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MIDSUMMER DECREASE IN VERTICAL GEOMAGNETIC FIELD AT THE MAGNETIC POLE UNDER STRONG SOLAR RADIATION INTO THE POLAR IONOSPHERE

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Abstract: The vertical component of the geomagnetic field Z on the ground shows a noticeable decrease in midsummer, amounting to several tens of nT, in the polar region at and around the geomagnetic pole. This peculiar phenomenon seems to be attributable to the eastward Hall current in the sunlit polar ionosphere at the lower E region produced by the perpetual eastward neutral wind in the summer season, which is recently detected with the EISCAT experiment.

1. Introduction

In the polar region of the earth the vertical intensity of the geomagnetic field Z reveals a noticeable decrease in midsummer, amounting even to several tens of nT around the geomagnetic pole. This peculiar phenomenon restricted to the sunlit polar region has been well known since the Second Polar Year 1932–33, through an extensive analysis of the world geomagnetic records by VESTINE *et al.* (1947). Later with the data during IGY 1957–58 and subsequent years, a number of interestng and important papers have been published concerning this midsummer characteristic of the geomagnetic field in the Arctic region, for example, in NISHIDA *et al.* (1966), FRIIS-CHRISTENSEN *et al.* (1971, 1972), IWASAKI (1971), SVALGAARD (1973), and NAGAI and FUKUSHIMA (1979a, b). RODGERS (1980), LANZEROTTI *et al.* (1994), and MANSUROV and MANSUROVA (1971) demonstrated that the same kind of Z-decrease was also observed during local summer seasons in the Antarctica.

The midsummer decrease in the geomagnetic Z-values on the ground seems to be restricted to the polar regions with geomagnetic latitudes higher than 75°, referring to Fig. 1 showing the smoothed monthly-mean H and Z values at Canadian stations. An equivalent overhead electric current-system for the peculiar Z-decrease in the summer polar-cap region seems to be an eastward zonal current flowing at the geomagnetic latitude above 75°. At the Japanese Antarctic Syowa Station (69.00°S, 39.58°E; geomagnetic latitude $-70.25°$) the midsummer decrease in Z does not seem to be observed.

2. Intense Solar Radiation into the Summer Polar Region

Figure 2 shows the latitude dependence of the daily-mean values of the solar radiation received on the earth, for the equinoctial (solar declination δ is 0) and solstitial

