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IONOSPHERIC DISTURBANCE FEATURES IN IONOGRAMS ASSOCIATED WITH LOW-LATITUDE AURORAE

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Abstract: Ionospheric disturbance features in ionograms during low-latitude aurorae was studied for two auroral events on 21 October and 17 November, 1989. Large scale periodic traveling ionospheric disturbances were observed by Japanese ionosonde chain with three remarkable wave fronts during the aurora on 21 October 1989. The growing phase of the waves was found from the variations in *h′F* values. This TIDs was estimated to originate from approximately 55–60 degrees in geographic latitude to the northwards of Japan. An increase of *foF2* values due to an equatorial anomaly appeared from Okinawa to Akita for the magnetic storms on 21 October 1989. Concerning the spread-*F* phenomena it was peculiar that the ionospheric scintillations were rather weaker at northern station than southern station for both cases of ionospheric disturbance associated with auroral substorms on 21 October and 17 November, 1989.

1. Introduction

Low-latitude aurorae have not been observed in Japan for 31 years since February 11, 1958 during the IGY period. During the maximum activity phase of solar cycle 22 the low-latitude aurorae were observed in northern Japan at the time of large magnetic storms on 21 October 1989, 17 November 1989 and 30 March 1990. Maximum *H*-component ranges of these three magnetic storms at Kakioka were 307 nT, 252 nT and 219 nT *H*-component respectively. These magnetic disturbances were not so severe than the auroral event on 11 February 1958 with the maximum range of 617 nT in *H*-component at Kakioka. An analysis of low-latitude auroral events during the last half century has been made by TINSLEY *et al.* (1986). Ionospheric disturbance effects like the traveling ionospheric disturbances (TIDs) following an onset of auroral disturbances have been studied intensively by HUNSUCKER (1982).

In this study we used the data from the CRL ionospheric observation networks including ionosondes, oblique sounding, HF Doppler measurements, TEC measurements by ETS-II and scintillation measurements by satellites (NNSS, CS, BS and ETS-II). However this paper focuses on the ionospheric disturbance in the ionogram during low-latitude aurorae. Ionosonde chain of CRL was very effective to detect the features of large scale periodic TIDs, northward expansion of the equatorial anomaly and latitudinal dependence of spread *F* echoes.

