

A Midday Bite-Out Event of the F_2 -Layer Observed by MU Radar

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An F -region midday bite-out event was observed in the height range between 150 km and 450 km by MU radar at Shigaraki (34.85°N, 136.10°E), Japan, around noon on November 12, 1985. Time variation of the height structure of the electron density showed that the event developed from high to low altitudes as if the whole F layer was pushed down. Spatial distribution of the event was examined using ionograms from five Japanese stations: Wakkanai (45.40°N, 141.69°E), Akita (39.73°N, 140.13°E), Kokubunji (35.71°N, 139.49°E), Yamagawa (33.20°N, 130.62°E) and Okinawa (26.28°N, 127.81°E). This event was detected at all stations except the northernmost station, Wakkanai, and most prominently at Kokubunji. It occurred slightly earlier at higher latitudes. These facts suggest that the event was caused by poleward neutral winds.

1. Introduction

The midday bite-out of the F_2 -layer at middle and low latitudes is an event in which electron density is anomalously depressed in the daytime. Such events have been studied mainly by using foF_2 data in the middle latitude region. They are thought to be caused by poleward neutral winds (KOHL and KING, 1967; KHAN *et al.*, 1985). On the other hand, HUANG and JENG (1978) stated that unusually depressed variations of foF_2 at Chung-li (18.6°N magnetic latitude) are associated with the Appleton anomaly when a forenoon bite-out is present. BHARATHI and JOGULU (1985) examined monthly averaged diurnal variations of the electron density at fixed heights above Waltair (20°N dip) by using ionograms, and found that the electron densities at altitudes above 200 km gradually decreased to reach a minimum around midday in some months. However, these studies used ionograms, and therefore the height structure above the F_2 -peak could not be known.

Recently the MU radar at Shigaraki (34.85°N, 136.10°E) in Japan has begun to provide data by means of incoherent scatter echoes from the ionosphere. This radar is a 46.5 MHz pulse-modulated monostatic Doppler radar with an active-phased array system, and the radiation power is 1 MW with maximum average power of 50 kW. The details of the MU radar system were given in FUKAO *et al.* (1985a, b) and

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measurement techniques were presented by SATO *et al.* (1989). By using this radar, we can get height profiles of the electron density, which are estimated from the strength of the echo, with a time resolution of 15 min. Therefore, we can study the variation of the electron density profile during the bite-out period. In this paper, we first give the daily variation of the profile on November 12, 1986 when a clear bite-out event was observed around noon. Next, we study the spatial structure of this event using ionograms from the Japanese observatory chain.

2. Measurement

The electron density profile was measured by MU radar on November 12, 1985. This measurement was made by using a pulse 448 microseconds in length modulated by a 7-bit Barker code. The height resolution was 9.0 km and the observed height range was from 150 to 400 km altitude. The observation period was from 09 h JST on November 12, to 07:30 JST on November 13, 1985 (JST=UT+9 h). We observed the altitude profile at every 4.8 km from 150 km to 450 km with a time resolution of 15 min. The ratio (Tr) of the temperature of the electrons to that of the ions is necessary in order to estimate the electron density from the intensity of the incoherent scatter echo from the ionosphere. In the present observation we estimated the absolute value of the electron density from the height profile of the echo strength by assuming constant Tr and by calibrating the maximum electron density obtained from the observation by the ionosonde at the radar site.

3. Results

Figure 1 gives the time variation of the observed electron density (N_e) profile. The thick dashed line represents the location of the $F2$ peak, and the dot-dashed and dot-dot-dashed lines show the sunrise and sunset at the height of the observation point and that of its conjugate point, respectively. The most significant feature is that there are two maxima in the peak electron density at 10:45 JST and 13:45 JST and a minimum at 12:15 JST. Another feature is the decrease of the $F2$ -peak altitude, accompanied by the increase of the electron density at post-sunset time. The former is the midday bite-out, and the latter is the post-sunset increase. We will focus on the former (midday bite-out) in the following. The electron density of both maxima of this bite-out is about $1 \times 10^6 \text{ cm}^{-3}$ and that of the minimum at 12:15 JST is $3 \times 10^5 \text{ cm}^{-3}$. Corresponding to the minimum, $foF2$ decreases by 3.2 MHz. The total electron content between 150 km and 450 km altitude decreases from $6.5 \times 10^{14} \text{ m}^{-2}$ at 10:30 JST to $4.6 \times 10^{14} \text{ m}^{-2}$ at 12:00 JST and then recovers to $6.2 \times 10^{14} \text{ m}^{-2}$ at 13:15 JST.

