11, 1958. The arrows of D component point geomagnetic eastward. The thick arrow denotes the times when the aurora was observed. At shaded periods, the brightness or the structure of aurora varied.

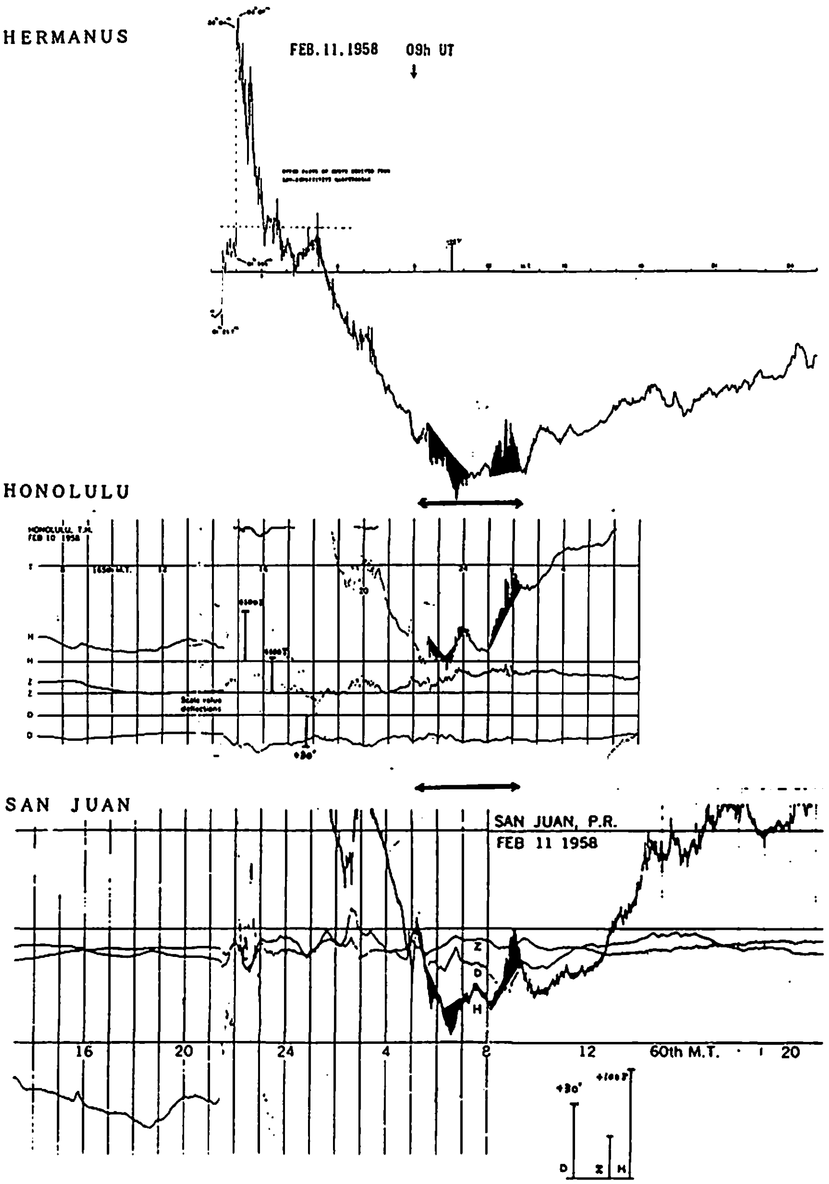

Figure 4 Geomagnetic records of February 11, 1958 storm at Hermanus, Honolulu and San Juan. The upward directions in the figure are same as Figure 3 for H and Z components, but for D, geomagnetically eastward for Honolulu and westward for San Juan, respectively. The meanings of the thick arrow and shaded parts are same as Figure 3.

From Figs. 3 and 4, it can be seen that H component increased gradually from 1200 to 1230 UT with the following sharp pulsive variations at about 1230 UT of similar amplitude (~100nT) at all the Dst stations. Though the variation forms were similar to that of bay disturbance, these variations may be explained by a global geomagnetic process such as the magnetospheric compression, because the variation forms and senses are similar at the wide longitudinal range in low latitude. This variation may be distinguished from aurora associated bay disturbances discussed so far and is mentioned for the first time in this paper. Hereafter, we call this 'the second type' for simplicity. It is noted that the aurora was intensified at the beginning of the shaded parts (1210to 1230 UT), that is, the sharp increases of H component at near 1230 UT occurred with a time lag of nearly 20 minutes from the start of auroral intensification.

