Simultaneous Ground-Based Observations of Electric and Magnetic Field Variation Near the Magnetic Equator for Space Weather Study

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ABSTRACT

In order to clarify the global nature of penetration mechanism of DP 2 electric fields from the polar to the day- and night-side equatorial ionospheres, and to understand the solar wind-Earth's magnetosphere coupling as a space weather study, we have carried out simultaneous magnetic and electric field observations using the Frequency Modulated-Continuous Wave (FM-CW) HF radar and the Circum-pan Pacific Magnetometer Network. The DP 2 electric fields caused by the solar wind interaction with the Earth's magnetic field may be imposed on the polar ionosphere, and the ionospheric DP 2 electric fields are penetrating instantaneously from the polar ionosphere into both the day- and night-side equatorial regions.

INTRODUCTION

It is well known that daytime DP 2 magnetic variations observed on the ground are well correlated with changes of the solar wind Bz component (Nishida, 1968 a & b). Electric fields caused by the solar wind interaction with the Earth's magnetic field are believed to be imposed on the polar ionosphere and penetrate into the equatorial ionosphere (Nishida, 1968b; Kikuchi et al., 1996). DP 2 magnetic variations in the daytime are clearly seen on the ground in the equatorial region where the ionospheric Cowling conductivity is zonally enhanced, while those in the nighttime are difficult to observe because of the lower ionospheric conductivity. The dip equator is a peculiar region where the ionospheric conductivity is much larger than those at low latitudes, and therefore DP2 phenomena observed near the dayside dip equator can be a useful tool for monitoring the change of the interplanetary magnetic field (IMF) in the solar wind.

In order to clarify the global nature of the penetration mechanism of DP 2 electric fields from the polar to the day- and night-side equatorial ionospheres, and to understand the solar wind-Earth magnetosphere coupling as a space weather study, we have carried out simultaneous magnetic and electric field observations using the Frequency Modulated-Continuous Wave (FM-CW) HF radar (Nozaki et al., 1999) and the Circum-pan Pacific Magnetometer Network (CPMN; Yumoto et al., 1996; Tachihara et al., 1996; see the website of http://denji102.geo.kyushu-u.ac.jp/denji/obs/obs_e.html).

OBSERVATIONS

The magnetic field data at the CPMN stations in the opposite day/night equatorial regions were obtained at Davao (7.11°N, 125.61°E, Dip=-0.6°) in the Philippines and at Gadalupe (14.0°S, 75.95°W, Dip=-2.6°) in Peru. We measured electric field variations near the dip equator by means of a FM-CW HF radar, which was installed at the University of San Carlos Talamban campus, Cebu, Philippines (10.35°N, 123.91°E, Dip= 2.6°), during the WestPac campaign of February 18-March 29, 1999. The FM-CW HF radar with ionosonde mode was operated to deduce azimuthal ionospheric electric fields of DP 2 variations near the dip equator. Radio waves are emitted every 5 minutes with continuously sweeping frequency in the range of 2-19 MHz during about 3 minutes. The radar reflections of emitted radio-waves are expected to occur at ionospheric heights of 100-600 km in the dayside equatorial region. From temporal variations of the reflection heights of each 0.05 MHz bin radio-wave, we can estimate apparent upward/downward velocity (*Vd* ; i.e., within 60 m/s, which must be ***E*** x ***B*** drift velocity in the ionosphere). The ionospheric electric field variation (***E***) in the east/west direction can then be deduced, especially, in the ambient magnetic field (***Bo***) near the equatorial region, i.e., ***E*** = ***B*** x ***Vd***.

OBSERVATIONAL RESULTS

Fig. 1 shows diurnal variations of the H-component magnetic fields near the dip equator observed at Davao (7.11°N, 125.61°E, Dip= -0.6°) in the Philippines and at Gadalupe (14.06°S, 75.95°W, Dip= -2.6°) in Peru. We can see magnetic enhancements of Sq variations and DP 2 variations with several ten-minute periods during the local noon time of each station.

