GLOBAL PROBING OF MID-LOW LATITUDE D-REGION DISTURBANCES BY TWEEK ATMOSPHERICS OBSERVATIONS

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ABSTRACT

Observations of tweek atmospherics are useful for nighttime electron density measurements in the mid-low latitude D-region ionosphere. It has been confirmed that electron densities at reflection points by tweek atmospherics are nearly in agreement with electron densities measured by MF radar. It is advantageous that tweek atmospherics are available for measuring electron densities in a wide area over oceans. We investigated mid-low latitude D-region disturbances by tweek atmospherics during severe magnetic storms. As the result, it was found that electron densities at reflection points increased in storm days than in quiet days.

INTRODUCTION

In early years, measurements of electron density profiles at mid-latitude D-region ionosphere have been performed by rocket experiments [1]. The result revealed that that nighttime electron density was orders of 10^1-10^4 electrons/cm^3 in the 70-100 km altitude range.

Tweek atmospherics are VLF/ELF electromagnetic waves that are originated from lightning discharges and are propagated in the Earth-ionosphere waveguide over long distance, reflecting in the 70-100 km altitudes. Tweek atmospherics are usually received 100-200 times per one minute in nighttime, and the dispersion of tweek atmospherics is obtained. The aim of previous tweek studies was to clarify propagation mechanism by the analysis of the tweek signals [2][3]. Some direction finding methods were used for determining positions of the sources and the propagation mechanism for atmospherics such as whistlers [4][5][6][7]. Discussions whether tweek atmospherics are effective for the study of the lower ionosphere has been made since 1970's. However, the discussions have not been progressed, because the analysis by sonagrams and computers in 1970’s were not well performed for their parameter estimations. The study of the lower ionosphere using tweek atmospherics has two advantages. First, electron density variations can be estimated below 100 km altitude at which they cannot be measure by the ionosonde. Second, electron density variations at the D-region are obtained in the global area because of characteristics of long-distance propagation of tweek atmospherics.

In this study, we provide the effectiveness of tweek atmospherics for the study of the lower ionosphere, comparing the reflection surfaces (equal electron-density surfaces) by tweek atmospherics with electron density profiles by MF radar. Further, we examine electron density variations in at low-middle latitude D-regions during severe geomagnetic storms.

METHOD OF ANALYSIS

ELF/VLF signals of tweek atmospherics are used by MT tape during two minutes per one hour, which are regarded as representative during the hour. Observations of tweek atmospherics are carried out at Moshiri Observatory (Geographic coordinate, 44.37 ° N, 142.27 ° E) and Kagoshima Observatory (31.48 ° N, 130.72 ° E) of STE Laboratory, Nagoya University in Japan. 40 kHz radio wave signals reception at Kagoshima Observatory from Fukushima (37.37 N, 140.85 ° E) are complementarily used at, in order to examine the D-region ionosphere at the middle point of the propagation path. MF radars are coordinately operated at Wakkanai (45.36˚ N, 141.81˚ E) and Yamagawa (31.20 ° N, 130.62 ° E) of Communication Research Laboratory in Japan.

We fit received tweek atmospherics with theoretical frequency-time curve on the dynamic spectrum by the root-mean-square method, and estimate the cut-off frequency, the propagation distance, and the propagation time on the first-order mode. The reflection height is also estimated from the cut-off frequency on the first order mode. Atmospherics sources (lightning discharges) are fixed from cross points calculated by two propagation distances from Moshiri and Kagoshima by the spherical triangulation. The fixed points are compared with Lightning Imaging Sensor (LIS) data, Optical Transient Detector (OTD) data and cloud distributions data by satellites, and then are confirmed that source locations of tweek atmospherics are coincident with lightning positions by ± 5 degrees.

We assume that tweek atmospherics are reflected at the middle point of the propagation path on the first-order mode and estimate the reflection surfaces. The reflection surfaces are equivalent to the surfaces of equal electron density (20-30 cm^{-3}) by theoretical extraordinary-mode. When the electron density increases (decreases) in the D-region, the bottom height of the D-region falls down (rises up), keeping the shape of the electron density profile of IRI-95 model.

RESULTS

We analyzed tweek atmospherics observed during November 4-6 and 24-26 in 2001, in which periods the maximum of D_{st} index were -257 nT and –225 nT, respectively. Average estimation errors of reflection heights and the propagation distances reduced are ± 2.07 km and ± 945 km, respectively. Although the error of the propagation distance is about ± 8.51 degrees in geographic coordinate, source positions calculated from propagation paths can be estimated within this accuracy. It was found that the fixed source positions of tweek atmospherics show good agreement with the lightning locations by LIS data with about ±8 degrees.