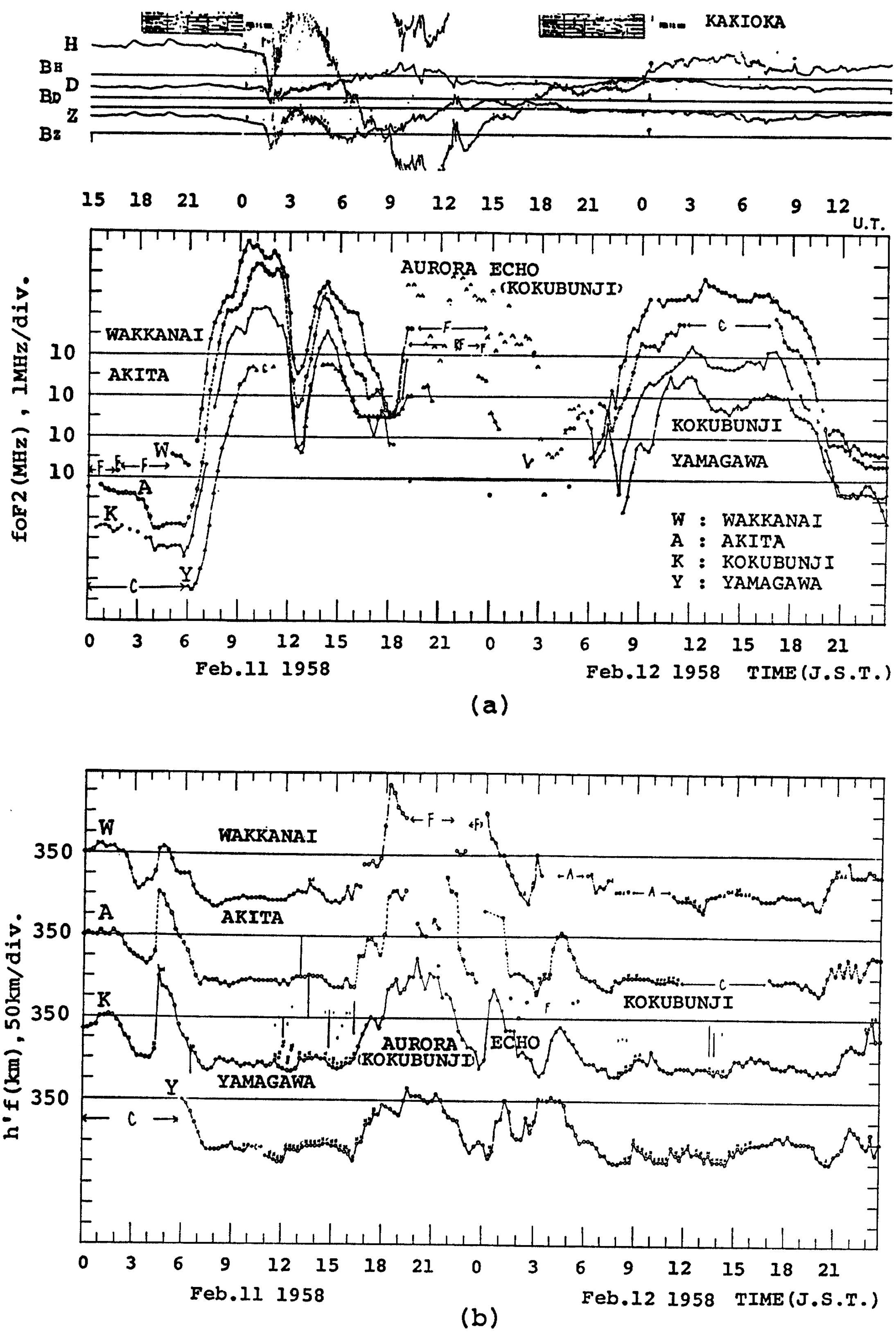

Fig. 1. *Variations of (a) the critical frequency foF2 and (b) the virtual height h′F of the ionospheric F-region during the large magnetic storm of 11–12 February 1958, when low-latitude aurorae were observed in Japan.*

2. Ionospheric Disturbance Features during the Historical Low-latitude Aurora of February 11, 1958

Figure 1 shows the variations of critical frequency *foF2* and virtual height *h'F* during the historical low-latitude auroral event of February 11, 1958 in order to compare with ionospheric disturbance features during the auroral events of 21 October and 17 November, 1989. A severe magnetic disturbance of 617 nT in the *H*-component range followed the SSC at 0126 UT of February 11, 1958. On the other hand the SSC took place in the evening for both cases of auroral event on 21 October and 17 November, 1989. A short-interval depletion of *foF2* occurred about 0300 UT, associating with the onset of a very large impulsive increase in *H*-component (NAKATA, 1958). A bright aurora was observed twice during 1030–1050 UT and 1210–1230 UT (HURUHATA, 1958). The first aurora occurred after the increase in the *foF2* value around 0900 UT. During these auroral events the ionogram showed a spread *F* echo. A scattering echo appeared in the ionogram at Kokubunji station. This type of echo is called an auroral echo and also appeared during the auroral events of October 21 and November 17, 1989.