The upper panel of Fig. 2 shows ionograms obtained at Cebu (10.35°N, 123.91°E, Dip=2.6°) in the noontime interval from 01:40 to 01:55 UT (i.e., 10:40-10:55 LT) on March 2nd, 1999. The lower panel shows the H-component DP 2 magnetic variation simultaneously observed at the Davao station at nearly the same local time. The time variations of the reflection heights at each 0.05 MHz bin radio-wave emitted every 5 minutes

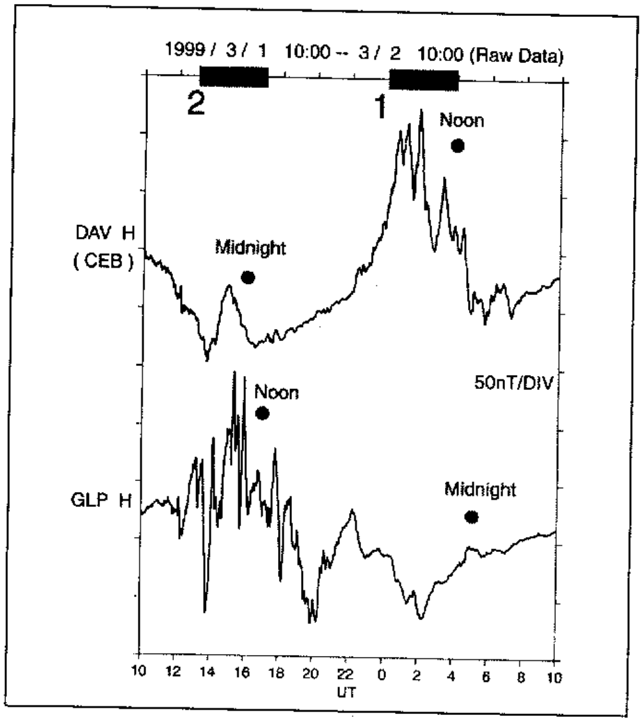

Fig. 1. Diurnal variations of the H-component magnetic fields near the magnetic dip equator stations at Davao in Philippines and at Gadalupe in Peru on March 2, 1999

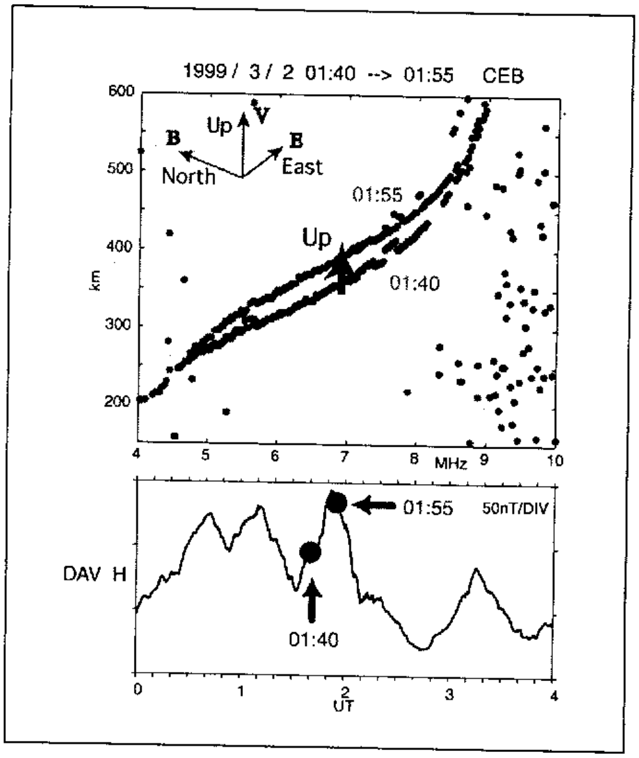

Fig. 2. (Upper) Ionograms obtained at Cebu in the noontime of 10:40-10:55 LT on March 2, 1999. (Lower) H-component DP 2 magnetic variation simultaneously observed at Davao

show apparent upward velocity at each 0.05 MHz bin, which must be caused by ***E*** x ***B*** drift in the ionosphere. In the interval from 10:40 to 10:55 LT, the ionospheric electric field must be oriented in the eastward direction near the dip equator. From the upward/downward velocity at each reflection height, the azimuthal ionospheric electric fields are deduced, and plotted as time-height diagrams (Fig. 3.). Upper and lower panels of the figure show the estimated azimuthal electric fields at each reflected height at Cebu, and the DP 2 magnetic field observed at Davao, respectively. The red and blue colors indicate east and westward electric fields, respectively. It is noteworthy that the estimated electric field and the observed H-component magnetic field show a good correlation to each other.

