THE CONTRIBUTIONS
FROM THE
MARINE RESEARCH LABORATORY

HYDROGRAPHIC OFFICE OF JAPAN

Vol. 2 **NOVEMBER 1960** **No. 2**

ON THE LOCAL CHARACTER OF THE GEOMAGNETIC PULSATION, Pc*

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Received August 31, 1960

Abstract

It is well known that Pc type pulsation occurs simultaneously in the world-wide region. The author studied the results observed by induction magnetometers at the Japanese four stations (Memanbetsu, Onagawa, Simosato and Kanoya). From the results of the studies, local inequality of Pc was found. Period or mode of Pc changes with latitude, and amplitude of Pc becomes larger with increasing latitude. Such local Pc type pulsation may be produced by the hydromagnetic oscillations in the region between the inner Van Allen Belt and ionosphere. Two mode of oscillations exist in this region, toroidal and poloidal oscillation. In the higher latitude the poloidal and toroidal oscillations are observed, in the lower latitude only the poloidal oscillation is observed. Therefore, local Pc occurs frequently in the higher latitude than in the lower latitude.

1. Introduction

The geomagnetic pulsation has been studied for a long time since the first discovery made by B. Stewart(1861), and it has become clear that geomagnetic pulsations have many interesting characters. There are many investigations on the pulsation of the earth magnetic field, studied by T. Terada(1917), H. Hatakeyama(1937), Y. Kato(1957) etc. in Japan, and recently the studies on the pulsation were developed by Y. Kato and T. Watanabe(1957), T. Obayashi(1958), and the author (1959) from the results of observation on the pulsation during I. G. Y.

From July 1957 to Dec. 1958, the International Geophysical Year was held by the cooperation of many countries in the world. The observation

* This paper was read at the Spring Meeting of the Society of Terrestiral Magnetism and Electricity of Japan on May, 1960.

of the pulsation by induction magnetometer was continued at the four magnetic observatories in Japan during I. G. Y.

The positions of these four observatories are as follows:

	λ			φ		
Memanbetsu	144°	12′	E	43°	55′	N
Onagawa	141	28		38	26	
Simosato	135	56		33	35	
Kanoya	130	53		31	25	

In these magnetic observatories, the Simosato Magnetic Observatory is operated by the Hydrographic Division of Maritime Safety Board, the Onagawa Magnetic Observatory is a observatory of Tohoku University, Sendai, Japan: also, the Memanbetsu and Kanoya Magnetic Observatories is operated by the Meteorological Agency in Japan.

The time variations of three components of the earth's magnetic field, $\frac{dH}{dt}$, $\frac{dD}{dt}$ and $\frac{dZ}{dt}$ are recorded by the induction magnetometers with Sendust cores at Simosato and Onagawa : and $\frac{dX}{dt}$, $\frac{dY}{dt}$, and $\frac{dZ}{dt}$ are observed by the induction magnetometers with loops at Memanbetsu and Kanoya.

The author studied on characters of geomagnetic pulsation, Pc, from the induction magnetograms observed at four stations in Japan during I. G. Y.

