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Post-noon ionospheric absorption observed by the imaging riometers at polar cusp/cap conjugate stations

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Abstract An example of post-noon ionospheric absorption observed by the imaging riometers at Ny-Ålesund / Danmarkshavn in the arctic region and Zhongshan Station in Antarctic is presented. The post-noon absorption observed simultaneously between the hemispherical stations was a spike-type with weak intensity (<1 dB) during the high solar wind dynamic pressure. The absorption spikes might be caused by precipitation of high-energy electrons (30 - 300 keV) in the closed dayside magnetosphere. It should be noted that the precipitation region of the absorption spike associated with the steep pressure increase (~ 13 nPa) was localized and shifted equatorward.

Key words post-noon ionospheric absorption, conjugate imaging riometer, high solar wind dynamic pressure.

1 Introduction

The interest of the dayside ionospheric phenomena in high latitudes is increased in recent years for the study of the solar wind-magnetosphere-ionosphere interaction. As an example, it has been understood that the cusp/cleft auroral activity obtained by the ground-based optical observation at the polar-cap boundary region is controlled by the solar wind dynamic pressure and interplanetary magnetic field (IMF) orientation (e. g. Sandholt *et al*. 1994).

On the other hand, the imaging riometer for ionospheric studies (IRIS) can measure two-dimensionally radio wave absorption, and was firstly developed at South Pole (Detrick and Rosenberg 1990). The IRIS installed thereafter at Sondre Stromfjord in Greenland has been used for the study of the solar wind-magnetosphere merging and associated ionospheric convection disturbances in the high-latitude (Stauning *et al.*

1994). Further developments of the IRIS multiple installations in the northern and southern polar regions enabled us to examine interhemispherical features of ionospheric absorption during years. The IRIS at Zhongshan Station, Antarctica was installed in January 1997 for this study as a collaborative project between National Institute of Polar Research, Japan and Polar Research Institute of China.

In this paper, we present an example of post-noon absorption obtained by the conjugate observations between the existing IRISs at Ny-Ålesund/Danmarkshavn in the arctic region and the IRIS at Zhongshan Station, Antarctica. As a case study, we examine conjugate features of the post-noon absorption event on August 3, 1997 which was observed during the specific condition of the high solar wind dynamic pressure.

2 Observations

Table 1 shows geographic coordinates of Danmarkshavn (DMH) in Greenland, Ny-Ålesund (NYA) in Svalbard and Zhongshan Station (ZHS) in Antarctica, their corrected geomagnetic coordinates, approximate magnetic-noon time in UT and total magnetic field intensities according to the IGRF model.

Table 1. Geographic coordinates of Danmarkshavn (DMH), Ny-Ålesund (NYA) and Zhonhshan Station (ZHS), their corrected geomagnetic coordinates, approximate magnetic noon in UT and total magnetic field intensities according to the IGRF model

Station	Geographic		Corrected geomagnetic		Magnet. noon	Total magnetic fields
	Lat.	Long.	Lat.	Long.		
Danmarkshavn (DMH)	76.77°N	18.66°W	77.26	87.38	1036 UT	53660 nT
Ny-Ålesund (NYA)	78.92°N	11.92°E	76.05	112.20	0847 UT	53959 nT
Zhongshan (ZHS)	69.37°S	76.38°E	−74.52	96.25	1014 UT	53733 nT

The IRISs at ZHS and DMH have almost same technical performances ; two-dimensional 8 by 8 dipole-elements with the spacing of half-wavelength at 38.2 MHz, while the IRIS at NYA has two-dimensional 8 by 8 dipole-elements with the spacing of 0.65 wavelength at 30.0 MHz. Approximate IRIS field-of-view is 400 km square and 200 km square at a 90 km altitude for DMH/ZHS and NYA, respectively. The technical details were reported by Stauning *et al.* (1992), Nishino *et al.* (1998) and Nishino *et al.* (1993), respectively. The formed 8×8 beams are assigned as N1, N2, …, N8 or S1, S2, …, S8 in the north-south cross section, and as E1, E2, …, E8 in the east-west one.