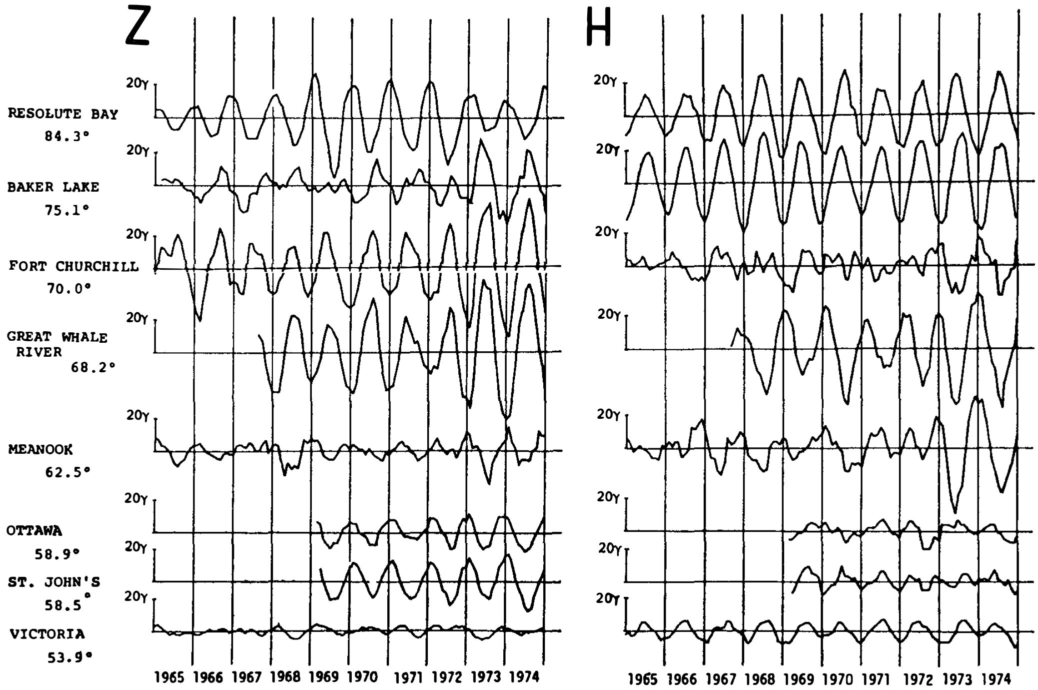

Fig. 1. Filtered monthly means for H and Z values at Canadian magnetic observatories in the period 1965–1974 with the corrected geomagnetic latitude (after NAGAI and FUKUSHIMA, 1979a).

($\delta=23.5°$) seasons, after neglecting the absorption of the radiation during its passage through the earth's atmosphere. The ordinate of the diagram is taken here to be unity at the equator for the equinoctial season. The actual calculation of the curves was carried out in the following way.

On the sunlit side of the spherical earth of radius r_E, the zenith angle χ of the sun with its declination δ at point P ($r_E \sin\theta \cos\phi$, $r_E \sin\theta \sin\phi$, $r_E \cos\theta$) is given by

$$\cos\chi = \cos\delta \sin\theta \sin\phi + \sin\delta \cos\theta,$$

and

$$I(\theta) = \frac{1}{2}\int \cos\chi \, d\phi \quad (\text{for } \chi \leqq 90°, \text{ in the sunlit region})$$

was calculated with different θ-values for two ranges of (1) $0° < \theta < 23.5°$ and (2) $23.5° < \theta < 156.5°$, where region (1) is illuminated throughout a day without sunset. In region (2) the range of ϕ for integration depends on the colatitude θ of the observing point on the earth; ϕ ranges from 2π to 0 with changing θ from 23.5° to 156.5°. The region of $156.5° < \theta < 180°$ is the dark polar region without sunshine in winter.

We see in Fig. 2 that the daily amount of solar radiation incidence to the earth and its atmosphere is strongest at the geographic pole in the summer hemisphere. The calculated result for region (1) shows that the daily-mean amount of solar radiation incidence in the summer polar region is $\pi\cdot\sin\delta\cdot\cos\theta$-times that at the geographic equator in the equinoctial season. Such a strong incidence of solar radiation at the pole

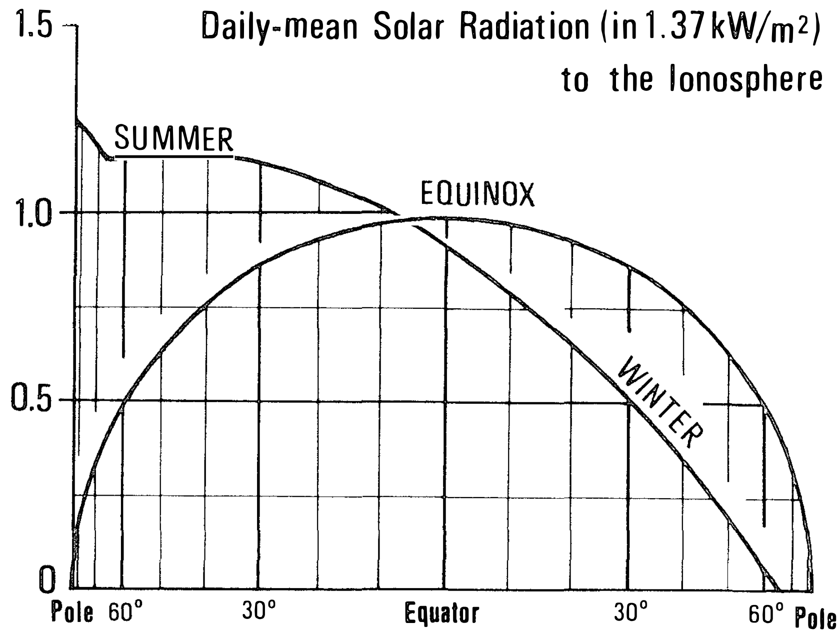

Fig. 2. Daily-mean intensity of solar radiation depending on the latitude of observing points in the equinoctial and midsummer-midwinter seasons.