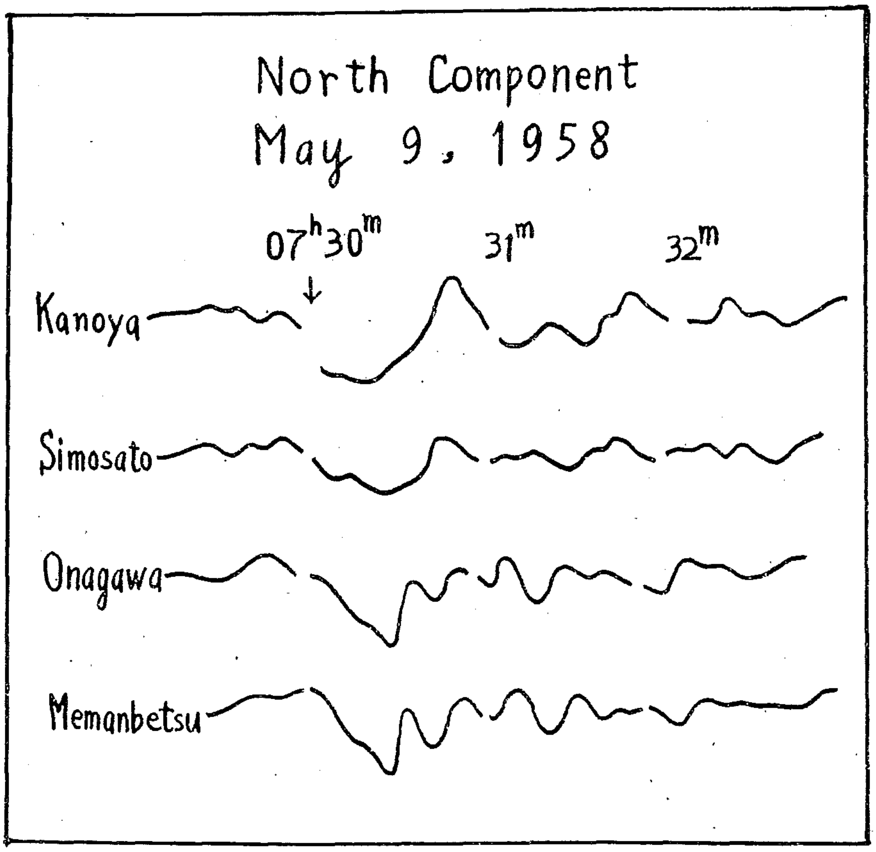

Fig. 1. An example of local Pc.

The results obtained from the investigation are as follows:

1) There are local Pc's in Pc observed during daytime. Periods or modes of local Pc change with latitude, and local Pc occurs frequently in the higher latitude than in the lower latitude. Many local Pc was observed at Onagawa and Memanbetsu, and an example is shown in Fig. 1.
2) The maximum of occurrence frequency of local Pc lies in equinox, and the minimum lies in winter at the station.
3) The frequency of occurrence of local Pc depends on the local mean time, and the maximum frequency of it's occurrence lies around 13^h (L. M. T.).

2. Mechanism of the Occurrence of Local Pc.

Recently, Dungey(1954) discussed the geomagnetic pulsation would be caused by the hydromagnetic oscillation of the outer atmosphere, and the theoretical relation between the hydromagnetic oscillation of the outer atmosphere and geomagnetic pulsation has been studied by many investigations (Kato and Watanabe, 1957 : Obayashi, 1958 etc.).

The author discusses the possibility of the occurrence of local Pc in this paper. According to the studies on hydromagnetic oscillations of the outer atmosphere, it seems that Pc type pulsation is caused by the hydromagnetic oscillation of the outer atmosphere excited by the corpuscular streams from the sun. Therefore, local Pc type pulsation may be produced by the hydromagnetic oscillation of the outer atmosphere.

Now, if it is assumed that local Pc type pulsation is caused by means of the hydromagnetic oscillation in the region between the inner Van Allen Belt

