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REAL-TIME MONITOR OF GEOMAGNETIC FIELD IN THE NEAR-POLE REGIONS AS AN INDEX OF MAGNETOSPHERIC ELECTRIC FIELD

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Abstract: Solar wind electric field that penetrates into the magnetosphere is an important key for causes of magnetospheric disturbances. Since *PC* index, produced from the variation of the magnetic field in the near-pole regions is known to be a good indicator of magnetospheric electric field, monitoring the magnetic activity in the near-pole regions in real-time is useful for nowcasting/forecasting space weather. From the comparison of horizontal components of the magnetic field data between two stations, Eureka and Thule, it is found that the correlation between these two stations are quite high except for the summer months. This result suggests that magnetic field variations in the near-pole region are uniform, and the index can be produced throughout the year using magnetic field data in the northern and southern near-pole region.

1. Introduction

Solar wind-magnetosphere interactions have been studied for several decades. Solar wind electric field that penetrates into the magnetosphere plays a key role for magnetospheric disturbances. Plasma convections are induced by the electric field that penetrates into the magnetosphere (OBAYASHI and NISHIDA, 1968). The geomagnetic storm is caused by the enhanced electric field in the magnetosphere (*e.g.*, GONZALEZ *et al.*, 1994). Furthermore, the plasma transported to the inner magnetosphere under magnetospheric electric field is a possible source of relativistic electron enhancement (LI *et al.*, 1997).

In-situ observation of the solar wind in front of the magnetosphere is one of the way to estimate magnetospheric electric field. Recently, ACE satellite in orbit around the L 1 point provides us nearly 24-hour real-time solar wind data for space weather forecast (ZWICKL and JOSELYN, 1997). However, the solar wind observation at L1 point does not always predict solar wind conditions affecting the Earth (CROOKER *et al.*, 1982; RICHARDSON *et al.*, 1998). For comparative studies and space weather forecast, it is meaningful to estimate magnetospheric electric field independently from the ground-based observations.

While it is difficult to monitor the electric field in the magnetosphere directly, the electric field projected onto the ionosphere can be estimated from HF radar (*e.g.*, RUOHONIEMI *et al.,* 1989) and geomagnetic field observations (*e.g.,* FRIIS-CHRISTENSEN *et al.,* 1985). From the space weather forecast point of view, the information about the magnetospheric electric field is continuously needed in real time. While HF radar observations cannot always measure the magnetospheric electric field due to the lack of radar echoes from the ionosphere, magnetic field observations can be always used for estimating the electric field.

The purpose of this paper is to examine the usefulness and limitation of geomagnetic field at a single station in the near-pole regions as an index of the magnetospheric electric field and to examine the merits of real-time monitoring. Further, the future plan for the real-time monitor of geomagnetic field in the near-pole regions is introduced.

2. The Characteristics of Magnetic Field Variations in the Near-Pole Regions

It is well known that the two-cell convection pattern at high latitudes named the *DP* 2 current system depends on solar wind parameters (NISHIDA, 1968). Based on this information, TROSHICHEV *et al.* (1979) proposed the polar cap (*PC*) index. The *PC* index is produced from the horizontal component of the magnetic activity in the near-pole regions. A detailed description of this index is shown in TROSHICHEV *et al.* (1988). Only one geomagnetic observatory in each of the near-pole regions is used to make this index. Currently, the *PC* index is derived independently from Thule and Vostok. From the results of TROSHICHEV *et al.* (1988), the *PC* index shows a good correlation with the merging electric field $E_m = V_{SW} B_T \sin^2(\theta/2)$ introduced by KAN and LEE (1979). Daily and seasonal variations are statistically normalized with respect to E_m from the linear correlation analysis. The *PC* index correlates well with *AE, AL,* and *AU* indices (VENNERSTROM *et al.,* 1991). Therefore, the *PC* index is affected from *DP* 1 current system as well as from *DP* 2 current system. Magnetic field variations in this region are caused by the Hall current in the polar cap and field-aligned current at the poleward rim of the auroral oval (VENNERSTROM *et al.,* 1991). PRIMDAHL and SPANGSLEV (1977) suggests that during the sunlit conditions the dominant source is ionospheric Hall currents, while the distant field-aligned currents are dominant in darkness.

An example of the scatter plot of 1 hour averaged *PC* versus E_m estimated from WIND data in September 1995 is shown in Fig. 1. *PC* shows a good correlation with E_m. The linear correlation coefficient, 0.80 is one of the best case of this year. The average linear correlation coefficient in this year is 0.74. This is consistent with the correlation analysis by TROSHICHEV *et al.* (1988). There is some reason for the scattering of the data point in Fig. 1. The contribution from *DP* 1 current system causes the contamination in the relationship between the magnetospheric electric field and the *PC* index. IMF *By* component controls the flow pattern of *DP* 2 and modulates the *PC* index (VENNERSTROM *et al.,* 1991). Therefore, we should notice that the *PC* index has some limitation as an index for the magnetospheric elecric field.