2.1 Solar wind conditions

Fig. 1 shows time variations of the total magnetic field B_T (in nT) of the IMF and its Bx, By and Bz components, solar wind bulk flow speed (in km/s), ion density (in number/cm^3) and ion dynamic pressure (in nPa) during 0900 – 1500 UT on August 3, 1997 observed by the WIND satellite. The satellite was located at Rx ~ +80 R_E, Ry ~ −60 R_E and Rz ~ +15 R_E (in GSE). The IMF-By showed a gradual variation from

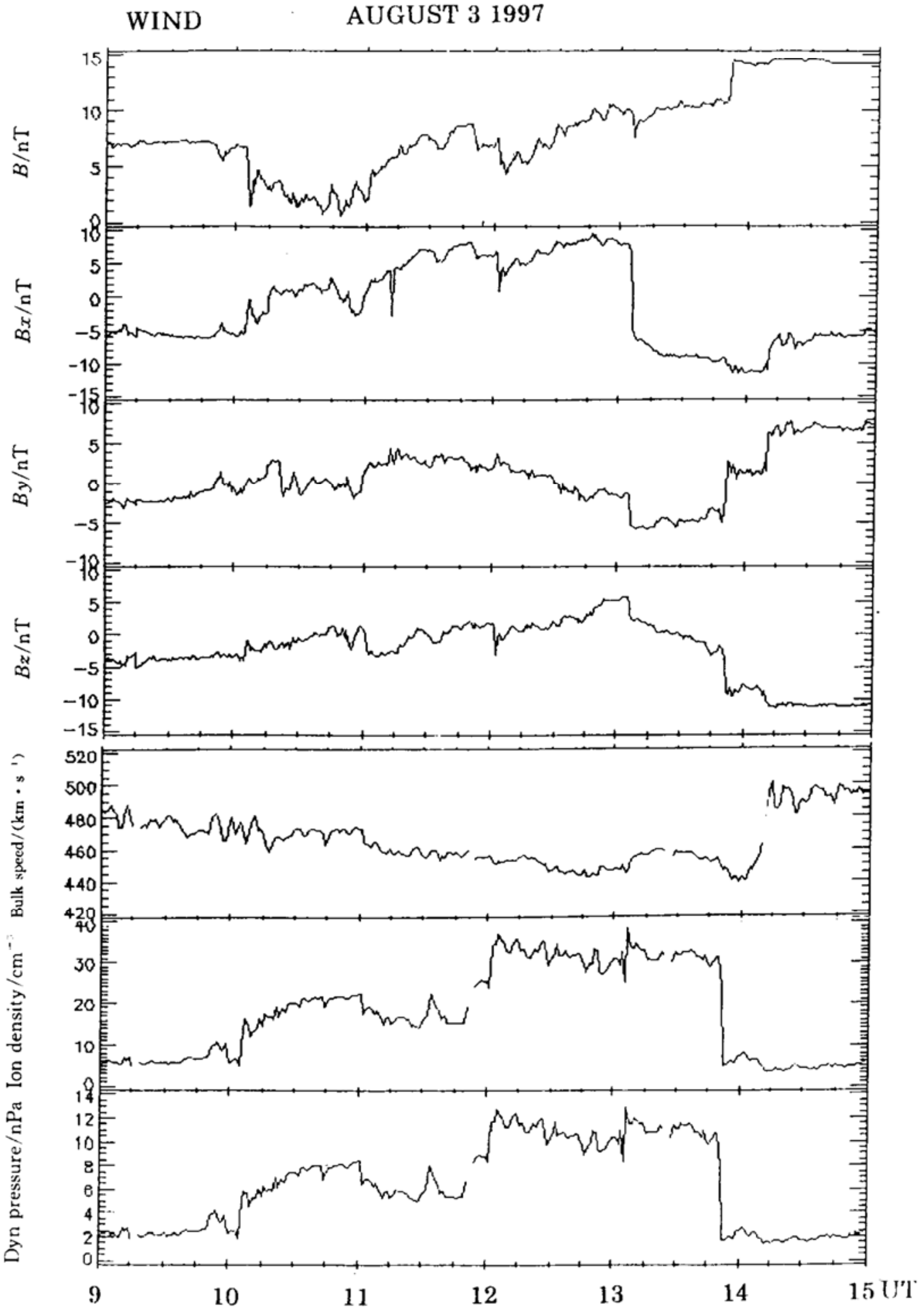

Fig. 1. Time variations of the total magnetic field of the IMF and its *Bx*, *By* and *Bz* components, solar wind bulk speed, ion density and ion dynamic pressure on August 3, 1997 observed by the WIND satellite.

