

ENHANCEMENTS OF THE PLASMASPHERIC DENSITY IN ITS LOW-L PART DURING MAGNETIC STORMS

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ABSTRACT

The plasmaspheric plasma density at $L \sim 1.3$ was monitored by three ground magnetometer stations during the magnetic storm on July 13 - 16, 2000. The density was significantly increased to about two times the pre-storm value. We compared this feature with the ionospheric response, which [1] observed at $L=1.34$ during the same interval. The maximum of foF2 at $L=1.34$ occurred at 1630UT on July 15, before the plasmaspheric density maximum at $L \sim 1.3$ estimated from the ground magnetometer data; at the time of the latter maximum, foF2 showed a significant drop.

INTRODUCTION

The inner plasmaspheric plasma density can be inferred from the observed field-line eigenfrequency if appropriate models of the magnetic field and the plasmaspheric plasma density are assumed. At low latitudes, the first harmonic of geomagnetic field-line eigenoscillations (caused by field-line resonances (FLR) [2], [3]) has its frequency in the Pc 3-4 frequency band. We can identify FLR and measure the fundamental field-line eigenfrequency by applying the cross-phase method [4] and the amplitude-ratio method [5] to magnetometer data from two closely spaced stations located along the same meridian [6]. It is difficult for spacecraft to continuously monitor the low-L part of the magnetosphere, because of the rapid motion of spacecraft. On the other hand, ground magnetometers can observe geomagnetic pulsations continuously for hours or days. Hence, FLR observed on the ground is useful for monitoring the plasma density in the low-L part, which has not been observed continuously, before. Then, the aim of this study is to investigate the plasma distribution in the low-L part of the plasmasphere during magnetic storms. For this objective, we installed fluxgate magnetometers in Japan at Kawatabi (KWT) and Iitate (ITA), which stations are located at low latitudes ($L = 1.3 \sim 1.4$), and started observing FLRs. Here we examine the variation of the plasmaspheric density during a magnetic storm on July 13 - 16, 2000, by applying the two (cross-phase and amplitude-ratio) methods to the data from these stations at $L = 1.3 \sim 1.4$. We will show that the plasmaspheric plasma density at this low latitude was significantly increased during the main phase of the storm and it quickly decreased afterward. We will also show the ionospheric response during the same time interval.

Table 1. Names and coordinates of stations used in this study

Station	Code	Geomagnetic		L-value
		Latitude	Longitude	
Kawatabi	KWT	31.96	212.53	1.39
Iitate	ITA	30.90	212.01	1.36
Kakioka	KAK	29.39	211.89	1.32

DATA

The above-stated fluxgate magnetometers in Japan at Kawatabi and Iitate were installed in May 20, 2000 [7]. Since then, we have been analyzing data from these stations and Kakioka magnetic observatory, Japan. The locations of these three stations are listed in Table 1. These three stations are located approximately along the 210 degree magnetic meridian from $L=1.32$ to 1.39 . These adjacent stations are separated from each other by about $50 \sim 150$ km. The fluxgate magnetometers at these stations record the geomagnetic H, D, and Z components with a resolution of 0.01 nT, and the sampling time is 1 s with precise GPS timing. At these stations, $LT = UT + 9$ hours. As stated above, in this paper we analyze data from these stations for a storm on July 13 - 16, 2000.

ANALYSIS

Identifying FLR

By using the above-stated geomagnetic data, we can distinguish FLR events from other types of magnetic pulsations by applying the amplitude-ratio method and the cross-phase method. The two methods are briefly reviewed below.

The amplitude-ratio method

The amplitude of the H-component magnetic pulsations reaches a maximum at the resonance point [5]. The ratio of the dynamic spectra of the H-component data at latitudinally-separated two ground stations will show a bipolar structure, because the power spectrum densities at the two sites reach maximum at different frequencies. Therefore, we can decide the frequency at the center of the bipolar peaks to be the resonance frequency at the central point between the two stations.

The cross-phase method

The concept of the cross-phase (as named by [4]) technique was first proposed by [8]. The H-component phase jumps by 180 degrees across the resonance point [5]; because the latitudinal gradient of the phase is the steepest at the resonance point, the phase difference of the H-component between the two stations is expected to become the largest when the resonance point is located at the center between the two stations. Thus, we can decide the peak frequency to be the resonance frequency at the central point.

The analyzed interval (July 13 – 16, 2000) is divided into 20-min intervals; for each of the 20-min intervals, we have examined if FLR exists in the H-component data of all KWT, ITA and KAK stations, by using the amplitude-ratio method and the cross-phase method. Then, if FLR is identified in the interval by the both methods, we further examine if the two values of the field-line eigenfrequencies coming from the two methods agree with each other (allowing for 5mHz difference between two values of the field-line eigenfrequencies). When this agreement is present, we decide that FLR existed in the 20-min interval.

