Special Contributions, Geophysical Institute, Kyoto University, No. 7, 1967, 23-27

PRELIMINARY REPORT ON A PRACTICAL METHOD OF ANALYSIS OF THE DAILY GEOMAGNETIC VARIATIONS[1]

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(Received November 17, 1967)

Abstract

A new method of analysis of the daily geomagnetic variations is proposed and discussed. This method is a combination of the two (analytical and numerical) methods already introduced and developed. Although the method is not perfect with some ambiguity involved, it may be useful for the purpose of practical analysis.

1. Introduction

Two methods are usually employed for the analysis of the daily geomagnetic variations such as Sq or L. One is the method of spherical harmonic analysis (or the analytical method) initiated by Gauss [1839], and the other is the method of surface integral (or the numerical method) introduced by Hasegawa [1936] and by Vestine [1941]. The former is usually easy and quick, but it contains one difficulty for representing a sharply changing part such as the equatorial electrojet effect by a limited number of harmonics. On the other hand, the latter is applicable to any distribution of the geomagnetic field, but this involves much more labor than the former.

Although many excellent works have been done by these two methods, we cannot overlook defects they possess. The purpose of this preliminary report is to propose and to discuss a new method which may diminish such defects.

2. Principle of the method

The most essential point of the method presented here is to separate the original geomagnetic field into a local and a background parts. In this case it is preferable that such a separation is made on a physical basis. However, it is not always possible to do so. If we take the geomagnetic Sq field, for ex-

[1] This paper has been presented at the IAGA/IUGG meeting in Switzerland on September 25 to October 7, 1967.

ample, we know that the amplitude of Sq is strongly enhanced on and near the magnetic equator. This phenomenon often called the equatorial electrjet effect is caused by the enhancement of the electrical conductivity in the equatorial ionosphere, and it cannot be regarded as an anomalous behavior of Sq. In this reason it is not possible to separate this equatorial part of Sq into a local (or a jet) and a background parts on any physical basis. It might, however, be possible to do so in a technical manner. The method of separation employed in this paper is such a technical one; namely, the strongly enhanced equatorial part of Sq, called here the jet part, is separated from the background. The background part is analysed by the analytical method, whereas the jet part is analysed by the numerical method. The results of these two are combined to give a final result.

3. Processes of analysis

In order to explain our method, the *H* (horizontal) and the *Z* (vertical) components of Sq in Zone 3 (American zone) for the E months analysed by Matsushita and Maeda [1965] are used. The latitudinal distribution of the amplitude and phase of the diurnal component, for example, is shown in Fig. 1 for the *H* component and in Fig. 2 for the *Z* component. These distributions are divided into the symmetric and antisymmetric parts with respect to the magnetic equator. As is seen in the distribution of the phase, the *H* component consists of a main symmetiric part and a remaining antisymmetric part; whereas the *Z* component has a main antisymmetric part and a remaining symmetric part.

If we assume that the equatorial jet current is symmetrical with respect to the equator, it produces a symmetric *H* component and an antisymmetric *Z* component near the equator. It may, therefore, be expected that most of the equatorial enhancement in the *H* and *Z* components are caused by such a symmetric part of the jet current. Thus, the main part of the *H* and *Z* components would be separable into the jet and the background parts with this approximation. These processes may be illustrated as follows:

- Original *H* component
  - Main symmetric part
    - Jet part
    - Background part
  - Remaining antisymmetric part

- Original *Z* component
  - Main antisymmetric part
    - Jet part
    - Background part
  - Remaining symmetric part

Preliminary results of this separation are shown in Fig. 1 (for *H*) and Fig.

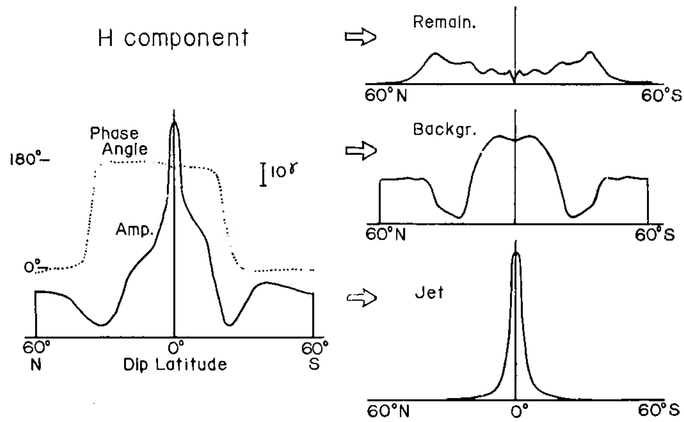

Fig. 1. The amplitude and phase of the original H component (left) and their separation into three parts (right).

