

Simultaneous observations of Syowa East HF radar and Zhongshan Station optical aurora associated with the solar wind negative pressure impulse

N. Sato¹, Y. Murata¹, H. Yamagishi¹, A. S. Yukimatu¹, M. Kikuchi¹, K. Makita²,
Yang Huigen (杨惠根)^{1,3} and Liu Ruiyuan (刘瑞源)³

1 National Institute of Polar Research, Tokyo 173, Japan

2 Takushoku University, Tokyo 193, Japan

3 Polar Research Institute of China, Shanghai 200129, China

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Abstract The field of views of the Syowa East HF radar covers over Zhongshan Station (magnetic latitude $\sim 74.5^\circ\text{S}$). We examined the relation between HF radar signatures and optical aurora by using the data obtained on 3 August 1997. A geomagnetic negative sudden impulse (SI^-) occurred at ~ 1432 UT on 3 August 1997 associated with the sudden decrease of solar wind plasma density. From the behavior of the optical aurora observed by all-sky TV camera and scanning photometers at Zhongshan Station, a sudden enhancement of auroral emission intensity and poleward moving signature occurred associated with the negative SI. It is interesting that the temporal and spatial variations of the HF radar backscatter power showed one to one correlations with optical aurora data. The details of this event are examined and compared with the data onboard WIND satellite and from ground based magnetometers.

Key words aurora, HF radar, plasma convection, magnetic variation, Zhongshan Station.

1 Introduction

Transient magnetospheric phenomena and their relationship to the conditions of the solar wind are very important to investigate the energy transfer process from the solar wind to the Earth's magnetosphere. It has long been known that sudden positive changes of the solar wind dynamic pressure can trigger the geomagnetic sudden commencement (SC) and long period magnetic pulsations (Kaufmann and Walker 1974). Now it is becoming increasingly clear that large amplitude impulsive variations of the solar wind dynamic pressure are quite common (Sibeck *et al.* 1989) and that these variations can drive magnetopause motion, magnetospheric magnetic field compression, transient oscillations in high-latitude ionospheric flows, ground magnetic field pulsations, increased ULF/VLF wave activity (Hirasawa 1981) and cosmic noise absorption (Matsushita

1961). However, the study on the phenomena associated with the solar wind negative pressure impulse (SI^-) is still very limited (Araki and Nagano 1988), especially, as far as we know, no report for their relation to the optical aurora.

The field of views of the Syowa East HF radar covers over Zhongshan Station. The geomagnetic latitude of Zhongshan Station, as same as that of South Pole Station, is $\sim 74.5^\circ S$, which is the average location under the cusp region. We have examined the relation between HF radar signatures and optical aurora by using the data on 3 August 1997. High time resolution camping beam of the HF radar with the sampling period of 17 s over Zhongshan Station has operated under clear sky and geomagnetically disturbed condition. A geomagnetic negative sudden impulse (SI^-) occurred at ~ 1432 UT on 3 August 1997 was associated with the sudden decrease of solar wind plasma density. In association with this event, a sudden southward turning of the interplanetary magnetic field (IMF) B_z also occurred. We examine in details on this event by using simultaneous observations of HF radar and optical aurora, comparing with data from WIND satellite and ground based magnetograms.

2 Instruments and data sources

The field of views of the Syowa East HF radar covers Zhongshan Station. The Syowa East HF radar is a Japan-operated component of the extended network of HF radars called SuperDARN (Super Dual Auroral Radar Network) (Greenwald *et al.* 1995). The field of view of this radar extend from $\sim 65^\circ S$ up to $\sim 85^\circ S$ in magnetic latitude and covers up to ~ 4.5 h in magnetic local time. The radar employs linear phased arrays of 16 log-periodic antennas and its operational frequency is between 8 MHz and 20 MHz. The radar forms a single beam which is narrow in azimuth (between 2.5° and 6° , depending on the transmitted frequency) but broad in elevation (up to $\sim 40^\circ$ at 8 MHz). A radar scan over a 52° angular segment is completed in each 60 s or 120 s by sweeping the single beam through 16 successive positions differing by 3.25° . In near-real time, the backscatter power, line-of-sight Doppler velocity, and Doppler spectral width are found at each beam position by fitting the autocorrelation functions for 70 range bins of width 45 km, starting at a slant range of 180 km. The field of view of the Syowa East and other SuperDARN radars in the southern hemisphere are shown in Figure 1. Also shown are the locations of ground-based observatories including Zhongshan Station and South Pole Stations.