3. Results and Discussion

3.1. Latitudinal dependence of critical frequency foF2 during the auroral substorms on 21 October 1989

Figure 2 shows the variations of *foF2* at 5 observatories from Wakkanai to Okinawa. After the SSC of 0917 UT on 20 October 1989, the *foF2* values at Yamagawa and Okinawa increased about 5 MHz. Furthermore, the increase of critical frequency appeared at Akita, Kokubunji, Yamagawa and Okinawa stations, following the onset of a marked *H*-decrease at 0900 UT on 21 October 1989. These phenomena are due to an equatorial anomaly. The latitudinal dependence of *foF2* variations are shown in Fig. 3. At 1000 UT the *foF2* value of Magadan was about 4 MHz. During the recovery phase of this magnetic storm the ionograms at Magadan indicated a black-out phenomenon due to a severe absorption. The first aurora was observed at several places of northern Hokkaido from 1140 to 1200 UT during the development of the equatorial anomaly. The peak of equatorial anomaly at southern stations appeared at approximately 1200 UT as shown in Fig. 2. At 1400 UT before the onset of the second aurora the *foF2* values decreased at all stations. A spread-*F* echo in ionogram was not severe at Wakkanai station during the aurora on 21 October 1989. Furthermore, from the observation results of ionospheric scintillations appeared in the beacon waves from NNSS satellite received at Kokubunji the scintillation intensity was weak at northern Japan during the auroral phenomena on 21 October 1989.

It seems that the generation of irregularities in the ionosphere was suppressed during the auroral event. But the generation mechanism of scintillations at low-latitude has not been understood clearly yet. So further study is necessary in order to explain the irregularities at low-latitude.

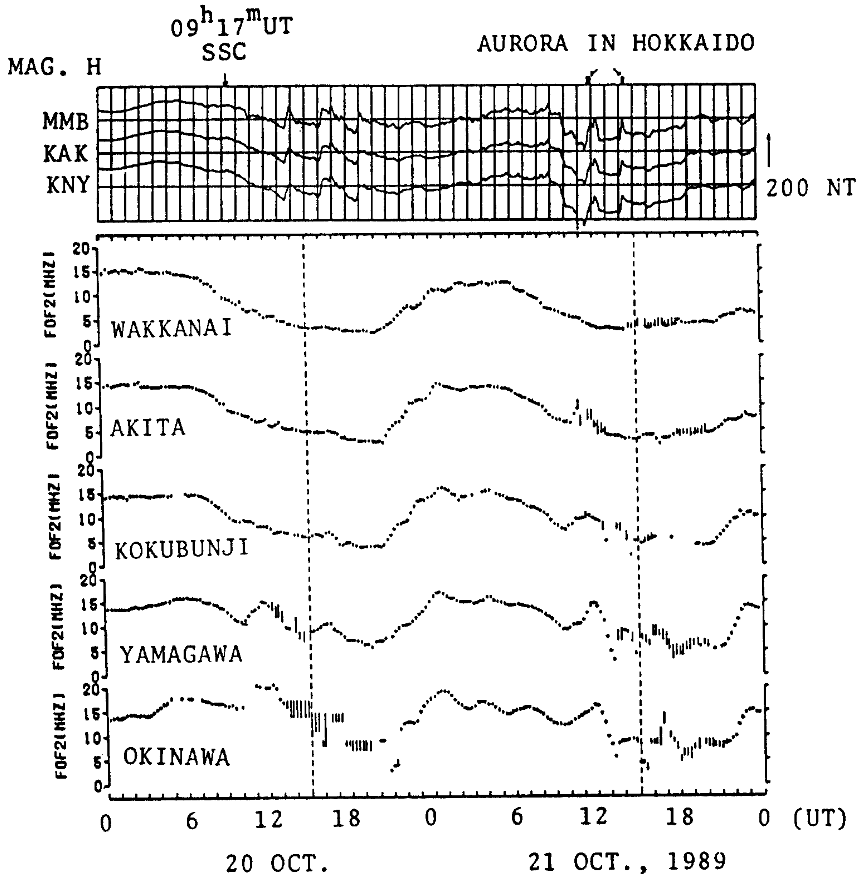

Fig. 2. Variations in the critical frequency foF2 of the F-region on 20–21 October 1989.