Figure 2 shows the altitude (solid line) where the electron density becomes the maximum and those (dashed lines) at which the electron density takes half of the peak value. Figure 3 gives the time variation of N_e at 200, 250, 300 and 400 km altitude and the maximum electron density (N_{max}) from 09 h to 15 h JST on November 12, 1985. These figures show that the bite-out event occurs slightly earlier

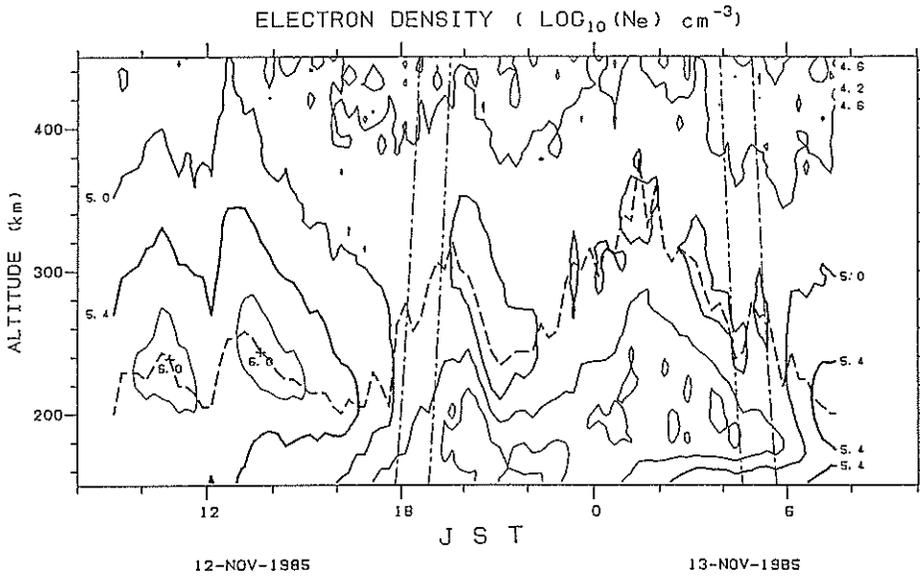


Fig. 1. Time variation of electron density (N_e) profile from 09:00 JST on November 12 to 07:30 JST on November 13, 1985. Contours are drawn at every 0.4 in $\log_{10} (N_e (\text{cm}^{-3}))$. Dashed line represents the altitude of the F2 peak, dot-dashed line the sunrise and sunset time, and dot-dot-dashed line the time of the conjugate point.

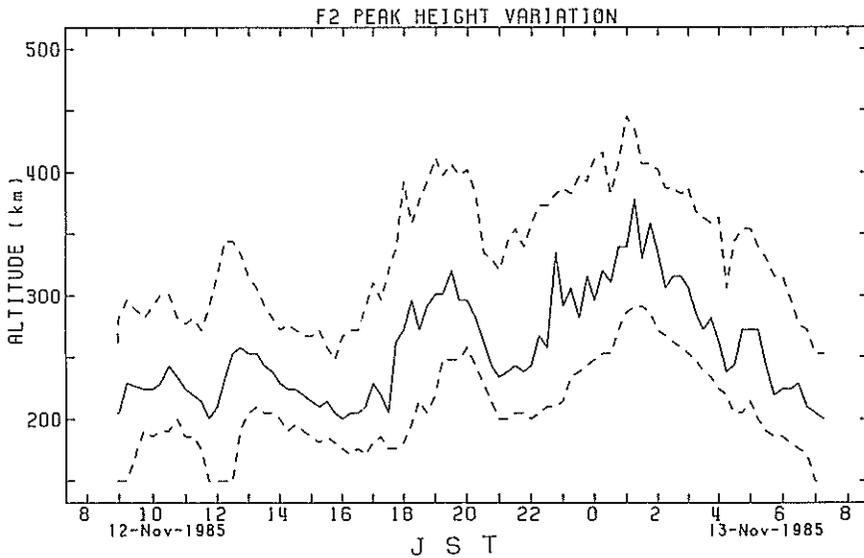


Fig. 2. Variation of the height of F2 layer. Solid line represents the height of F2 peak, and dashed lines show the heights where electron density is half of the maximum value.