2.4 November 13, 1960 event

Analogue records at Memambetsu, Kanoya and Guam (near Japanese meridian) for November 13, 1960 storm are shown in Fig. 5. In this case, the geomagnetic storm was also severer (the H component at Kakioka reached the minimum at near 07.2 UT and the storm

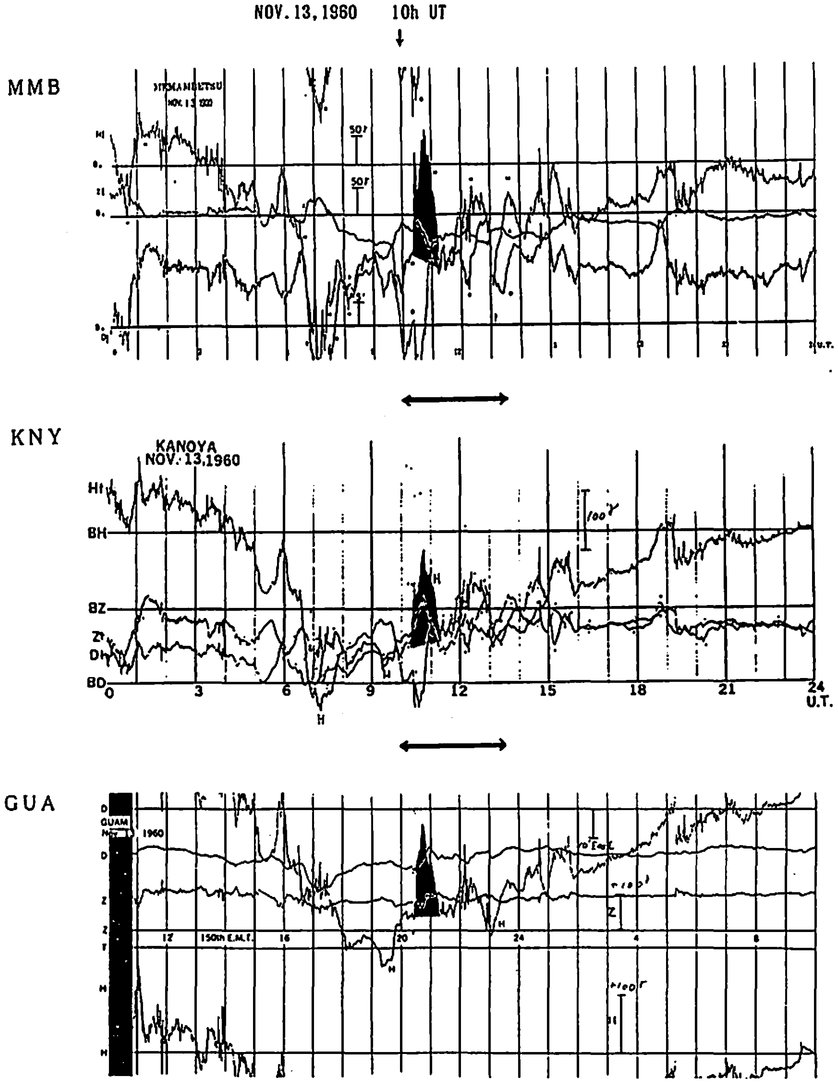

Figure 5 Geomagnetic records of November 13, 1960 storm at Memambetsu, Kanoya and Guam. The upward direction for three components and the meanings of the thick arrow and shaded parts are same as Figure 3.

range was 417 nT) than the events in 1989. The second brightest aurora at Memambetsu in the IGY period was observed at this storm but its intensity was one tenth of that on Feb. 11, 1958 in 630.0nm emission and the ratio of 630.0 nm to 391.4 nm emission is much larger than unity. The optical observation was started at 0945 UT (1845 JST) and stopped at 1400 UT (2300 JST) by bad weather ('REPORT OF THE AURORAS OBSERVED AT MEMAMBETSU THROUGH 1958 AND 1960', 1969). The aurora was intensified from 1024 to 1026 UT (1924 to 1926JST) at Memambetsu, when H component increased impulsively at all the stations. As can be seen from Fig. 6, similar variations are observed at Hermanus (late morning) and at Honolulu (midnight). It is the same as the second type seen in Feb. 11, 1958 event that the increases of H component were simultaneously observed in the wide longitudinal range and was possibly due to the magnetospheric compression. In this case, the intensity of the aurora and the H component increased almost simultaneously.