We further calculated the averaged electric field in the region from lower to upper reflection heights during each 5 minute period in Fig. 3, in order to see more clearly the relationship between the electric and magnetic fields of DP 2. Fig. 4 shows the correlation charts of the average ionospheric electric field and the H-component magnetic field observed simultaneously at the dayside equatorial stations. The vertical axis indicates eastward (upward) and westward (downward) electric fields. It is found that the H-component DP 2 magnetic variations show a clear in-phase relation to the azimuthal ionospheric electric fields observed simultaneously at the dayside station. The DP 2 magnetic variations observed on the ground are due to the enhanced ionospheric current caused by the DP 2 electric field in the daytime equatorial region.

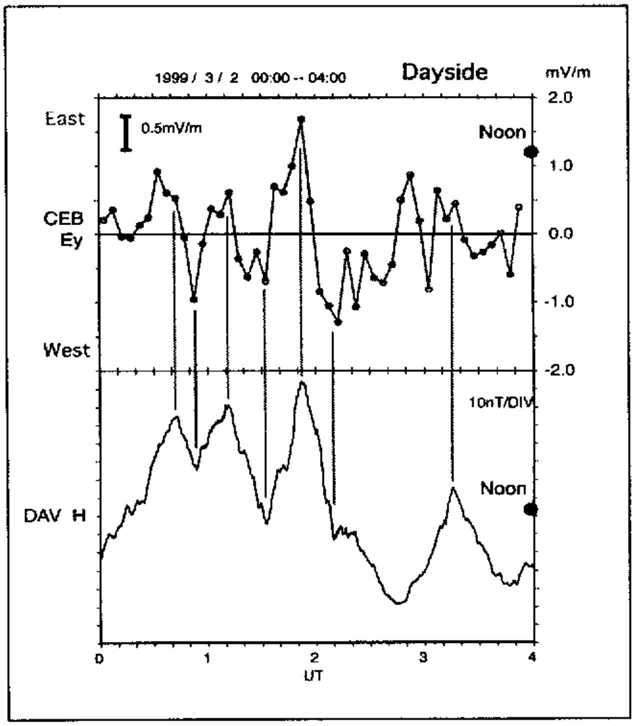

Fig. 4. The correlation chart of the averaged ionospheric electric field obtained from the upper panel of Fig. 3 and the H-component magnetic field observed simultaneously at the dayside equatorial Davao stations in the interval of 00:00 – 04:00 UT on March 2, 1999

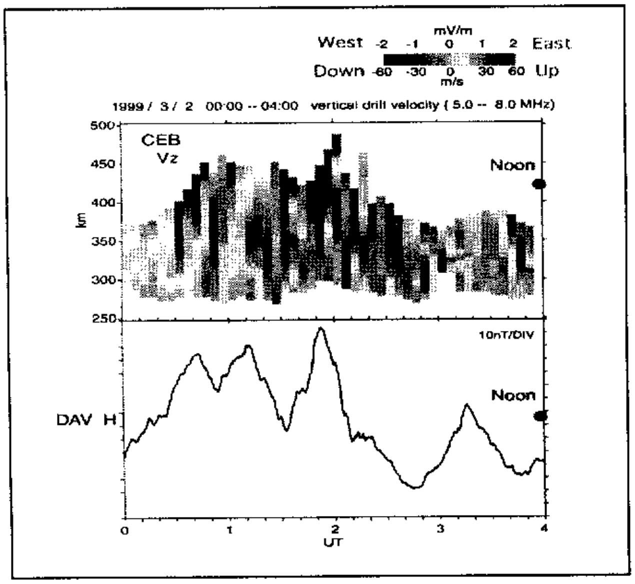

Fig. 3. (Upper) Time-height diagram of estimated azimuthal electric fields at each reflected heights at Cebu, estimated by using upward/downward velocity at each reflection heights during the interval of Fig. 2. The red and blue colors indicate east and westward electric fields, respectively. (Lower) DP 2 magnetic field simultaneously observed at Davao.