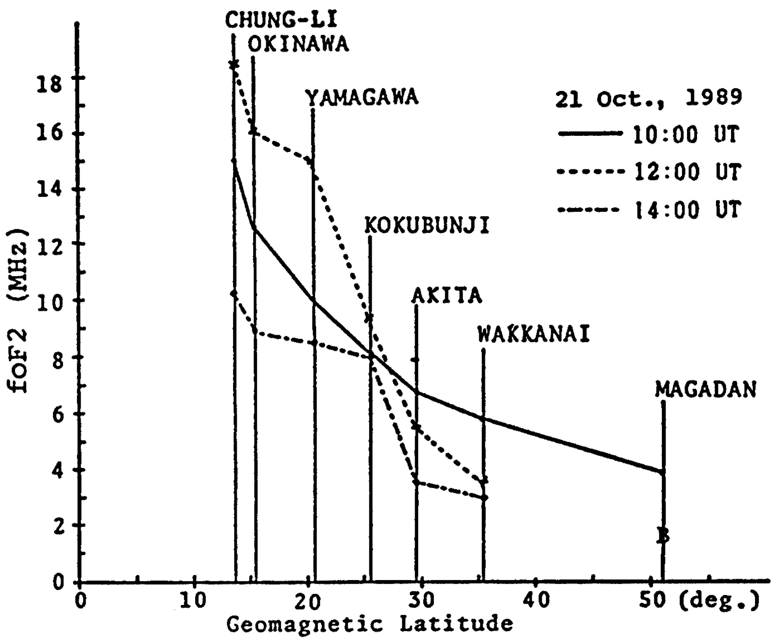

Fig. 3. Latitudinal dependence in the critical frequency foF2 at Magadan, Wakkanai, Akita, Kokubunji, Yamagawa, Okinawa and Chung-li with time. The letter B at Magadan denotes black-out phenomena in ionogram due to severe absorption.

3.2. *Large-scale traveling ionospheric disturbances during the auroral substorms on 21 October 1989*

During the auroral event on 21 October 1989 very remarkable periodic variations in *h'F* appeared as shown in Fig. 4, following the onset of auroral substorms at approximately 1140 UT (THOME, 1968). This is a typical large-scale traveling iono-

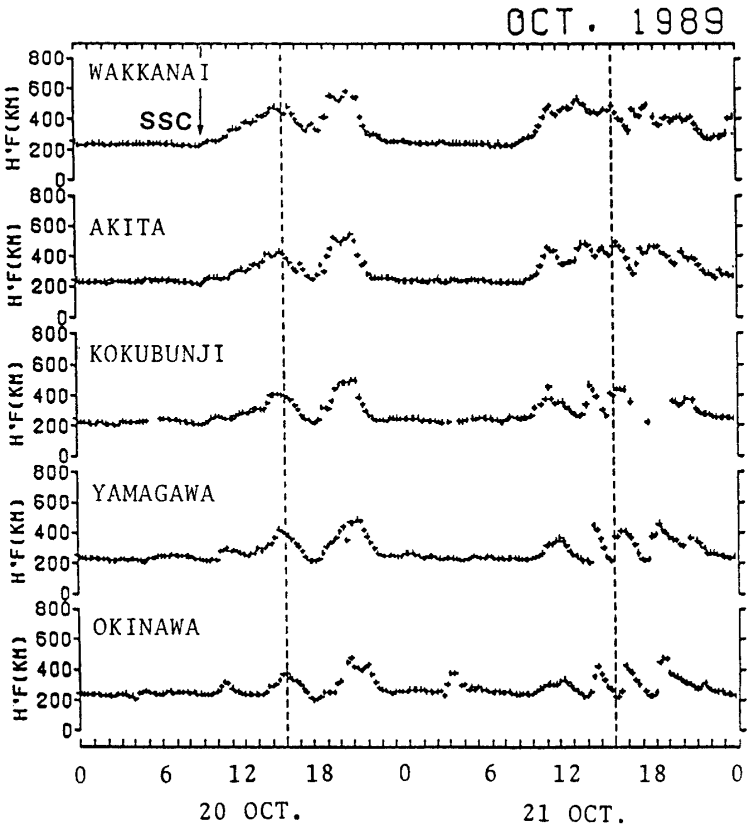

Fig. 4. Variations in the virtual height h'F at Japanese observatories on 20–21 October 1989.