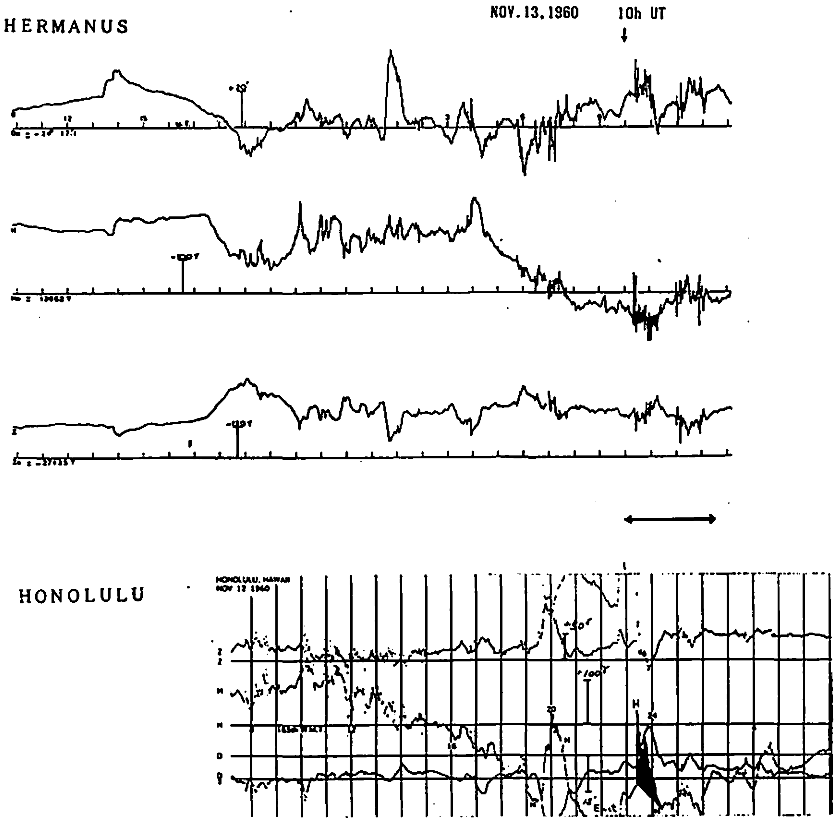

Figure 6 Same as Figure 5 at Hermanus and Honolulu.

3. Discussion

As mentioned in the previous section, there appearred two characteristics of the geomagnetic variations associated with low latitude auroras when the magnetic storm had significantly developed already. One is the bay disturbance and the other is the increases of H component in a wide longitudinal range in low latitude (the second type). There seems less relationships between the maximum brightness of the aurora and the range of magnetic storm. On the other hand, the amplitude of the auroral associated bay disturbance may correlate to the brightness of aurora somewhat; the larger bay disturbance (Oct. 21, 1989 event) accompanied the brighter aurora than the smaller one (Nov. 17, 1989 event). However, the amplitude of the bay disturbance may not be the unique parameter related to the brightness of the aurora because there was a case of the brighter aurora (Feb. 11, 1958 event) with smaller amplitude of the bay disturbance. In any case, the development of the magnetic storm may give the basic situation for low latitude aurora event through such as the equatorward shift of the auroral oval.

It is interresting that the aurora was not intensified associated with Pi2 pulsation occurred at the beginning of the bay disturbance at 1125 UT on Oct. 21, 1989 (Kuwashima et al., 1990). The dominant period of the Pi2 pulsation was longer (~100 seconds) than that associated with the brightening of aurora (~40 seconds). The period of Pi2 pulsation was possibly related to the latitudinal position of the auroral break up; the higher the latitude of auroral break up the longer the dominant period of Pi2 which is simultaneously observed from high to low latitudes (Kuwashima and Saito, 1981). The fact that the aurora did not appear at the time of the former Pi2 may be a useful information for the investigation of the relationships between the aurora and the bay disturbance.

In Fig. 7, time derivatives of geomagnetic one second values at Memambetsu, Kakioka and Chichijima from 1600 to 1659 UT on Nov. 17, 1989 are shown. There can be seen two Pi2 pulsations at about 1625 UT and 1638 UT. The aurora, being recognized at about 1641 UT at Memambetsu, might be associated with the latter Pi2 with apparently shorter period. From the spectrum features of both Pi2's (Fig. 8 (a) and (b)), the dominant periods of them are about 90 seconds and about 60 seconds, respectively. The latter Pi2 shows another peak around 18 seconds. Meanwhile, no other distinctive peaks are found for the first Pi2. It is possibly inferred that the former peak of the second Pi2 reveals the information of the position of the auroral oval and that the latter is related to the appearance of the low latitude aurora.