Estimating the equatorial plasma density

The field-line eigenfrequency is dependent upon the plasma density and the magnetic field intensity in the region of space threaded by the field line, and the length of the field line. When we observe the resonant frequency of geomagnetic field lines and assume a model for the latitude profiles of the magnetic field and the plasma density (with the equatorial density as a free parameter), we can estimate the equatorial plasmaspheric plasma density. The plasma densities corresponding to these field-line eigenfrequencies can be calculated by using the formula given by [5], in which a dipole magnetic field and a plasma density $\rho \sim r^{-4}$ are assumed, where r is the geocentric distance.

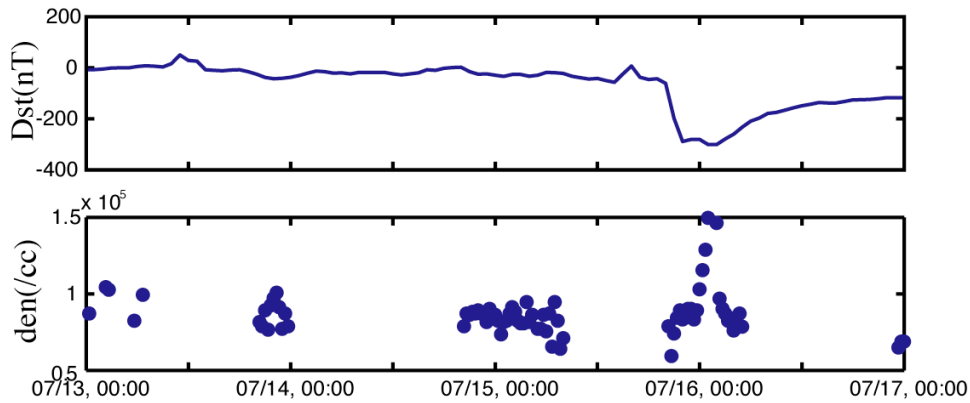


Fig. 1. (From top to bottom) Dst index, plasmaspheric densities inferred by the observed resonant frequencies.

RESULTS

The top panel of Fig.1 shows the Dst index (a measure of the storm activity) for July 13 –16, 2000, which shows that a magnetic storm occurred in this interval. The bottom panel of Fig. 2 shows the equatorial plasma density at $L=1.34$, calculated from the ITA and KAK data by using the procedure explained above. The panel shows that the plasmaspheric plasma density at $L=1.34$ increased from 1930UT on July 15 to 0430UT on July 16, which interval is included in the storm interval (as shown by the decreased Dst). We note that we have also found the same feature (an increase in the plasma density during a storm) for other two storms, too (0200-0900UT, August 12, 2000 and 0000-0500UT, June 26, 2000).

DISCUSSION

We have compared the above-stated feature obtained in the present study with the F2 layer critical frequency (f_oF2) during the same interval, measured at a observatory close to KWT, ITA and KAK, ANYANG ($L=1.32$, geomagnetic latitude= 29.5° , geomagnetic longitude= 199.4°) and analyzed in [1]. Fig. 2 shows their result. The maximum of f_oF2 occurred at 1630UT on July 15, before the density maximum estimated from FLR; at the time of the latter maximum, f_oF2 showed a significant drop; this drop corresponds to an ionospheric negative-phase storm at low latitudes on July 16. Reference [10] and [11] reported that the plasmaspheric plasma density increased after sunrise, which they ascribed to O^+ outflow from the ionosphere (due to sunrise); from this we conjecture that our observation of the increased density at $L=1.34$ could have been caused by a stormtime O^+ outflow, although we do not know of such reports in literature. However, for our event, the actually observed ionospheric density decreased (as suggested by the f_oF2 decrease). Thus, it is questionable that this maximum in the plasmasphere plasma density was caused by the ion outflows from the ionosphere. In order to come up with an alternative explanation of this point, we are now looking at more events, including the above-mentioned two events in August 2000, and June 2000.

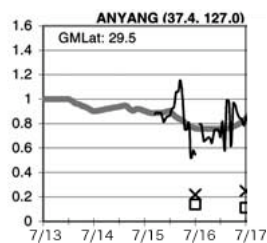


Fig. 2. (Copied from Fig.2 of [1]) The black line represents the ratio of the hourly f_oF2 to the monthly mean. The thick gray line corresponds to the empirical model (the STORM model) output.

Acknowledgements

The Dst index was provided by T. Iyemori through the World Data Center for Geomagnetism. Geomagnetic data from Kakioka were provided by the Kakioka Magnetic Observatory, Japan. This study has been supported by "Professor Tatsuuro Matsumoto Scholarship Fund".

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