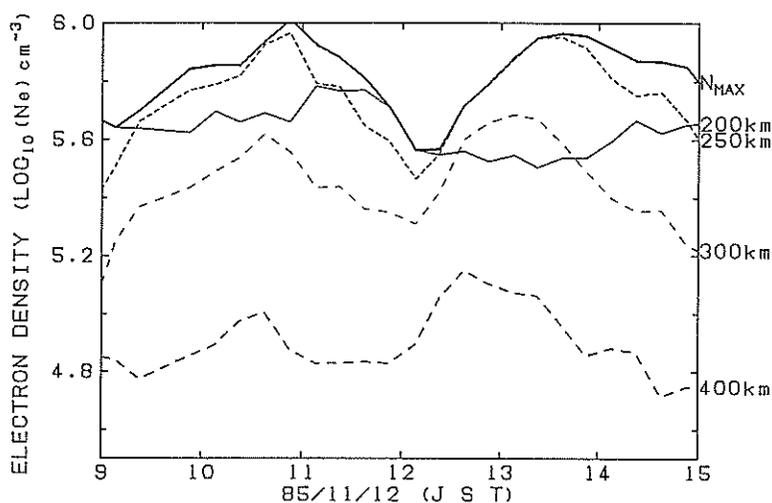


Fig. 3. Time variation of electron density at 200, 250, 300 and 400 km altitude and the maximum electron density from 09 h JST to 15 h JST on November 12, 1985.

in the higher altitude region; the minimum appears at 400 km between 11 h JST and 12 h JST. N_e at both 300 km and 250 km decreases from 10:40 JST to 12:10 JST and recovers from then, but N_e at 300 km begins to decrease slightly earlier than N_e at 250 km. This suggests that this event begins at the upper F region and descends to the lower region. On the other hand N_e at 200 km altitude first increases and then begins to decrease around 11:40 JST and reaches its minimum around 13:20 JST. The first increase is caused by the descent of the total layer, and the next decrease is due to the approach to the chemical equilibrium state. From Figs. 1, 2 and 3 we can see that the bite-out appears in the whole height range of the radar observation, but the time when the event becomes maximum is earlier at higher altitudes.

Figure 4 gives $foF2$ at Japanese ionospheric observatories, Wakkanai (45.40°N , 141.69°E), Akita (39.73°N , 140.13°E), Kokubunji (35.71°N , 139.49°E), Yamagawa (33.20°N , 130.62°E) and Okinawa (26.28°N , 127.81°E) on the day under consideration. The $foF2$ was measured every 15 minutes. This figure shows that there is a clear bite-out event at Akita, Kokubunji and Yamagawa and a small bite-out at Okinawa, but no bite-out at Wakkanai. The time of the minimum is 11:45 JST at Akita, 12:00 JST at Kokubunji, 12:45 JST at Yamagawa and 13:45 JST at Okinawa. The decrease of $foF2$ starts 45–60 minutes before local noon (indicated by vertical arrows in Fig. 3) at the three northern observatories (Akita, Kokubunji and Yamagawa) and just after local noon at Okinawa. The local time of the minimum of $foF2$ is around noon at Akita and delays from local noon towards low latitudes (13:15 LT at Okinawa). The decrease of $foF2$ is largest at Kokubunji (1.3 MHz). Figure 5 gives $h'F$ (thin lines) and $h'F2$ (thick lines) at the same observatories as in Fig. 4. It is seen that both $h'F$ and $h'F2$ have a minimum around local noon at all