The fact that the Pi2 pulsations associated with the auroral intensifications at the events on Oct. 21, 1989 and Nov. 17, 1989 include short period components may be important for discussing the mechanism of the precipitation of low energy electrons. The acceleration of electrons which excite the aurora might be generated when the short period Pi2 occurred. Tinsley et al.'s (1986) model to explain the generation of the precipitations of neutral atoms may give a hint for obtaining the mechanism. In this paper, however, it is difficult to make a further discussion on this mechanism, with the data used here.

As to the mechanism of accelerating low energy electrons with respect to the global H

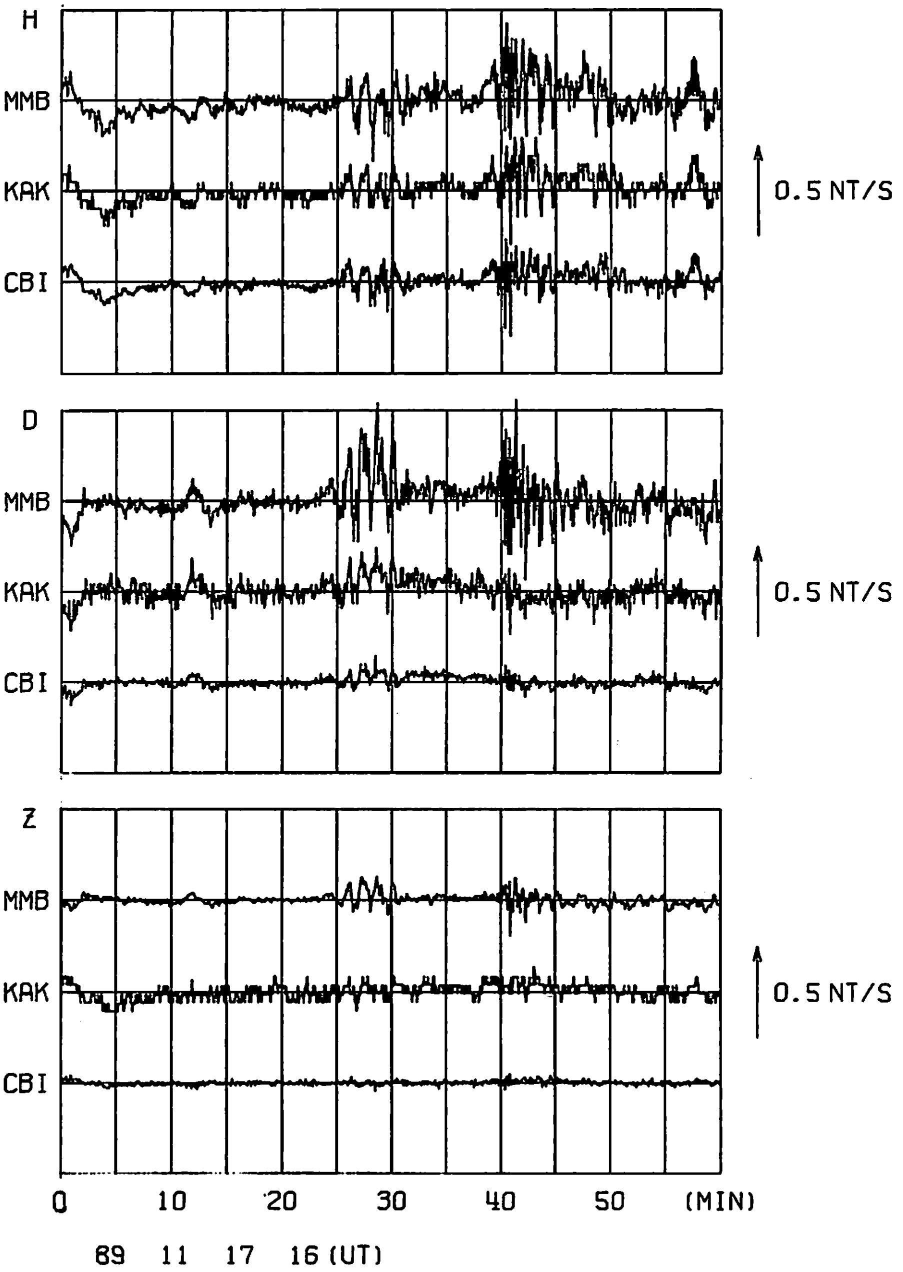

Figure 7 Time derivatives of one second values at Memambetsu, Kakioka and Chichijima at 1600-1659 UT on November 17, 1989. Directions of arrows are same as Figure 1 for all components.