Table 1 shows the electron densities at reflection heights measured by the MF rada at Yamagawa or Wakkanai. The difference between the middle points of the tweek propagation path and MF radar site is less than 1000 km in distance. The electron densities calculated from tweeks are 20-30 cm^{-3} , while the electron densities measured by the MF radar is 40-100 cm^{-3}, indicating that electron densities obtained by tweek atmospherics and by MF radar are approximate.

Figure 1 shows a distribution of reflection heights obtained from tweeks on November 5 11:50-52UT, 2001, which corresponded to the storm (November 4-6) recovery. The reflection height was the lowest of 65-70 km around the geographic coordinate of 40 ° N, 160 ° E (orange circle). However, tweek atmospherics were not observed in and around Japan. Therefore, intensity and the phase records of 40 kHz radio-wave signals are complementary used, so that ionospheric disturbances over Japan were observed during the time period. This indicates that there is a possibility of the ionospheric disturbances in the wide area from Japan Island to eastern part far from Japan Island, that is, electron-density increase in the mid-latitude D-region ionosphere.

Figure 2 shows a distribution of reflection heights obtained from tweeks on November 24 in 2001, which corresponded to the storm recovery. The reflection height was relatively lower in the localized area from Chinese to northern part of Korea, although the higher reflection height was presented at the northern part of the above area. The phase and the intensity records of 40 kHz radio wave signals showed the ionospheric disturbances. Consequently, the electron density increase occurred in the mid-latitude D-region during the magnetic storm.

CONCLUSIONS

Electron densities at reflection points obtained by tweek atmospherics were nearly equal to electron densities measured by MF radar. This indicates that tweek atmospherics observations are available for measuring electron densities in D-region ionosphere. It was also recognized that the mid-latitude electron densities increased in the recovery phase during the severe magnetic storms.

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Table 1. Comparison reflection height of tweek with MF radar

Tweek No.	MF radar (cm-3)	Reflection height (km)	Distance (km)
1	48.53	83.41	651.5
2	49.60	81.03	681.2
3	52.75	82.55	764.4
4	54.75	87.84	143.4
5	54.77	85.21	125.1
6	64.96	87.85	668.1
7	66.21	83.49	372.1
8	90.28	86.85	979.4
9	92.82	91.25	721.2
10	93.36	85.36	708.3
11	197.10	90.60	740.0

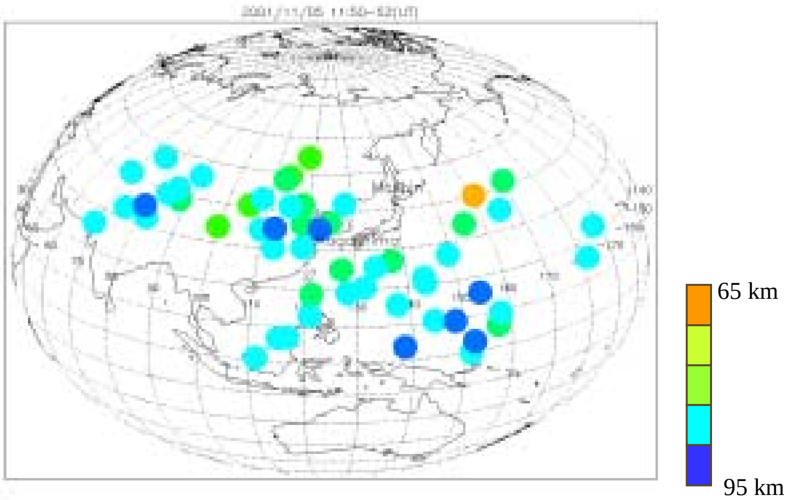

Fig. 1 Reflection height on November 5, 11:50-52UT, 2001

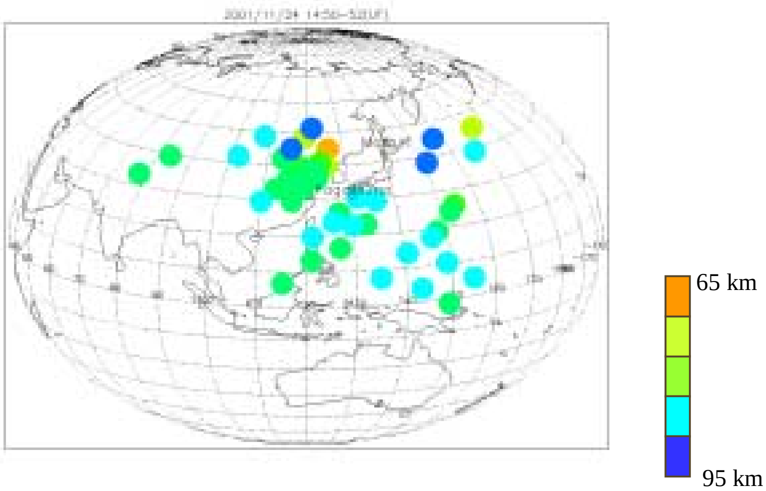

Fig. 2 Reflection height on November 24, 14:50-52UT, 2001