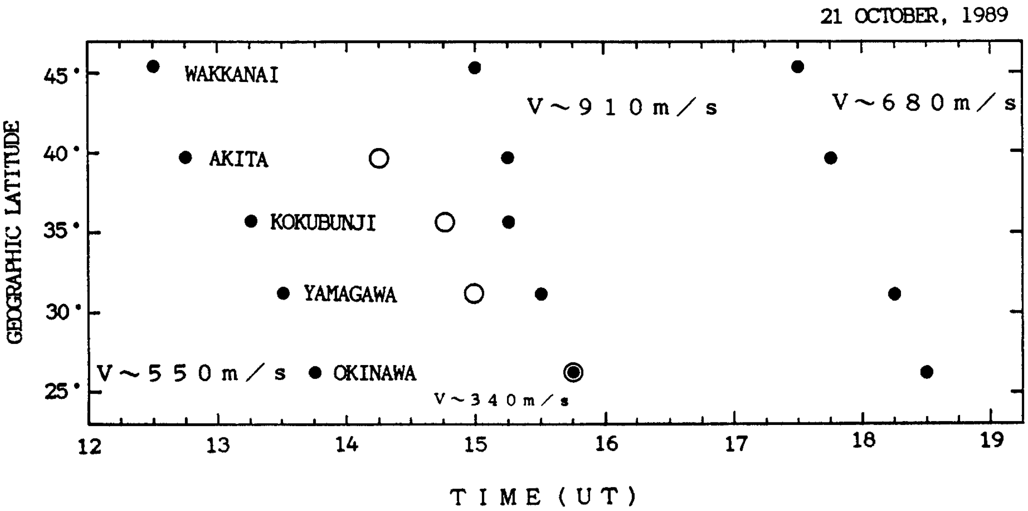

Fig. 5. Latitudinal locations with time and the estimated velocities of the wave fronts of TIDs.

spheric disturbances (LS TIDs). Three peaks of wave front were manifested in the variations of *h'F* at Okinawa station. The period of the waves was from 120 to 150 minutes. The periodic structure was not clear at Wakkanai station but became pronounced for Kokubunji, Yamagawa and Okinawa stations; such a case was earlier reported by HAJKOWICZ and HUNSUCKER (1987). These phenomena seems to be due to a filtering effect in the ionosphere on acoustic gravity waves (AGWs).

Figure 5 shows the geographical positions of wave fronts as a function of time in order to derive the horizontal velocities of LS TIDs. Three wave fronts appeared at Okinawa station very clearly. The horizontal velocity of the waves was obtained from a linear regression approximation. The velocity of the first cycle was approximately 550 m/s. The second wave front was not clear for the subsequent stations of north. It looks like a mixed wave with fast velocity 910 m/s and slow velocity 340 m/s, respectively. The velocity of the third cycle was approximately 680 m/s.

The onset time of the first auroral emission was approximately 0940 UT on 21 October 1989. The auroral source positions of TIDs can be estimated approximately 55–60 degrees in geographic latitude, which was derived from the intersection of the