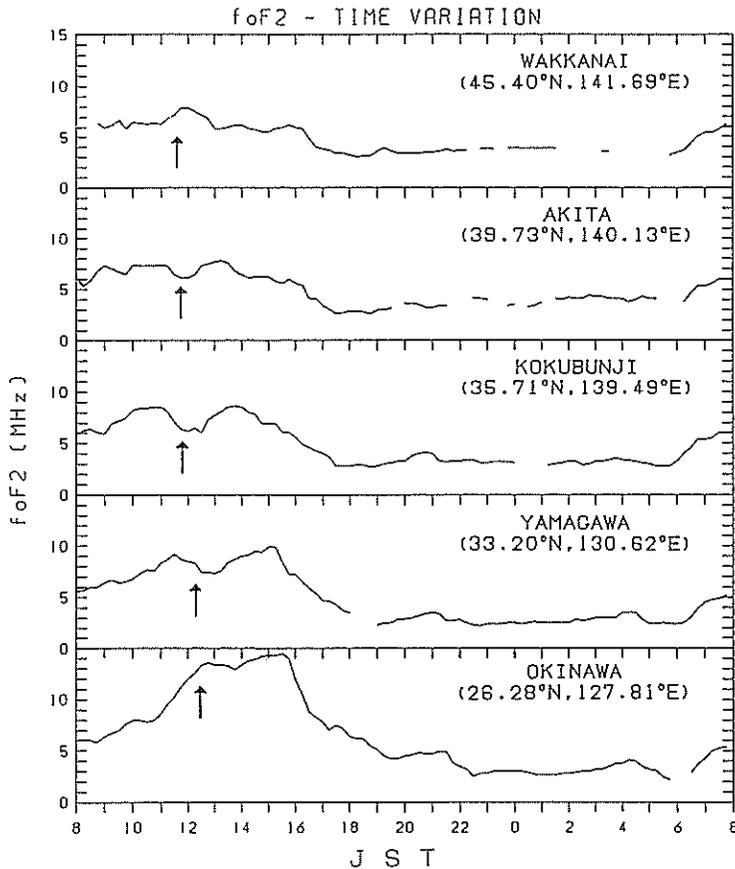


Fig. 4. Time variation of $foF2$ at Wakkanai (top), Akita (second), Kokubunji (third), Yamagawa (fourth) and Okinawa (bottom) from 08 h JST on November 12 to 08 h JST on November 13, 1985. Arrows indicate local noon at each observatory.

observatories, except for Wakkanai. The relation between $h'F$ and $h'F2$ at Kokubunji, which is the ionospheric observatory nearest to MU radar, seems to show the earlier appearance of the minimum at higher altitude. This is in accordance with our observation by MU radar. Although this earlier appearance of the minimum at higher altitudes is not so clear at Akita, Yamagawa and Okinawa, the recovery from the minimum seems to be earlier at higher altitudes at Akita and Yamagawa.

Examining $foF2$ at Kokubunji on November 12, it is found that $foF2$ is smaller at 12 h than the monthly median value, while the $foF2$'s at 10 h, 11 h, 13 h and 14 h LT are greater than the corresponding monthly median values. This means that this bite-out event is caused by both a decrease of the electron density around noon,