The *PC* index will be possibly used for forecasting geomagnetic storms and flux enhancement of relativistic electrons at the outer radiation belt. NAGATSUMA *et al.* (1998) suggested that the ring current development is estimated from the *PC* index since

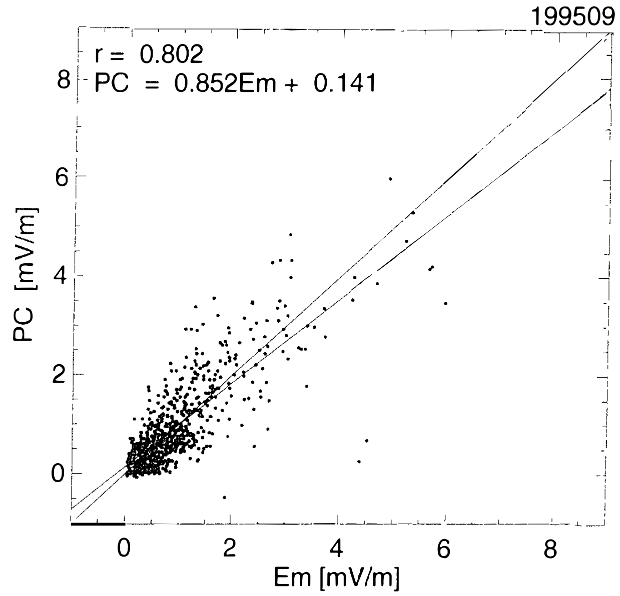

Fig. 1. Scatter plot of one hour averaged PC versus E_m in September 1995.

the *PC* index shows a good correlation with the energy injection rate of the ring current. OBARA *et al.* (1998) shows the correlation between the *PC* index and the enhancement of relativistic electrons at geosynchronous orbit.

3. Comparison of Geomagnetic Field Variations between Thule and Eureka

As shown in the previous section, *PC* index has been shown to be useful as an index of the magnetospheric electric field. However, it is necessary for us to check whether or not the *PC* index based originally on the observed data at only one station can be assumed to represent a wide region in the polar cap. To confirm the uniformity of magnetic field variations in the near-pole region, we compared the geomagnetic field data obtained from two stations, Thule (CGMLat. (1994): 85.7 deg., CGMLon. (1994): 34.5 deg.) and Eureka (CGMLat. (1994): 88.8 deg., CGMLon. (1994): 317.86 deg.). Yearly variations of average correlation coefficient of two horizontal components of the geomagnetic field at Thule and Eureka in 1994 are shown in Fig. 2, for daily correlation values and monthly average with solid dots. It is seen that the correlation tends to be high except for summer. This result suggests that the geomagnetic field variations in the near-pole region are uniform except the summer months, supporting the view that the dominant source of the variations is distant field-aligned currents due to the low ionospheric conductivity as PRIMDAHL and SPANGSLEV (1977) suggested. In summer, it is suggested that a new equivalent current system is formed within the polar cap under the northward IMF condition (MAEZAWA, 1976) and localized current systems are significant due to high ionospheric conductivity. These current systems can produce the difference of magnetic field variations at Thule and Eureka.

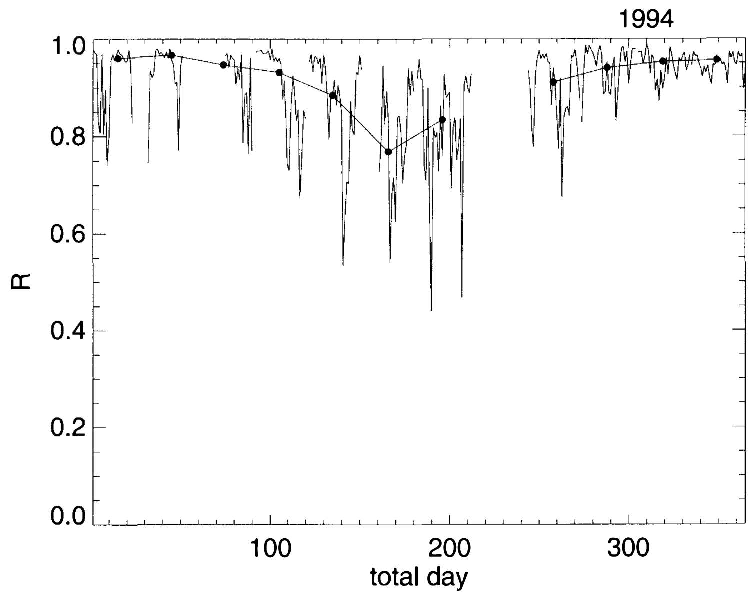

Fig. 2. Variations of average correlation coefficient of two horizontal component of geomagnetic field from Thule and Eureka in 1994.

4. Merits of Real-Time Monitoring

Monitoring of geomagnetic field in real-time has several merits. One of them is keeping track of the current conditions of the geomagnetic field variations for the space weather. As we already have shown in the previous section, the geomagnetic field variations in the near-pole regions can be used as an index of the magnetospheric electric field.