In this paper the data from a panchromatic all-sky TV cameras at Zhongshan Station, ground based magnetograms at Zhongshan Station and Syowa Station in the southern hemisphere and the International Monitor for Auroral Geomagnetic Effects (IMAGE) (Lühr *et al.* 1998) array in the Scandinavian region are analyzed and compared with the data of interplanetary magnetic field, solar wind dynamic pressure and plasma density onboard WIND satellite (Ogilvie and Parks 1996).

3 Results

The top panel of Figure 2 (see Plate 1) shows Keogram produced from all-sky TV images. In order to compare the spatial and temporal relation between the optical aurora

SuperDARN

Southern Hemisphere Map

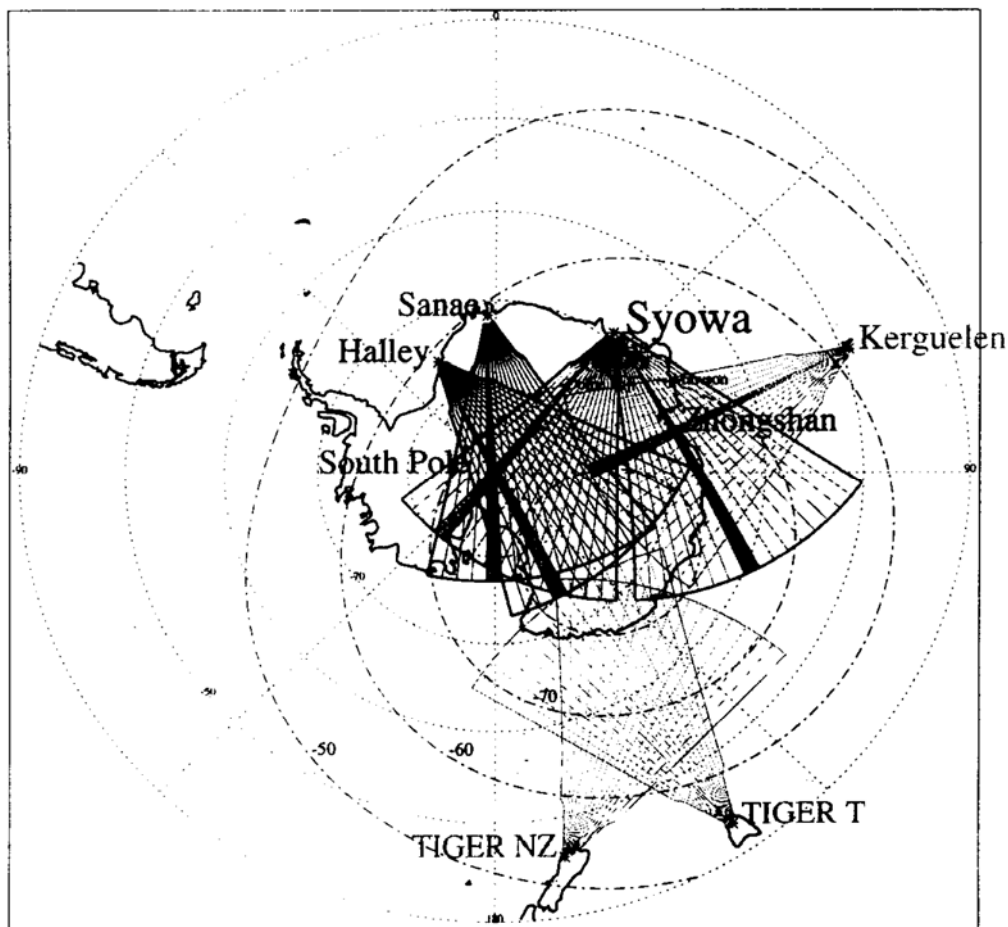


Fig. 1. The field of view of SuperDARN radars in the southern hemisphere.

and HF radar signatures, the vertical axis of this Keogram shows direction along the beam 6 of the Syowa East radar. The middle panel of Figure 2 shows the HF backscatter power of the beam 6. The bottom panel shows the H component of magnetogram at Zhongshan Station. It is clearly found that optical auroral intensity and HF backscatter power enhanced simultaneously at $\sim 1432 - 1439$ UT. It is also found that the intensity enhanced region moved to poleward with time for both of optical aurora and HF backscatter with almost same manner. Then both of the HF backscatter power and optical emission ceased at ~ 1439 UT. It is very important to point out again that the spatial and temporal variation signatures for both of the phenomena look very similar. It is also found that the H-component of magnetic variation showed very similar variations as the optical auroral luminosity variations during the time interval for the time period of $\sim 1432 - 1445$ UT.