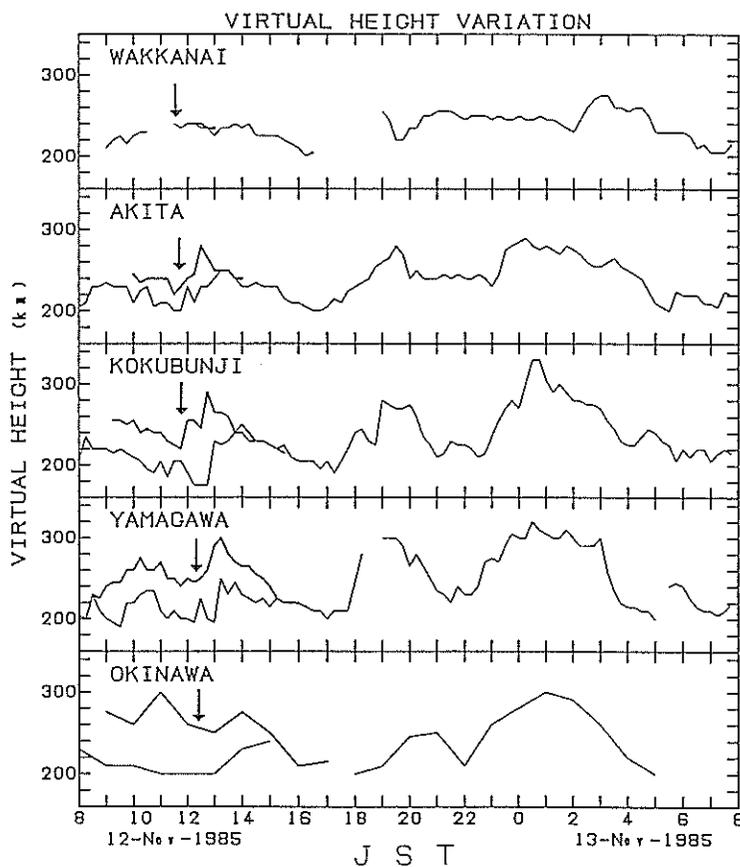


Fig. 5. Same as in Fig. 3, but of $h'F2$ (thick lines) and $h'F$ (thin lines).

probably by enhancement of the poleward wind, and an increase of the density before and after noon by the diminishment of the wind.

4. Discussion

Two mechanisms of a mid-latitude bite-out event have been proposed: 1) An anomalous neutral wind blowing poleward, which is excited by anomalous heating in some region, causes ions to move along the magnetic field-line to the lower altitude region, where the loss rate is higher. 2) The $\mathbf{E} \times \mathbf{B}$ drift causes vertical motion of the ionospheric plasma and makes an anomalous depression or enhancement in the daily variation of the electron density. In a middle latitude region, if a westward electric field is applied, the F layer is first pushed down, but the equatorward neutral wind induced by the equatorward component of the ion drift pushes up the layer

and cancels out this effect in the stationary state. The characteristic time is the inverse of the neutral-ion collision frequency, which is less than one hour at the F_2 peak height in the daytime (RISHBETH and GARRIOTT, 1969). In the equatorial region, a noon bite-out event is produced by enhancement of the eastward electric field, which causes the Appleton anomaly, this mechanism is thought to be effective only within the trough region of the anomaly. However, HUANG and JENG (1978) examined the latitudinal extension of the forenoon bite-out observed at Chung-li (18.6°N magnetic latitude) and found that on some days the forenoon bite-out occurs not only at the region close to the peak of the Appleton anomaly, but also to higher latitudes (Wakkanai) with the time delay of the onset time. From this feature they suggested a relation between the forenoon bite-out event at higher latitudes and the Appleton anomaly. In the present observation the bite-out seems to occur at almost the same local time (around local noon), or at slightly earlier local time at higher latitudes if we take the longitudinal difference into consideration. Furthermore, Kokubunji (22.5°N geomagnetic latitude), at which this event is most conspicuous, is located outside the crest of the Appleton anomaly, and the height profile of the electron density observed at Shigaraki and Kokubunji suggests a downward motion of the total F -layer in the bite-out event. These facts support the idea that the bite-out was caused by the poleward neutral wind.

On the other hand, JONES (1973) showed by a theoretical investigation that F -region perturbations produced by neutral winds have the feature that the variation of hmF_2 precedes that of the peak electron density. SPURLING and JONES (1976) found that hmF_2 variations precede those of foF_2 during magnetic storms, and explained this as the effect of neutral winds. In the present case, Figures 2 and 3 show that the time of the maximum bite-out of foF_2 is 12:15 LT, and this is after the time of the minimum F_2 peak height (11:45 LT). This also supports the idea that this bite-out is caused by the neutral wind.

If this event may be caused by the neutral winds, variation of the global circulation in the thermosphere is expected. As for the geomagnetic activity, November 12 is one of the international five quiet days, and November 11 is also a relatively quiet day when the maximum Kp index is 3-, but November 10 is a slightly disturbed day when the maximum Kp is 5 and the maximum hourly value of the AE index is 794 nT at 21 h UT. Therefore, it is possible that a magnetic storm on November 10 is the cause of the variation of neutral winds. In fact, there is an foF_2 bite-out event at Kokubunji on November 11, but not on November 10. This suggests that the effect of the magnetic storm on November 10 remains until November 12.

However, this is the first observation of the bite-out event, and it is not certain that all bite-out events observed at Shigaraki are caused by the neutral winds. Accumulation of height profile data by MU radar will clarify these problems.

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