takes place if $\delta > \sin^{-1}(1/\pi)$ *i.e.* 18.56°. At the June solstice, the ratio of the total solar radiation incidence into the summer and winter hemispheres amounts to 2.3. Hence, insofar as the energy balance in the earth and its atmosphere is concerned, the summer hemisphere is a heat source, whereas the winter hemisphere is a sink region in solstices.

3. A Reasonable Interpretation for the Peculiar Decrease in Geomagnetic Z-Field in the Summer Polar Region

The peculiar decrease in the geomagnetic Z-field in the polar region of the earth restricted to the summer season must be originated primarily in the space above the earth, most probably in the lower ionosphere of 100–120 km in height, where the Hall conductivity shows a sharp maximum in its height-profile.

The global wind system in the ionospheric region over the earth is not yet fully known, in particular at high latitudes in the polar regions. However, it would not be unreasonable to assume the presence of an upward prevailing wind over the polar region at the summer solstice due to the strong solar radiation, which is to be accompanied by horizontal poleward wind possibly even in the lower ionosphere. The Coriolis force on the rotating earth will turn the poleward air motion gradually eastward, so as to produce eventually an eastward-flowing zonal wind, as schematically illustrated in Fig. 3.

The author is pleased to know that the analysis of recent EISCAT experiment data discovered the presence of a perpetual strong (~40 m/s) eastward neutral jet wind over Tromsø (geographic latitude 69.66°N) in the lower E-region (height between 96 and 119 km) on summer quiet days, independently of solar activity (NOZAWA *et al.,* 1997;

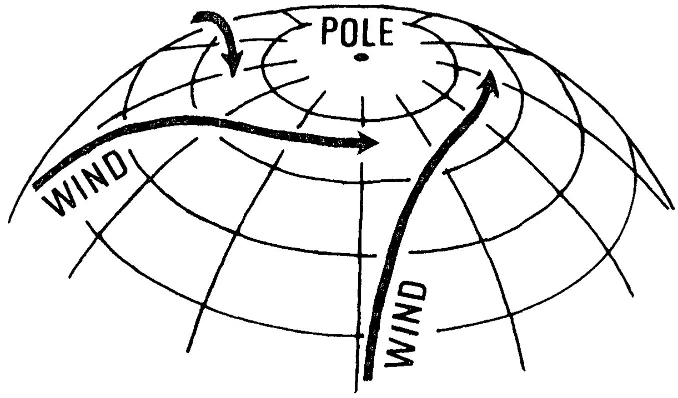

Fig. 3. A schematic illustration for the conversion of the poleward air motion to the zonal eastward wind at high latitudes over the rotating earth.

NOZAWA and BREKKE, 1999a, b). The observed eastward wind of 40 m/s will produce a northward electric field of 2.4 mV/m in the polar region with the magnetic field of 6 $\times 10^4$ nT. In the lower ionosphere (with the height-integrated Hall conductivity of 10 mho), the height-integrated horizontal eastward Hall current density amounts to 24 mA/m. If the circumpolar eastward Hall current is assumed to flow in 75°–85° latitude region everywhere with the same horizontal density of 24 A/km, the Hall current sheet will produce on the ground a northward horizontal magnetic field of ~20 nT (as is observed at Resolute Bay and Baker Lake in Fig. 1) and also a vertical magnetic field of ~20 nT (upward at Resolute Bay, and downward at Fort Churchill and Great Whale River in Fig. 1). This simple order-of-magnitude calculation seems to support that the dynamo action of the perpetual eastward neutral wind in the summer polar region (detected with the recent EISCAT experiment) would be a possible interpretation for the peculiar decrease in the geomagnetic Z-field in the summer polar region.

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