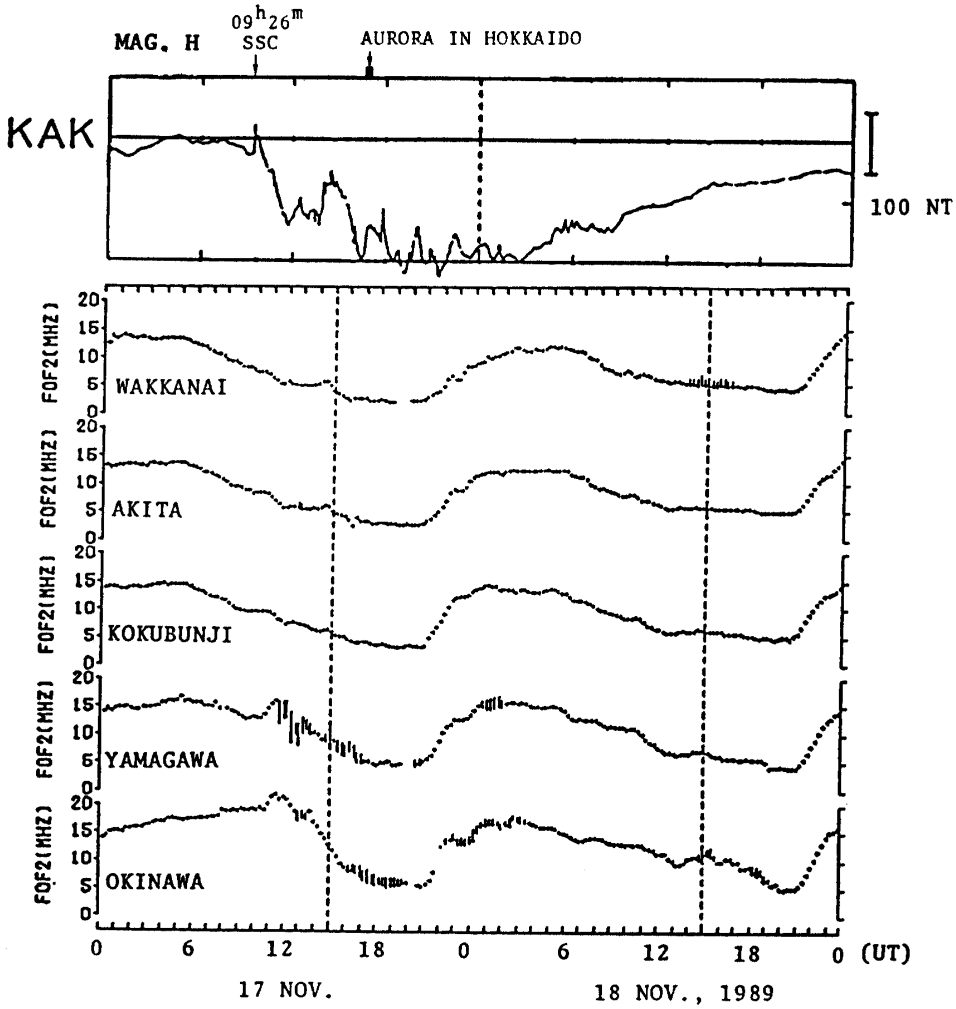

Fig. 6. Variations in the F-layer critical frequency foF2 on 17–18 November 1989.

auroral onset time and the linear regression line of the first wave fronts. The onset time of the second auroral breakup was approximately 1010 UT on 21 October 1989. The latitudinal positions of the auroral source of TIDs following this second aurora was also estimated approximately 55–60 degrees in geographic latitude. These results are consistent with the auroral imaging data observed by the EXOS-D satellite (E. KANEDA, 1990: private commun.).

3.3. Comparison of the ionospheric disturbance features for the auroral substorms on 21 October 1989 and 17 November 1989

The second auroral substorm was observed at Memambetsu Magnetic Observatory from 1640 to 1700 UT on 17 November 1989, following the SSC at 0926 UT on 17 November 1989. Figure 6 shows the variation of *foF2* during the auroral event on 17 November 1989. Following the SSC the *foF2* value increased at the both observatories of Yamagawa and Okinawa due to the quatorial anomaly. At these observatories the spread-*F* appeared during the auroral event and again in the daytime on the next day. But in the northern observatories the spread-*F* was not observed even during the auroral event. During the 21 October auroral event the spread-*F* was not observed clearly at Wakkanai observatory as shown in Fig. 2. The observation results of NNSS at Kokubunji showed that the scintillation observed at Wakkanai station was weaker than at the sourthern observatories.