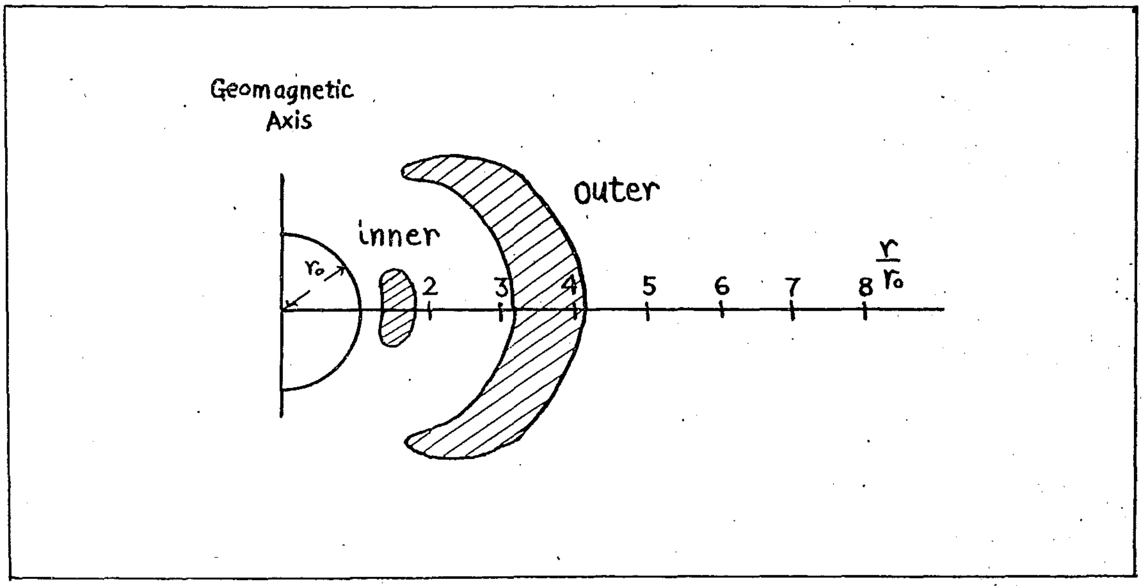

Fig. 2. Diagram of the Van Allen Belt.

and ionosphere as shown in Fig. 2, two modes of hydromagnetic oscillation exist in this region; that is, one of them is the toroidal oscillation and the other is the poloidal oscillation.

The general equations of hydromagnetic oscillation of the outer atmosphere were given as follows by Dungey (1954);

$$\left[4\pi\rho H^{-2}\frac{\partial^2}{\partial t^2}-r^{-2}\sin\theta\frac{\partial}{\partial\theta}\sin^{-1}\theta\frac{\partial}{\partial\theta}-\frac{\partial^2}{\partial r^2}\right](r\sin\theta E_\phi)$$
$$=c^{-1}\sin\theta\left(H_r\frac{\partial}{\partial\theta}-H_\theta r\frac{\partial}{\partial r}\right)\left((r\sin\theta)^{-1}\frac{\partial u_\phi}{\partial\phi}\right), \quad (1)$$

$$\left[4\pi\rho\frac{\partial^2}{\partial t^2}-(r\sin\theta)^{-1}\left((\boldsymbol{H}\cdot\nabla)(r\sin\theta)^2(\boldsymbol{H}\cdot\nabla)+H^2\frac{\partial^2}{\partial\varphi^2}\right)\right]\left(\frac{u_\phi}{r\sin\theta}\right)$$
$$=c\,(r\sin\theta)^{-3}\left(H_r r^{-1}\frac{\partial}{\partial\theta}-H_\theta\frac{\partial}{\partial r}\right)\left(r\sin\theta\frac{\partial E_\phi}{\partial\phi}\right) \quad (2)$$

We use the system of the spherical polar coordinates r, θ, and φ; r represents the distance of a representative point from the magnetic dipole situated at the earth's centre, which coincides with the origin of the polar axis, and its sense coincides with the negative direction of the polar axis $(\theta=\pi)$. The magnetic field $(H_r, H_\theta, 0)$ produced by the dipole represents the earth's magnetic field and its intensity H is expressed by

$$H=\frac{H_0 a^3}{r^3}\sqrt{1+3\cos^2\theta}, \qquad H_0=0.3\,\Gamma,$$

where a represents the length of the earth's radius and ρ represents the mass density of the earth's outer atmosphere.

The general equations of oscillation are too difficults to be solved analytically. But, if it may be assumed that the field quantities are independent of the azimuth φ, the above equations are reduced to the following two equations:

$$\left[4\pi\rho H^{-2}\frac{\partial^2}{\partial t^2}-r^{-2}\sin\theta\frac{\partial}{\partial\theta}\sin^{-1}\theta\frac{\partial}{\partial\theta}-\frac{\partial^2}{\partial r^2}\right](r\sin\theta E_\phi)=0 \quad (3)$$

and

$$\left[4\pi\rho\frac{\partial^2}{\partial t^2}-(r\sin\theta)^{-2}(\boldsymbol{H}\cdot\nabla)(r\sin\theta)^2(\boldsymbol{H}\cdot\nabla)\right]\left(\frac{u_\phi}{r\sin\theta}\right)=0 \quad (4)$$

In this case, we can solve these equations easily, but the coupling between above two oscillations, the poloidal and toroidal oscillations, is loosened.