Figure 3 shows the all-sky TV images observed at Zhongshan Station at every 1-minute interval from 1435:00 UT to 1440:00 UT. The directions of up, down, right and left in the all-sky image data indicate the magnetic southward, northward, eastward and westward, respectively. It is found that the faint auroral emission with east-west aligned band type aurora was verified at 1435:00 UT. Then the emission intensity

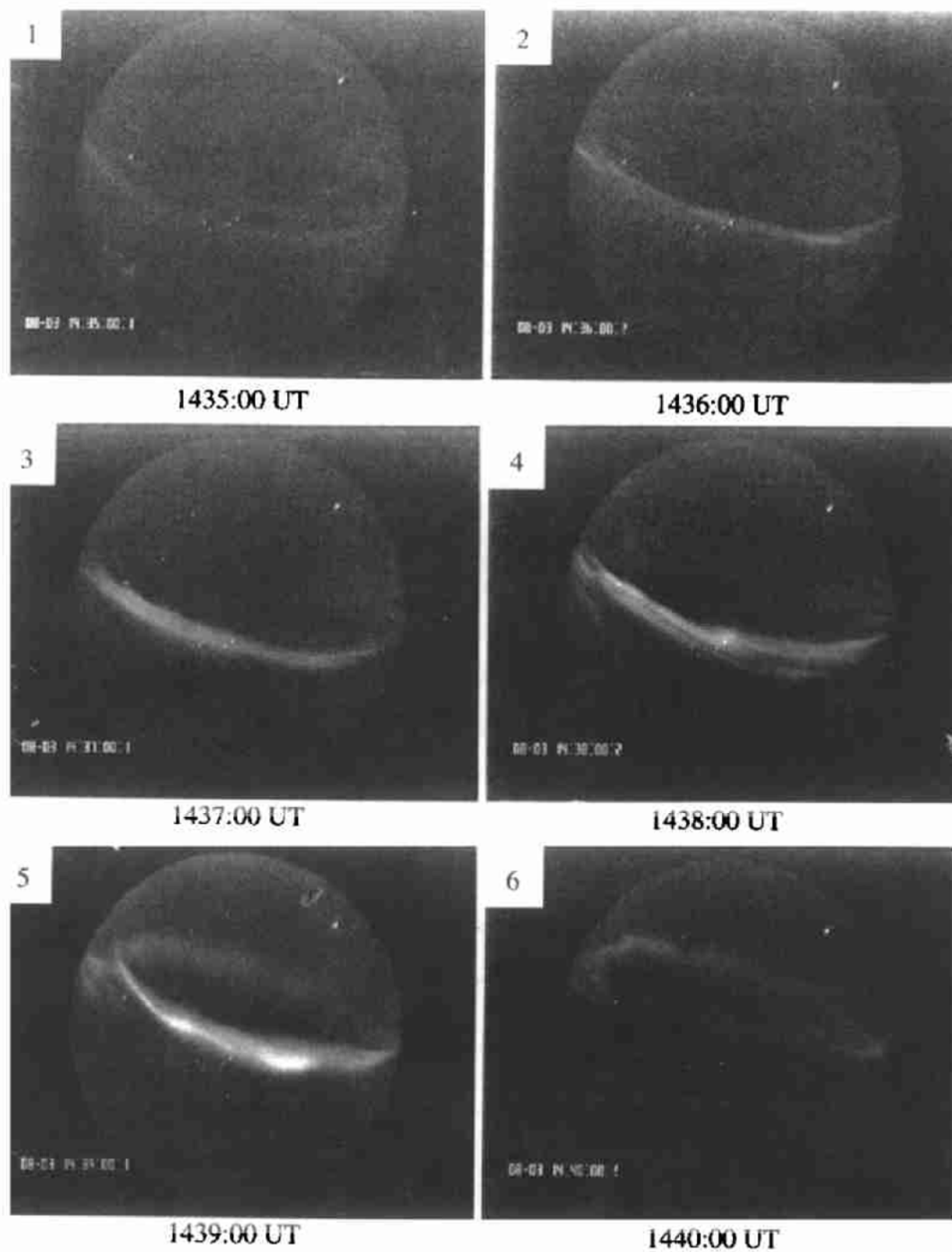
Zhongshan**All-sky TV Images****3 August 1997**

Fig. 3. All-sky TV images associated with the SI observed at Zhongshan Station.

started to enhance with time, and it reached the maximum intensity at $\sim 1439:00$ UT. Looking carefully the movement of the fine structure of the aurora, one can see that the emission peak was moving eastward and poleward.