small negative, small positive and subsequent negative through zero value at about 1230 UT until 1350 UT. The IMF-Bz also showed a gradual variation from small negative to positive with a negative spike at about 1200 UT. The bulk flow speed (V) changed slowly within the range of about 480 - 440 km/s. The ion dynamic pressure (NV^2)

displayed at the bottom panel increased steeply at about 1005 UT, persisted 6 - 8 nPa, decreased slightly at about 1100 UT, and subsequently showed a positive swing at about 1135 UT. Thereafter it showed a step-like increase (9 - 10 nPa) at 1150 UT and a steep increase (peak value of 13 nPa) at 1200 UT, followed by a quasi-periodic oscillation until 1305 UT. The ion density (N) at the second bottom panel showed the same variation as the dynamic pressure, indicating that the dynamic pressure was dominated by the ion density. It is also seen that the variations of the ion density and the total magnetic field are often anti-correlated, which is a general feature of the microstructure of the solar wind. In this study we shall concentrate on the interval of an available daytime absorption event from the conjugate riometer observations, that is, from 1030 UT to 1320 UT in the WIND time (see Fig. 2).

2. 2 *The daytime absorption event*

The top-to-third panels of Fig. 2 show time variations of the absorption observed at DMH, NYA and ZHS during 1100 - 1330 UT, respectively, and the bottom panel shows the time variation of the solar wind dynamic pressure. Here the time-axis of the pressure variation is shifted backward by 20 min to the absorption one, taking account of approximate propagation time from the WIND position to the polar ionosphere through the dayside magnetopause. The absorption variations are displayed for the east-west cross-section (E1 to E8) near the zenith over the stations. Large impulses appearing every 10 min at the S4E8 beam of ZHS are due to undesired noise in electric circuits. The absorption scale is 0. 7 dB, 0. 7 dB and 1. 0 dB per division for the respective stations. From the magnetic-noon time shown in Table 1, the absorption features occurred in the post-noon time sector. It is found that most of the post-noon absorption features showed a spike-type with a short time duration ($<$ 10 min) at the three stations, and show rather weak intensities less than 1. 0 dB, if we convert the 30 MHz intensity at NYA to the 38. 2 MHz one at DMH/ZHS.

In the following we shall note conjugate features from the three absorption variations in relation to the solar wind dynamic pressure. It is found that the two sequential absorption spikes during 1120 - 1135 UT are identified among the three stations (marked by dotted lines). These absorption spikes correspond to the positive change of the By, and negative change of the Bz during the high solar wind dynamic pressure variation (6 - 8 nPa)(see Fig. 1). This result indicates that the conjugate absorption corresponding to Zhongshan Station is extended in longitude at least over the distance ($\sim$ 700 km) between DMH and NYA in the arctic region. Thereafter the absorption spikes around 1153 UT and 1222 UT (marked by broken lines) are identified between ZHS-DMH and between ZHS-NYA, respectively. These spikes correspond to the pressure increases at about 1133 UT and 1202 UT in the WIND time, respectively. This result indicates that the conjugate absorption corresponding to ZHS was located only near the DMH and the NYA field-of-views, respectively. It is estimated that the spatial scale of the absorption spikes associated with the steep and strong pressure increase at 1202 UT is extended by a sheet-shape over 200 km length in longitude with narrow ($\sim$ 50 km) latitudinal range within the NYA field-of-view (not shown in the north-south cross section).