That is, the following two sets of quantities are governed by the different equations independently.

$u\,(u_r, u_\theta, 0)$ $\quad h\,(h_r, h_\theta, 0)$ $\quad E\,(0, 0, E_\phi)$

$u\,(0, 0, u_\phi)$ $\quad h\,(0, 0, h_\phi)$ $\quad E\,(E_r, E_\theta, 0)$,

The quantities of the above set are governed by the equation (3), which is called the equation of the poloidal oscillation. On the other hand, the quantities of the lower set are given by the equation (4), which is named the equation of toroidal oscillation. From these equation, the velocity of hydromagnetic waves is represented as following Alfven wave:

$V=\frac{H}{\sqrt{4\pi\rho_{\rm eff}}}$, on the poloidal and toroidal waves.

where $\rho_{\rm eff}$ is the effective mass density.

The toroidal wave is propagated along the magnetic lines of force and the poloidal wave is at right angle to it. The sum of the poloidal and toroidal oscillations can be observed at the four observatories as Pc type pulsation.

The period of the poloidal oscillation in the region between the inner Van Allen Belt and ionosphere can be calculated as follows:

$$T_p=\int_{r_0}^{r}\frac{2\,dr}{V}$$

where, V : velocity of Alfven wave $\frac{H}{\sqrt{4\pi\rho_{\rm eff}}}$

r_0 : height of ionosphere,

r : height of inner Van Allen Belt.

From above equation the period of the poloidal oscillation is invariable on latitude.

On the other hand, with respect to the toroidal oscillation,

$$T_t=\int_{\theta_0}\frac{2\,ds}{V}$$

where, θ_0 : co-latitude,

s : length of magnetic line of force.

On the toroidal oscillation, its period varies with increasing latitude. These relations are shown in Fig. 3.

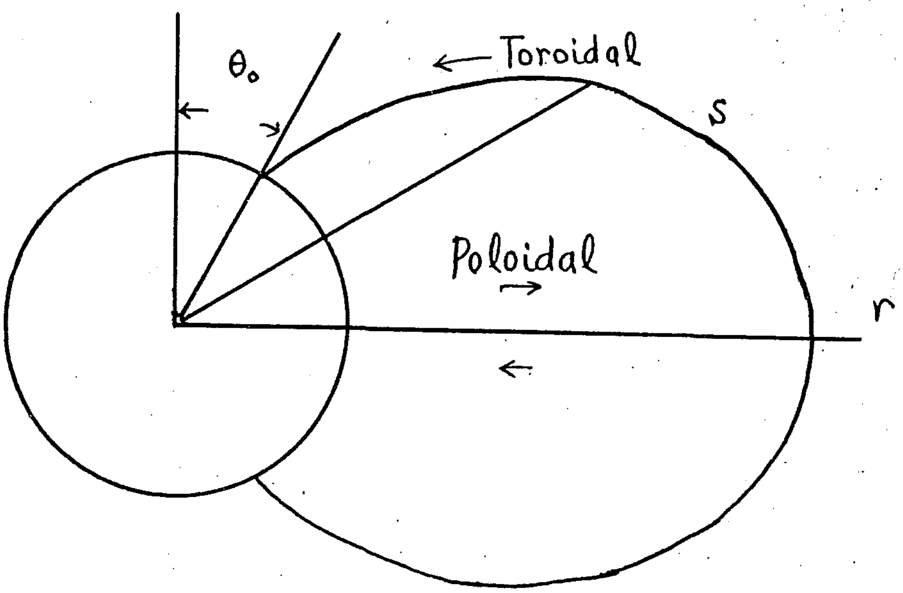

Fig. 3. Geometry of the geomagnetic line of force, and the Poloidal and Toroidal Oscillation.

Recently, Dessler(1958) stated that the Alfven wave velocity $H/\sqrt{4\pi\rho}$

varies very rapidly against the height from the ionosphere to inner Van Allen Belt, and is maximum at the height of about 1,000 km.
Desseler calculated the velocity distribution with altitude as shown in Fig. 4.