component increase, it should be known at first exactly what the variation is. Though it seems to be due to the magnetospheric compression, there may be a possibility that it is caused by other mechanisms. If it is attributed to the magnetospheric compression, the westward electric field accompanied on the front of the fast mode magnetosonic wave causing inward motions of the electrons (Tamao, 1974) or the trangent process such as the

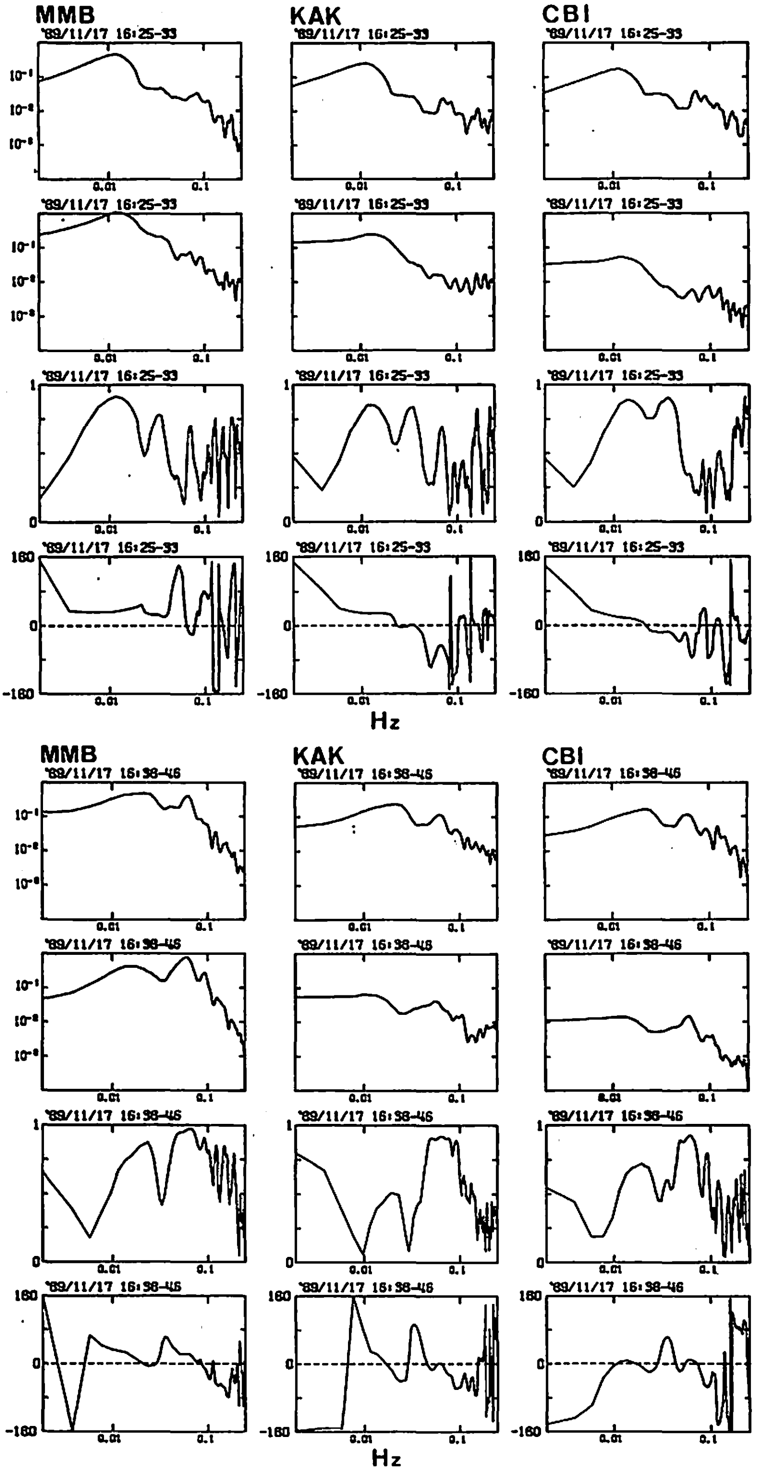

Figure 8 Auto-power Spectra of time derivatives of H and D components (in unit of $nT^2 \cdot sec^{-2}/Hz$), coherence and phase between H and D components at Memambetsu, Kakioka and Chichijima at the periods; (a) 1625-1633 UT and (b) 1638-1646 UT, on November 17, 1989. The former corresponds to the Pi2 pulsation occurred before the brightning of aurora and the latter does the auroral associated Pi2 pulsation. Abscissas are in unit of Hz for all blocks.