Another interesting feature is that the sequential absorption spikes during 1120 -

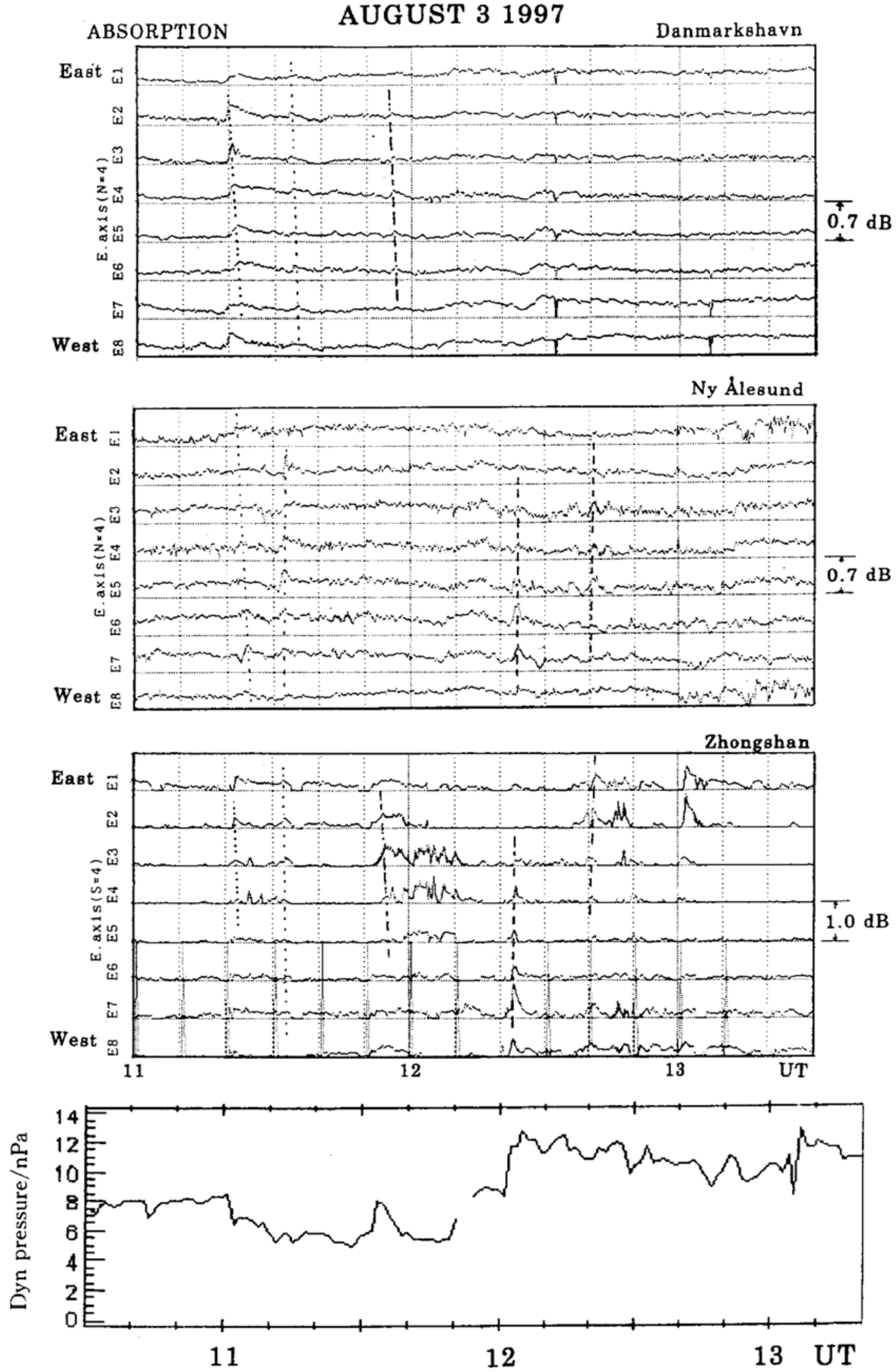

Fig. 2. The top-to-third panels show time variations of the ionospheric absorption at DMH, NYA and ZHS, respectively. The bottom panel shows time variation of the solar wind dynamic pressure.

1135 UT showed a westward drift motion at the three stations, although the motion of the NYA absorption spikes at 1132 UT seem to be no motion or eastward one. The absorption spikes at 1153 UT also showed a westward drift motion at ZHS and DMH. On the contrary, the absorption spikes at 1222 UT associated with the steep pressure increase showed an eastward drift motion at ZHS and NYA.

