IONOSPHERIC ELECTRIC AND GROUND MAGNETIC PC5 VARIATIONS AT LOW-LATITUDE STATIONS

ВАРИАЦИИ ИОНОСФЕРНОГО ЭЛЕКТРИЧЕСКОГО И НАЗЕМНОГО МАГНИТНОГО ПОЛЕЙ, СВЯЗАННЫХ С PC-5 ПУЛЬСАЦИЯМИ, НА НИЗКОШИРОТНЫХ СТАНЦИЯХ

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Пульсации Pc-5 (1мГц — 6,7 мГц) наблюдаются по всему миру на дневной стороне с помощью наземной сети. В частности, низкоширотные и экваториальные пульсации Pc-5 характеризовали токовую систему типа DP 2 в ионосфере. Тем не менее, наблюдения в ионосфере показывают другое. Мы предполагаем, что более широкое использование ВЧ радаров даст лучшее понимание пульсаций Pc5 в ионосфере и магнитосфере.

Настоящее исследование основано на данных с FM-CW радара, расположенного в Сасагури, Япония (SAS; Широта = 23.2 градусов, Долгота = 199.6 градусов, LT = UT + 9.5 часов). FM-CW радар — это радар типа ВЧ, который может измерять диапазон целей, таких как доплеровское смещение радиоволн, отраженных от цели (например, от ионизированного слоя). Из наблюдаемого Доплеровского смещения мы можем рассчитать восточно-западно направленное электрического поля в ионосфере.

30 октября 2003 года пульсация Pc-5 была обнаружена в горизонтальной компоненте (H) в дневное время на экваториальной станции (YAP) с большой амплитудой 30 – 50 нТ. Также были обнаружены колебания доплеровской скорости (V) (примерно 25м/с) в диапазоне Pc 5 в дневное время на станции SAS. Наземные магнитные вариации Pc 5 могут быть вызваны ионосферными электрическими полями.

Разность фаз между экваториальными H и V на SAS составила примерно -30 градусов на частоте пульсаций 2 мГц. Разность фаз стала меньше с увеличением частоты. На 8 мГц задержка фаз между H и V была примерно 90 градусов. Такое соотношение фаз можно объяснить используя эффект индукции из-за высокой ионосферной проводимости на дневной стороне экватора.

Introduction

Low-latitude Pc5 pulsations (150-600 sec.) are observable by the ground-based magnetometers. Ziesolleck and Chamalaun [1993] examined the characteristics of low-latitude Pc5 pulsations. They showed that the amplitude of Pc5 pulsation decreased with decreasing of geomagnetic latitude, and concluded that the low-latitude Pc5 was caused by the global compressional wave. On the other hand, Motoba *et al.* [2002] examined Pc5 pulsation by ground magnetic field data obtained from many stations. They found that the DP2-type current system excited low-latitude ground Pc5 magnetic pulsation.

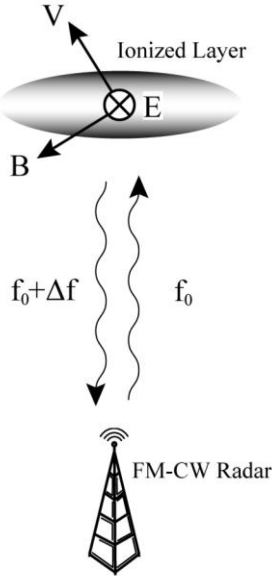

Figure 1. A schematic diagram of the Doppler measurement by an FM-CW radar.

Some researchers reported Pc5 pulsations by using ionosphere Doppler observations. Reddy *et al.* [1994] showed that the Pc5 oscillation in the Doppler frequency at the daytime equator correlated with ground magnetic field variation at afternoon high-latitude stations. They argued that the Pc5-range Doppler oscillations in the equatorial ionosphere were caused by the ionospheric electric field penetrating from high latitudes to the equator. In addition, Motoba *et al.* [2004] showed that daytime and nighttime Pc5 pulsations in the Doppler frequency were caused by dawn-to-dusk polar electric fields at low latitudes. Thus the ionospheric oscillation is seems to be caused by DP2 type current system.