The variations of the *F*-layer virtual height *h'F* is shown in Fig. 7. At 1615 UT the *h'F* increased suddenly to over 600 km at Wakkanai. The time of the first *h'F* peak

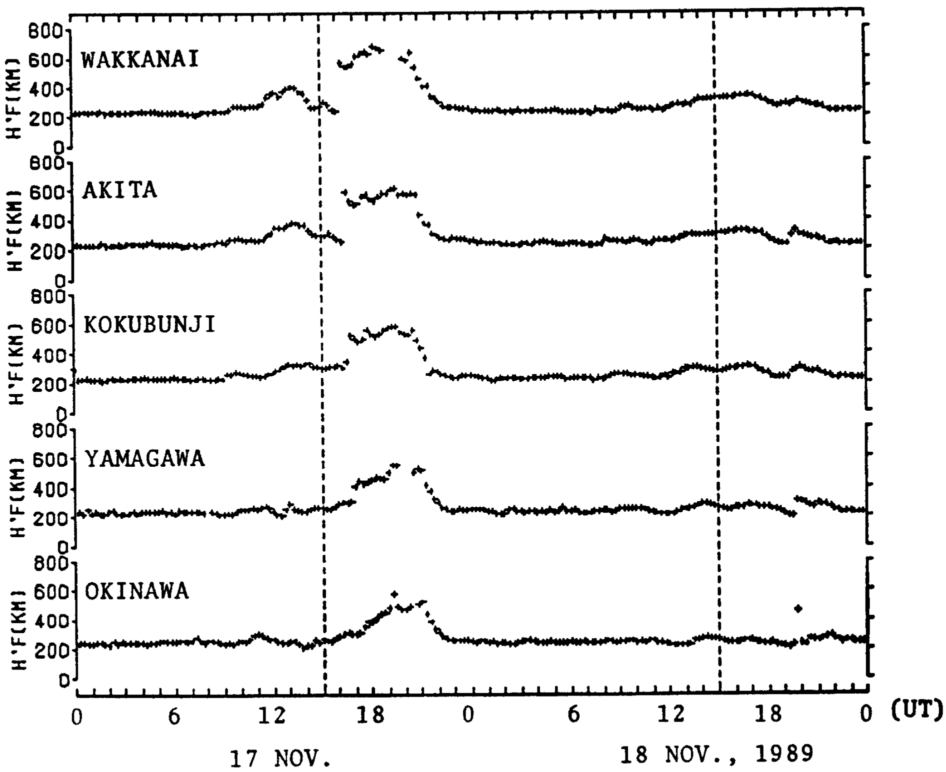

Fig. 7. Variations in the F-layer virtual height h'F on 17–18 November 1989.

was delayed for the southern stations. The estimated apparent velocity for the peak propagation is about 690 m/s. The periodic wave structure of the ionospheric disturbance was obscure, in contrast to the October auroral event.

4. Summary

Ionospheric disturbance features in the ionogram are presented for the two auroral events in 1989. The preliminary conclusions are as follows:

(1) Three peaks of periodic large-scale TIDs were observed clearly during the auroral event on 21 October 1989. The periodic variations in the virtual height of the *F*-region were remarkable in the southern observatory. These results show the growing process of the waves and the filtering effect in the *F*-region.

(2) The source positions of LS TIDs were estimated to be approximately at 55–60° in the geographic latitude, in the northward of Japan, for the auroral substorms on 21 October 1989.

(3) The equatorial anomaly phenomena caused the increase of *foF2* values from Okinawa station to Akita station during the auroral event on 21 October 1989. On the other hand, in the auroral event on 17 November 1989 the enhancement of *foF2* value due to the equatorial anomaly appeared only up to Yamagawa station.

(4) Spread-*F* phenomena during the auroral events were not severe at Wakkanai station. We suppose that the generation of ionospheric irregularities was suppressed at northern stations rather than southern stations for the both cases of the auroral events on 21 October and 17 November, 1989. These results were also supported by the scintillation data measured with the NNSS receiver.

Further coordinated studies are desirable to understand the ionospheric response associated with these low-latitude aurorae.

Acknowledgments

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