3 Discussion

In earlier years, conjugate observations of cosmic noise absorption in the polar cusp / cap region were carried out by means of a conventional broad-beam riometer. Eriksen *et al.* (1964) demonstrated the occurrence properties of short-duration absorption events exceeding 1.0 dB which were usually corresponding to nighttime (nightside) absorption. Hargreaves and Chivers (1965) revealed that ionosphric absorption tended to be relatively greater in local winter at the magnetically conjugate pair of high-latitude stations. Rosenberg (1987) exhibited that ionospheric absorption showed simultaneous onsets and similar time variations between the hemispherical conjugate stations, but in some cases, the absorption appeared in one hemisphere only.

Using the IRISs at Ny-Ålesund / Longyearbyen in Svalbard and at ZHS, Nishino *et al.* (1998) examined conjugate features of nighttime ionospheric absorption. The nighttime absorption associated with substorms showed simultaneous occurrence between the hemispherical stations in some cases, but the small-scale structure of the absorption was different between them. The nighttime absorption sometimes showed non-simultaneous occurrence between the hemispherical stations. The conjugate feature might be related to the north-south (Bz) and east-west (By) components of the IMF. Yamagishi *et al.* (1998) revealed that the conjugate points of ZHS would be displaced eastward for the nighttime absorption events under the condition of By ~ -4 nT and Bz ~ -2 nT, which result was consistent to the conjugate relationship calculated by T-96 model (Tsyganenko and Stern 1996). As described above, conjugate features of ionospheric absorption have been examined for nighttime events so far, but the conjugate feature for daytime absorption has not been examined yet, as far as we know.

According to the daily variation of conjugate points of Zhongshan Station mapped to the northern hemisphere by the magnetic field-line tracing with the T-96 model for summer solstice under the condition of IMF By $=$ Bz $= 0$, no conjugate point was determined around the magnetic noon (Yamagishi *et al.* 1998). This indicates that the magnetic field-lines connecting between the hemispherical stations are opened. However, as described at the previous section, the post-noon absorption was identified between the hemispherical stations under the specific condition of high solar wind dynamic pressure. The absorption region was extended longitudinally by the sheet-shape of at least 700 km length, associated with the positive change of the By and the negative change of the Bz during the high solar wind dynamic pressure. Thereafter the absorption region was localized near DMH and NYA, associated with the steep increases of the dynamic pressure around 1135 UT and 1200 UT (WIND time) during the small Bz-variation, respectively. This result indicates that the present post-noon absorption may be caused by precipitation of magnetospheric electrons in the closed magnetic field lines, associated with the high solar wind pressure. Particularly it should be noted that the absorption spikes at 1222 UT and the subsequent quasi-periodic oscillation identified between ZHS and NYA were shifted equatorward, comparing with the absorption spikes at 1152 UT identified between ZHS and DMH.

Newell and Meng (1994) recently demonstrated a map projecting magnetospheric regions into the ionosphere based on electron precipitation characteristics under low (<2 nPa) and high (>4 nPa) solar wind pressure conditions, in which the lower latitude boundary layer (LLBL) in the closed magnetosphere is extended to the time sector between 0800 - 1600 MLT at the lower latitudes under the condition of high solar wind pressure. This statistical result obtained by plasma observations of DMSP satellite sustains the present feature of the post-noon absorption.

The feature that the post-noon absorption events mostly showed the spike-type is referred by Stauning and Rosenberg (1996). They interpreted that the post-noon absorption spikes would be generated by precipitation of high energy magnetospheric electrons (30 - 300 keV). The precipitation would be related to a dynamic inverted-V potential structure through the intensified field aligned currents (FAC) at the afternoon convection reversal. The spatial scale of the absorption spikes which they estimated was $\sim$ 200 km length in longitude with narrow width ($\sim$50 km) in latitude. This generation mechanism could be appropriated for the present post-noon absorption spikes. The precipitation of high-energetic magnetospheric electrons was actually evidenced by intense auroral arc observed by simultaneous all-sky TV observations at ZHS which showed the longitudinal extension with the narrow width in the field of view (not shown here).

Another feature that the drift motion of the absorption spikes shown by Fig. 2 was changed before and after the steep pressure increase (1200 UT WIND time) would be related to convection enhancement and associated flow reversal in the post-noon sector. This change should be discussed in details by using HF radar and ground magnetometer data obtained at the northern and southern polar regions. Also, further analysis of the conjugate relationship of daytime absorption events will be carried out in order to study electrodynamics in the dayside magnetosphere under variable conditions of the solar wind parameters.

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