However, observations in the ionosphere are not so much reported. Especially phase relation between ground magnetic Pc5 and ionospheric electric fields are not examined well.

We believe that more extensive use of HF radars will lead to a better understanding of Pc5 pulsations. In this paper, we examine the general relationship between the ground magnetic and ionospheric electric fields.

Data Set

The present study is based on the data from FM-CW radar located at Sasaguri, Japan (SAS; M. Lat. = 23.2 degree, M. Lon. = 199.6 degree, LT = UT + 9 hrs). The FM-CW radar is a type of HF radar that can measure the range of target as well as Doppler shift for reflected radio waves from the target (e.g., ionized layer). This application of the FM-CW radar is a variation of a technique developed by Barrick [1973] to measure sea scatter. We target the ionospheric F region for Doppler measurement. Our radar is an improved version of the FM-CW radar developed by Nozaki and Kikuchi [1987, 1988]. We have succeeded in detecting geomagnetic phenomena by using of this type of radars [*e.g.*, Ikeda *et al.*, 2010].
The observed Doppler frequency Δf is represented by

$$\Delta f = \frac{v \times 2f0}{c} \qquad (1)$$

, where $f0$ is the transmitting frequency and v is vertical drift velocity of the ionosphere describe by

$$v = \frac{\Delta f \times c}{2f0} \qquad (2)$$

We use low frequency (e.g. 2.5 MHz) for the transmitting frequency $f0$ at night, and use higher frequency (e.g. 8.0 MHz) at daytime. The data of Doppler velocity are digitized with 3-sec or 10-sec sampling. The data accuracy of the vertical drift velocity is 1.5 m/s at 8.0 MHz.

By assuming that the v is caused by the frozen-in effects in the ionosphere, we can estimate the east-west ward electric field (Ey). The equation of the frozen-in effect is described

$$E = -V \times B \qquad (3)$$

, where E is east-west electric field (Ey), and B is the horizontal component (H component) of the ambient magnetic field intensity in the ionosphere, and v is obtained by FM-CW radars. A schematic diagram of the Doppler measurement by an FM-CW radar is shown in Fig. 1 .

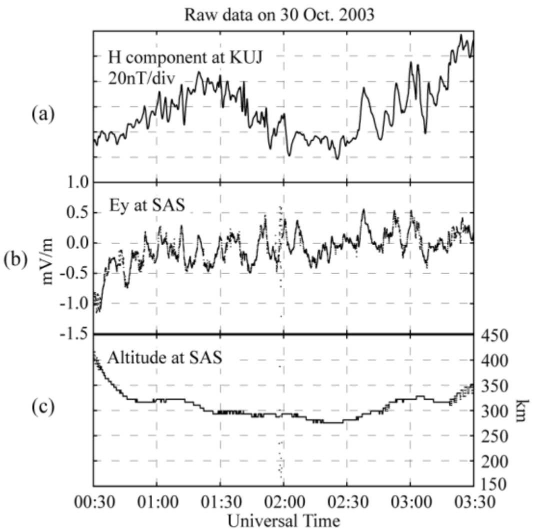

Figure 2. Waveform of daytime Pc5 on 30 Oct. 2003. Shown are H at KUJ, Ey at SAS, and observed altitude of Ey at SAS.

For comparison with ionospheric Ey, we analyzed ground magnetometer data obtained at the Circum-pan Pacific Magnetometer Network (CPMN) stations. [Yumoto et al., 1996; Yumoto et al., 2001]. The selected magnetic station was located at low latitude, Kuju, Japan (KUJ: M.Lat = 23.6 degree, M.Lon. = 203.2 degree, LT = UT + 9 hrs.).