pitch angle scatterings may play important roles. The intensification of the aurora of Nov. 13, 1960 event may be due to this process. It is thought that the time lag of the second type with respect to the intensification of aurora and the long duration (~20 minutes) of the third auroral intensification on Feb. 11, 1958 are difficult problems to be explained by the magnetospheric compression process. New observational findings or theoretical progress are necessary before the discussion of the process of this event.

Acknowledgement

The authors wish to express appreciations to Dr. Miyaoka of National Institute of Polar Research for useful discussions. They also thank Mr. Nagamine for the useful informations about the aurora on Feb. 11, 1958.

References

Akasofu, S.-I., Physics of magnetospheric substorms, Astrophysics and space science library, D. Reidel Pub. Co., 1977.

Hasegawa, K., The aurora observed at Memambetsu in Hokkaido, Kisyo, 34-2, pp 4-8, 1990 (in Japanese).

Hatakeyama, H., On the bay-disturbance in the terrestrial magnetic field, Geophys. Mag. Cent. Meteorol. Obs. Japan, 12, pp 15-66, 1938.

Kuwashima, M. and T. Saito, Spectral characteristics of magnetic Pi2 pulsations in the auroral region and lower latitudes, J. Geophys. Res., 86, pp 4686-4696, 1981.

Kuwashima, M., S.Tsunomura, T. Uwai, B. Saito, T.Takahashi and Y. Kiyama, Low latitude aurorae on October 21, 1989. Ⅱ , Proc. Japan Acad., 66, Ser. B-3, pp 52-57, 1990.

Miyaoka, H., T. Hirasawa, K.Yumoto, and Y.Tanaka, Low latitude aurorae on October 21, 1989. Ⅰ , Proc. Japan Acad., 66, Ser. B-3, pp 47-51, 1990.

Nagai, M., On the geomagnetic storm on February 11, 1958, Mem. Kakioka Mag. Obs., 11-2, pp 39-53, 1964.

Okamoto, A. and S. Fujita, Statistics on the geomagnetic phenomena observed at Kakioka, Mem. Kakioka Mag. Obs., 22-1, pp 21-42, 1987.

REPORT OF THE AURORAS OBSERVED AT MEMAMBETSU THROUGH 1958 AND 1960, in REPORT OF THE GEOMAGNETIC AND GEOELECTRIC OBSERVATIONS 1967 (RAPID VARIATIONS), pp107-130, published by Kakioka Magnetic Observatory, 1969.

Saito, T., T.Sakurai and Y. Koyama, Mechanism of association between Pi2 pulsation and magnetospheric substorm, J. Atmos. Terr. Phys., 38, pp 1265-1277, 1976.

Stringer, W. J. and A. E. Belon, The statistical auroral zone during IQSY and its relationship to magnetic activity, J. Geophys. Res., 72, pp 245-250, 1967.

Tamao, T., Unified picture for transient twin vortices of equivalent ionospheric currents in high latitudes, Rep. Ionos. Space Res. Japan, 28, pp 119-123, 1974.

Tinsley, B. A., R. Rohrbaugh, H. Rassoul, Y. Sahai, N. R. Teixeira and D. Slater, Low-latitude aurorae and storm time current systems, J. Geophys. Res., 91, pp 11257-11269, 1986.

低緯度オーロラに関連する地磁気変化の特性

角村　悟・上井哲也・山田雄二・長谷川一美

福井史雄・豊留修一・桑島正幸

概　　要

日本北部で，大きな磁気嵐の際に観測された低緯度オーロラに関連する地磁気変化の特性が，低緯度での地磁気データを元に調べられた．磁気嵐の主相中で，オーロラの強まりに同期して，２種類の型の地磁気変化が観測された．第一種は湾形変化であり，第二種は，広い経度範囲で同時にＨ成分の増加が見られることから，磁気圏の圧縮によるものらしいと考えられる．第一種はTinsley 他(1986)の解析例と同様であるが，第二種は今回新しく見出されたものである．第一種の機構を明らかにするための取り組みとして，地磁気毎秒値を活用して，短周期（約40秒以下）のPi2脈動が発生する際に低エネルギー電子の降下が引き起こされるであろうことを示した．