In order to clarify characteristics of DP 2 electric field, penetrating into the nightside equatorial ionosphere, we also examined the relationship between dayside H-component DP 2 magnetic variation at Gadalupe (14.06°S, 75.95°W, Dip= -2.6°) in Peru and nightside electric field variation at Cebu (10.35°N, 123.91°E, Dip= 2.6°) in the Philippines. Fig. 5 shows correlation charts of the averaged ionospheric electric field in nighttime and the H-component magnetic field in the daytime equator. It is noteworthy that the azimuthal ionospheric electric field variations in the nighttime equatorial region show a clear out-of-phase relation to the H-component DP 2 magnetic variations in the daytime equatorial region.

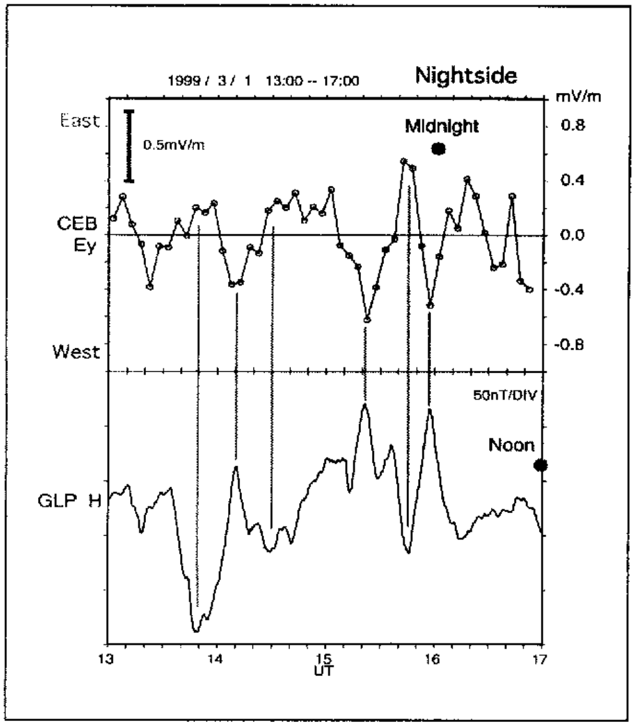

Fig. 5. The correlation chart of the averaged ionospheric electric field at Cebu, Philippines, in nighttime and the H-component magnetic field at Gadalupe, Peru, in the daytime equator in the interval of 13:00 – 17:00 UT on March 3, 1999

SUMMARY AND CONCLUSION

The peculiarities of simultaneous observations of electric and magnetic fields near the magnetic equator can be summarized as follows:

1. H-component DP 2 magnetic variations and the azimuthal ionospheric electric fields observed simultaneously at the dayside equatorial stations show a clear in-phase relation.

2. Amplitudes of DP 2 magnetic variations observed at the nightside equatorial station are very small and/or negligible, but the azimuthal ionospheric electric field variations near the Dip equator during nighttime are found to show a clear out-of-phase relation to the H-component DP 2 magnetic variations in the daytime equatorial region.

These results suggest that the ionospheric electric field variations associated with DP 2 are not in the zonal, but oriented in the dawn to dusk (or vice versa) direction in both the day- and night-side equatorial regions. The DP 2 electric fields caused by the solar wind interaction with the Earth's magnetic field are imposed on the polar ionosphere, and the ionospheric DP 2 electric fields are penetrating instantaneously from the polar ionosphere into the day- and night-side equatorial regions. This is not consistent with the magnetic zonal variation near the equator reported by Nishida (1986b), but consistent with the result of Gonzales et al. (1979). The DP 2 magnetic variations observed on the ground in the daytime equatorial region are due to the enhanced ionospheric current caused by the DP 2 electric field, while the magnetic variations on the ground in the nightside equatorial region may not be produced sufficiently by the ionospheric electric field because of the lower ionospheric conductivity during nighttime.

It is concluded that simultaneous ground-based observations using multi-techniques are a useful tool to clarify the nature of transfer and/or penetration mechanisms of global electric fields from the polar ionosphere into the day- and night-side equatorial regions, and to understand the coupling mechanisms between the solar wind and the Earth's iono-magnetosphere for the space weather study.

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