Data Analysis

Figure 2 shows Pc5 event on 30 October 2003 in the time period of 00:30-03:30 UT. This period was in a storm which occurred on 29 October 2003 with sudden commencement (SC). The panel (a), (b), and (c) show the horizontal component (H) of ground magnetic field at KUJ, Ey calculated from the v at SAS, and the observed altitude of v at SAS, respectively. KUJ and SAS were located at the local daytime sector during this period.

We found large-amplitude Pc5 in the H at KUJ. Also Ey at SAS showed Pc5-range oscillation correlated with the Pc5 in the H. During this event, v was observed at the virtual height of about 300 km with transmitting frequency of 8.0 MHz. Therefore, the radar echo was obtained from the ionospheric F region.

Band-pass filtered data of the H and Ey are shown in Fig. 3. Maximum peak-to-peak amplitudes of the H and Ey are ~30 nT and ~0.55 mV/m, respectively.

Figure 4 shows the correlations between the H-component Pc5 wave forms observed at KUJ and Ey at SAS. We calculated the correlation coefficient by using the band-pass filtered data (Fig. 2). Here the negative lag means H leads, and the positive lag means the Ey leads. The maximum correlation coefficient was 0.62 with small time shift of 13 seconds. Therefore, the magnetic and electric Pc5 was excited almost simultaneously.

Discussion and Summary

We examined Pc 5 pulsations on 30 Oct. 2003. We found that the Pc5-range oscillations appeared in ground magnetic field H and ionospheric Ey simultaneously. The Pc5 amplitude in the H at KUJ and in the Ey at SAS are ~30 nT and ~0.55 mV/m, respectively. The time lag between H and Ey was 13 seconds. Since H and Ey in Pc5 range oscillated without significant phase delay, it seems that the ground magnetic Pc5 is caused by the ionospheric electric fields which drive ionospheric current.

Acknowledgement

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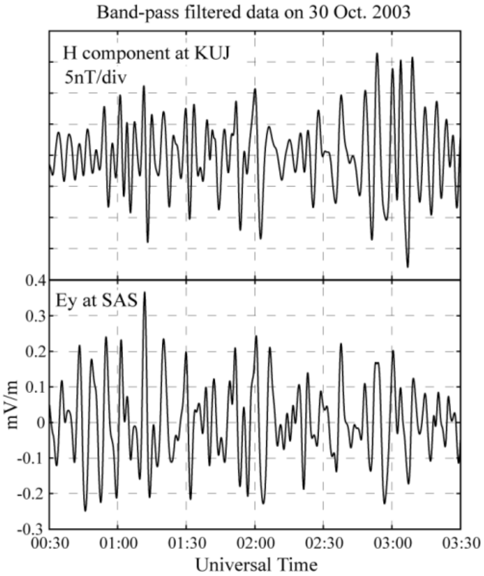

Figure 3. Band-pass filtered (150-600 s) data of the H and the Ey. The time interval is the same as Fig. 1. The top and bottom panels, show the filtered H at KUJ, and the filtered Ey at SAS, respectively.

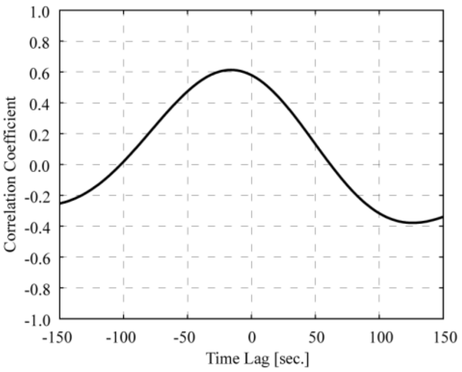

Figure 4. Correlation Coefficient between H at SAS and Ey at SAS. The negative lags means the H leads, and the positive lags means the Ey leads.