Figure 4 shows the X components of magnetic variation observed by IMAGE magnetometer array in the northern hemisphere, which locates very close to geomagnetic conjugate meridian of Zhongshan Station. The initial signatures of magnetic variation associated with SI^- occurred simultaneously at all stations at ~ 1432 UT. It is very interesting that the positive peaks of the magnetic variation showed a time lag between BJN and NAL, which locate in the cusp geomagnetic latitude. On the other hand, the time lag was very small between SOR and PEL which locate in the auroral and sub-auroral zone. It is worth noting that the maximum intensity variation was found at HOR.

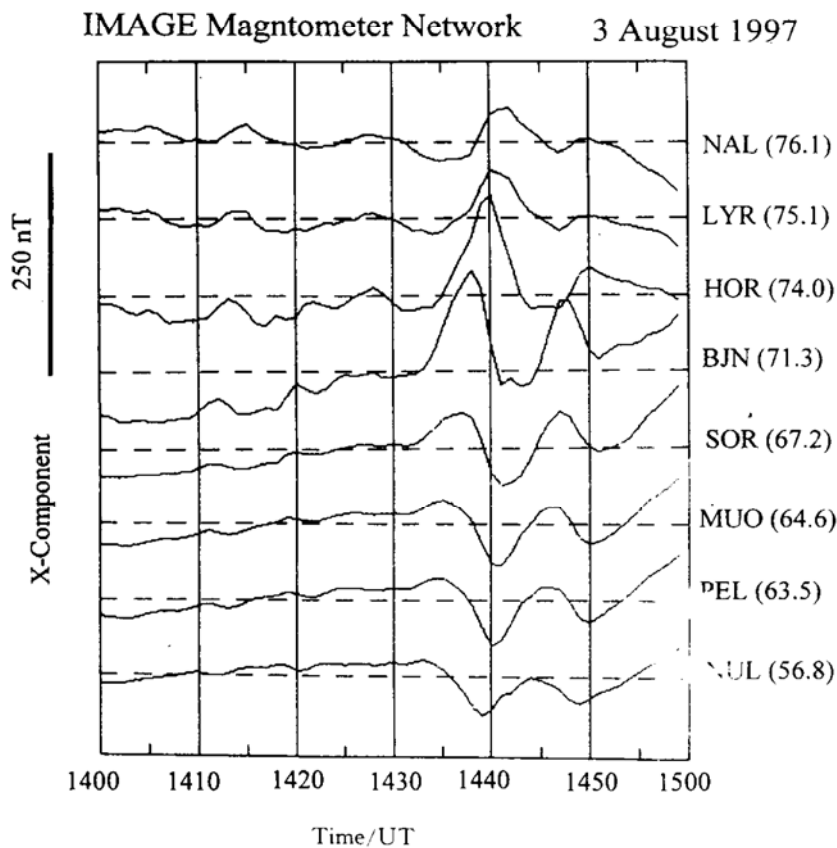


Fig. 4. IMAGE magnetometer network data associated with SI^- .

Figure 5 shows IMF data observed onboard WIND satellite. The spacecraft was at about $(79.7, -60.2, -14.8) R_E$ in GSE coordinates during this time interval. The panel from top to bottom shows the total intensity and 3-components of IMF (B_T, B_x, B_y, B_z), electron density and ion pressure, respectively. It is clearly found that the solar wind electron density and ion pressure showed negative impulse from ~ 23 el./ cm^3 to ~ 7 el./ cm^3 and ~ 17 nPa to ~ 4 nPa, respectively at ~ 1340 UT. Correspondingly, the B_T, B_y and B_z changed from ~ 11 nT to 14 nT, ~ -5 nT to $+3$ nT and ~ -1 nT to -9 nT, respectively. Such discontinuity occurred within the time interval of 2 min. It suggests that the sudden impulses of HF radar backscatter power, the optical auroral