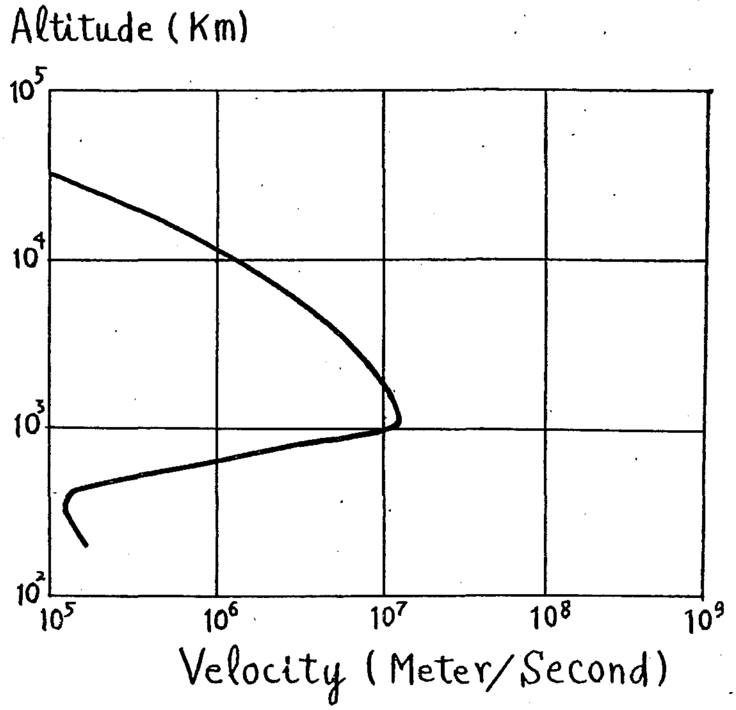

Fig. 4. Variation of Alfven wave velocity against height given by A. J. Dessler.

Using Desseler's results, the periods of the poloidal oscillation and the toroidal oscillation which occur in the region between the inner Van Allen Belt and ionosphere are calculated in the following table at four stations:

Oscillation \ Position	Memanbetsu	Onagawa	Simosato	Kanoya
Poloidal	20^s	20^s	20^s	20^s
Toroidal	47	42	—	—

If it is assumed that the hydromagnetic waves are produced by means of a corpuscular stream coming from the sun at the outer surface of the inner Van Allen Belt, as a magnetic line of force through Simosato and Kanoya is not reach to the inner Van Allen Belt, the toroidal oscillation is unable to be observed at these observatories.

Now, as the sum of the poloidal and toroidal oscillations are observed at the four observatories, the poloidal and toroidal oscillations are observed in the higher latitude as Memanbetsu and Onagawa, and only the poloidal oscillation is observed in the lower latitude as Simosato and Kanoya in Japan.

Then, the period of the toroidal oscillation depends on latitude, that is, it becomes longer with increasing latitude. Therefore, period or mode of local Pc changes with latitude, and local Pc occurs in the higher latitude than in the lower latitude.

3. Conclusion.

By the above discussions, the mechanism of Pc and local Pc was made clear; the turbulent motion of the solar corpuscular stream would excite the outer atmospheric poloidal and toroidal oscillations in the region between inner Van Allen Belt and ionosphere, and the magnetic fields occurred by the poloidal and toroidal oscillation are observed as Pc and local Pc at the earth's surface. Therefore, local Pc occurs frequently in the higher latitude than in the lower latitude by means of an influence of the toroidal oscillation of which period changes with latitude.

4. Acknowlegement.

The writer thanks to Mr. Y. Tsukamoto(Chief Hydrographer) and Mr. T. Matsuda(Chief of Survey Section, Hydrographic Office) throughout this work for their kind guidances. The writer wishes to express his sincere thanks to Professor Y. Kato for his kind guidance and valuable suggestion in this course of study, also wishes to acknowledge to valuable suggestion which he received from Professor T. Nagata, Tokyo University.

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