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ВРЕМЕННЫЕ ИЗМЕНЕНИЯ ВЕКТОРОВ ВИЗЕ В НЕКОТОРЫХ СЕЙСМОАКТИВНЫХ РЕГИОНАХ МИРА

TIME CHANGES OF THE WIESE VECTORS IN SOME SEISMIC ACTIVE REGIONS OF THE WORLD

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The results of long term investigations of Wiese vectors in the Transcarpathian deep are shown. Analysis of anomalous changes of induction arrows and seismic activity in the vicinity of observation point allows us to find out the dependencies between anomalous changes of Wiese vectors and earthquakes epicenters localizations. For the analysis of the Wiese vectors changes we developed algorithms and programs, which allowed carrying out high resolution in time of calculations of these vectors. The relationships of the seasonal and diurnal changes of the Wiese vectors were obtained in Transcarpathian deep, magnetic observatory "Irkutsk" (Russia), and magnetic observatories of Japan.

Компоненты вектора Визе A, B определяются как коэффициенты линейной комбинации вариаций компонент геомагнитного поля: $\delta Z = A\ \delta X + B\ \delta Y$. Компонента A направлена на север, а B – на восток. Построенная по этим компонентам стрелка указывает направление от аномалии электропроводности. Величины A, B часто называют также передаточными функциями геомагнитного поля. Временные изменения передаточных функций могут вызываться различными факторами. Значительное количество исследований посвящены изучению аномальных временных изменений векторов Визе при подготовке сильных землетрясений. Весьма интересные результаты получены в сейсмоактивных регионах Китая и Японии [1-3]. Похожие исследование проводятся свыше 20 лет на Карпатском геодинамическом полигоне (рис.1) в сейсмоактивном Закарпатском прогибе.

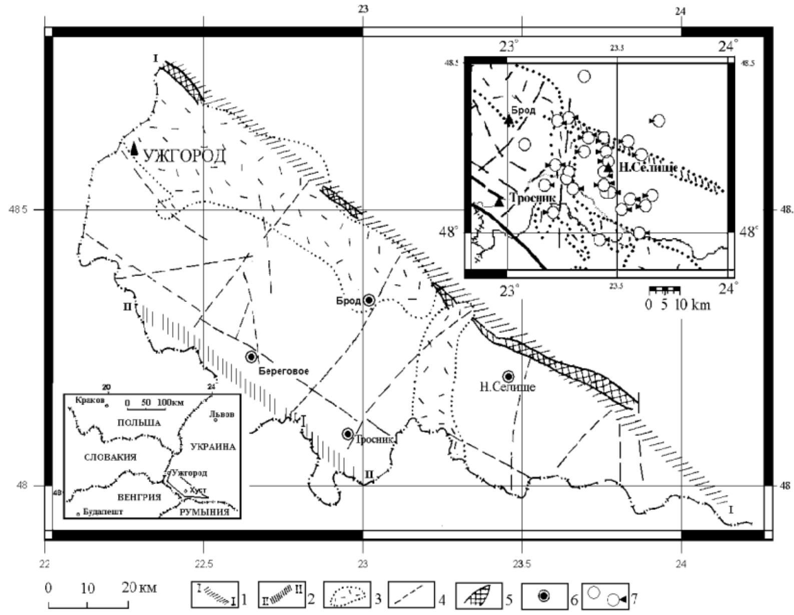

Рис. 1. Карпатский геодинамический полигон:
1 – Закарпатский глубинный разлом, 2 – Припаннонский глубинный разлом, 3 – Выгорлат-Гутинская вулканическая гряда, 4 – разломы донеогенового фундамента Закарпатского прогиба, 5 – Пенинская зона, 6 – режимные геофизические станции, 7 – эпицентры местных землетрясений. Геологическая основа с [4]

Поскольку местная сейсмичность в Закарпатье довольно слабая, убедительных связей временных изменений векторов Визе с местными землетрясениями не обнаружено. Однако некоторые корреляции с распределением сейсмичности были замечены [5]. Для землетрясений,