Secondly, these data can be used as the input parameters of the space weather prediction models and be compared with the output from these models. Since daily space weather conditions should be predicted for the space weather forecast service, comparisons between daily observations and predictions from the model during quiet and active conditions are necessary for evaluating the space weather forecast.

5. Project for Monitoring the Geomagnetic Field in the Near-Pole Regions

We have a plan to monitor geomagnetic field variations in the northern and southern near-pole regions in real-time for nowcasting of geomagnetic field disturbances. Using magnetic field data in the northern and southern near-pole region, the index can be produced throughout the year since magnetic field data from antipodal stations are used when one hemisphere is in summer. The data from Eureka will be collected as the data from northern near-pole region, since we are already collecting the data from Vostok in the southern near-pole region under other collaborative project. At Eureka, fluxgate and search coil magnetometers have been operated since 1992. The data stored by tape have been sent every month.

Recently the telecommunication line and Internet via geosynchronous satellite are stabilized since an improved telecommunication system has been installed at Eureka.

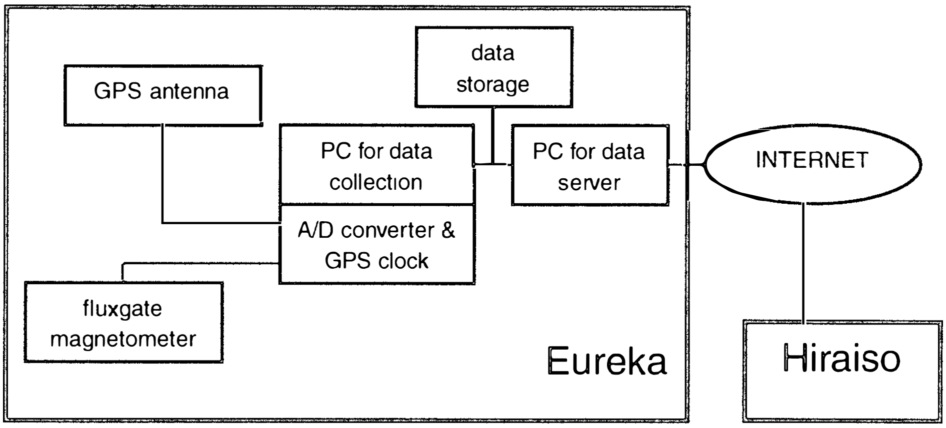

Fig. 3. Schematic diagram of the real-time geomagnetic field monitoring system.

Table 1. The list of magnetic observatories. The geomagnetic field data from these observatories are collected at Hiraiso in near-real time.

Name	Latitude	Longitude	Note
Tixie Bay (suspend)	71.58	129.00	INTERMAGNET
Memambetsu	43.90	144.20	INTERMAGNET
Hiraiso	36.37	140.63	CRL (Local observation)
Kakioka	36.23	140.18	INTERMAGNET
Okinawa	26.75	128.22	Other project at CRL
Guam	13.58	144.87	Other project at CRL
Amsterdam Is.	−37.80	77.57	INTERMAGNET
Dumont d'Urville	−66.37	140.01	INTERMAGNET
Vostok	−78.45	106.87	(INTERMAGNET)

To collect geomagnetic field data in real-time via Internet, the system for data transmission connects to the LAN at Eureka.

The configuration of our system is shown in Fig. 3. Two computers are used at Eureka site. One computer is for data collection. Three analogue outputs from the fluxgate magnetometer are digitized by an A/D converter with time adjustment for the GPS clock. Another computer is for the data server. This data server automatically transmits the data with a sampling rate of 1 minute every 12 minutes to Hiraiso site. Geomagnetic field data are stored by the disk unit shared by both of them. This system will be installed at Eureka in the summer of 1999.

Currently, the geomagnetic field data shown in Table 1 are collected in real-time. The interactive plot of these data can be obtained on our Web page.

http://crlgin.crl.go.jp/sedoss/geomag-interface

The data from Eureka will be monitored by the same plot.

6. Summary

The *PC* index produced from the magnetic field data in near-pole regions is useful for an index of the magnetospheric electric field. From the comparison between horizontal components of the magnetic field data at Eureka and those at Thule, it is found that the correlation between these two stations are quite high except summer months. This result suggests that the magnetic field variations in the near-pole region are uniform, and the *PC* index produced from geomagnetic field data at a single station suffices as an index of the magnetospheric electric field except summer months. Using the magnetic field data in the northern and southern near-pole regions, the index can be produced throughout the year since the magnetic field data from antipodal stations are used when one hemisphere is in summer. Real-time monitoring of magnetic field data is useful for status check of magnetometer as well as for the space weather forecast. The data collection system for geomagnetic field observations is planned at Eureka, as well as for the study of the relationship between solar wind variations and geomagnetic field variations in the polar cap regions. These data will be used for the monitor of geomagnetic field and the magnetospheric electric field.

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