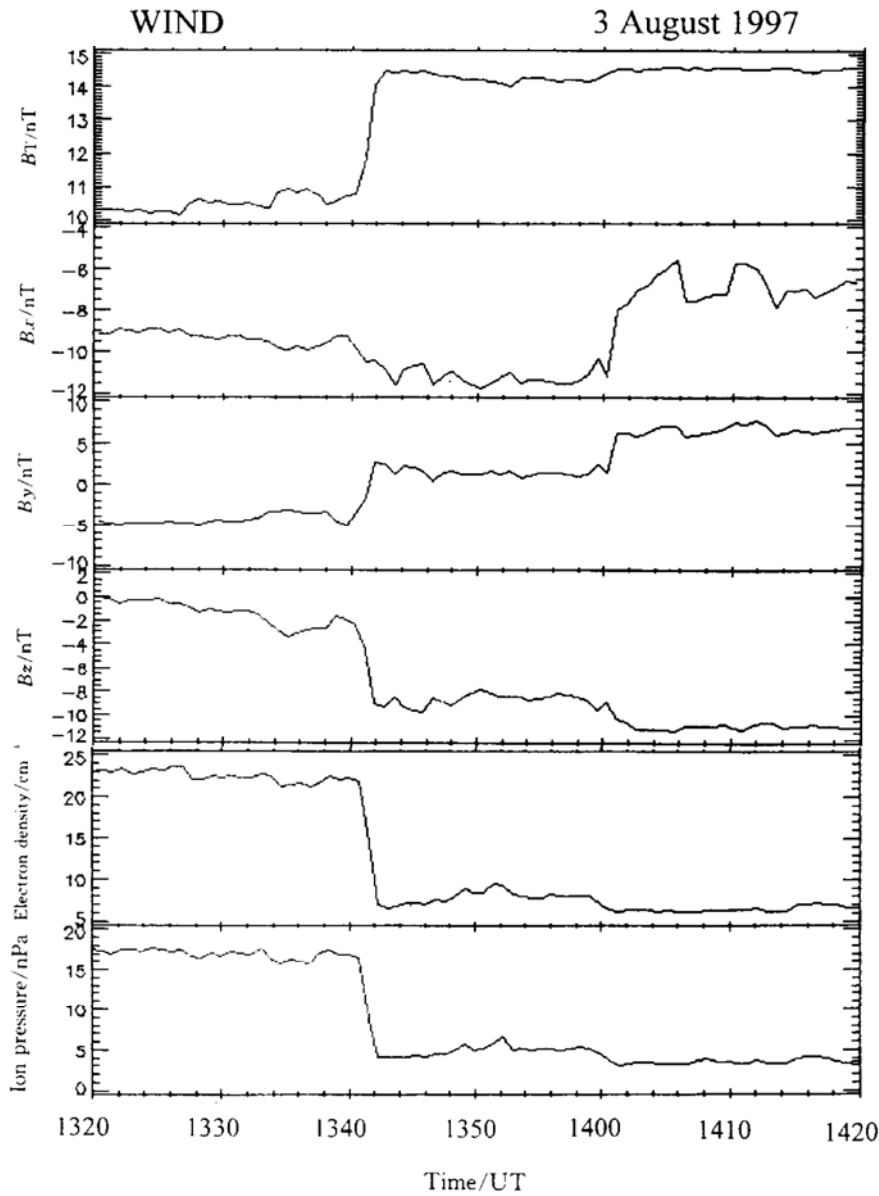


Fig. 5. The interplanetary magnetic field and plasma data observed onboard WIND satellite.

enhancement and magnetic variations observed in the ionosphere and on the ground should be caused by the impulsive discontinuity of solar wind negative pressure when we are taking in account the transportation time of solar wind between the position of WIND satellite and the Earth's magnetopause.

4 Discussion

The most interesting signature of this event is that one to one correlations between HF radar and optical aurora are found in spatial and temporal variations associated with the SI^- . It could be expected that the negative solar wind pressure impulse could cause the expansion of the magnetopause. The question is why the rarefaction of the magnetopause and magnetosphere can lead to the optical auroral enhancement and HF radar irregularities. Or does the sudden negative change of IMF B_z cause the direct effect

of auroral emission enhancement without the relation to solar wind negative pressure? In order to separate the different causes we have to analyze other events, under solar wind conditions such as negative pressure impulses associated with stable positive or negative IMF Bz. Another interesting signature of this event is that quasi-periodic variations with period of ~ 10 min are found for both of optical auroral intensity variations and magnetic variations. It suggests that solar wind sudden negative pressure impulse enhances the long period magnetic pulsations. The optical aurora also enhanced quasi-periodically with a close correlation to the magnetic pulsations. It has been well known that sudden positive changes in the solar wind dynamic pressure can trigger the long period magnetic pulsations. However, there are no evidences that a negative pressure impulse can also trigger the long periodic optical aurora and HF radar irregularities with a close correlation to magnetic pulsations, in our knowledge.

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