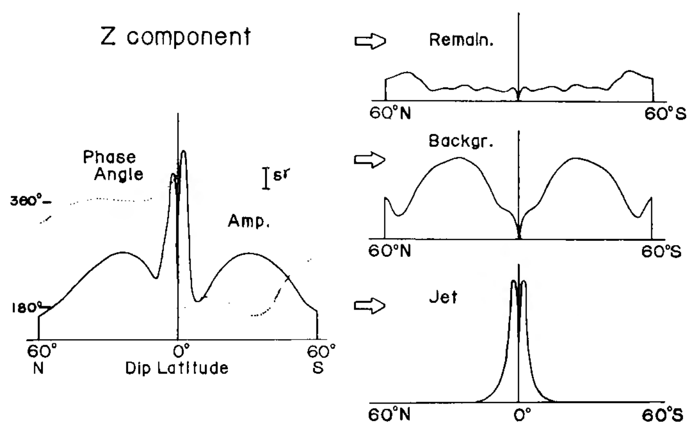

Fig. 2. The amplitude and phase of the original Z component (left) and their separation into three parts (right).

2 (for Z). It is seen from these figures that the background and remaining parts are more flat than the jet part. In this reason the former two are analysed by the analytical method, whereas the latter needs to employ the numerical method. Another Fourier components such as semidiurnal, terdiurnal, and others, can also be analysed in a similar manner to the diurnal.

4. Equatorial jet effect

For eliminating the jet part from the main part of Sq, we need to know the structure of the equatorial jet current. Our present purpose is to obtain a distribution of the jet current which produces the H and Z components observed on the ground.

If we suppose a model jet current flowing eastward at an altitude of 100

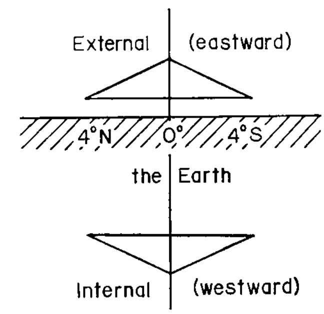

Fig. 3. Equatorial jet current model.

km, it produces the magnetic effects, H_e and Z_e, of external origin. At the same time such an external current induces an internal current within the earth, and gives rise to the magnetic effects, H_i and Z_i, of internal origin. Thus, we observe the combined effects of these two. Experimental calculations have been made for different models of the jet current, and it has been found that a good agreement with the observed H and Z components is seen for the following model (see Fig. 3) :

External current of

1. Density ···triangular distribution,
2. Width ···4°N and 4°S,
3. Altitude ···100 km,
4. Intensity···120 amp/km (for the diurnal component).

Internal current of

1. Image of the external,
2. Depth ···600 km,
3. Intensity···120 amp/km.

3. Discussion and conclusion

There would be a scathing comment on the separation of the jet part of Sq. As has been pointed out in Section 2, such a separation has no physical meaning. As is well known, the geomagnetic Sq or L field is often expressed by some typical harmonics of low degree; for example, P_1^1, P_1^3, P_1^5, etc., for the diurnal component, P_2^2, P_2^4, P_2^6, etc., for the semidiursal, and P_3^3, P_3^5, etc., for the terdiurnal, so that any sharply changing part such as the equatorial jet effect cannot be included in these low-degree harmonics. It seems, therefore, that a better expression of the Sq or L field by those limited harmonics is obtained by ignoring the strongly-enhanced equatorial part. Although our method is not perfect with some ambiguity in the separation, it may be useful for the practical analysis in such a reason.

Another comment may be made on the triangular distribution of the density of the equatorial jet current. We do not yet have any detailed and reliable information about the structure of the jet current, but it seems that our triangular model is supported by some experimental and theoretical studies.

Davis and others [1967] have recently shown in their Fig. 4 a cross-sectional profile of the jet current as derived from rocket measurements of the geomagnetic field near the coast of Peru. If we integrate over height the current density obtained by them, we have the distribution of the current density as shown in Fig. 4. It is noted in this figure that the distribution has a triangular shape. This results suggests that the eastward current near the magnetic equator cannot be approximated by $J_y = K_{yy}E_y$, as has been pointed out by Maeda [1965] and by Davis *et al.* [1967]. In fact, if we take the form $J_y = -K_{xy}E_x + K_{yy}E_y = (-K_{xy}(E_x/E_y) + K_{yy})E_y$ and use the values of E_x/E_y estimated by Maeda [1955], we have a triangular distribution of the effective conductivity $(-K_{xy}(E_x/E_y) + K_{yy})$. Thus our model for the distribution of equatorial current density seems to be realistic.

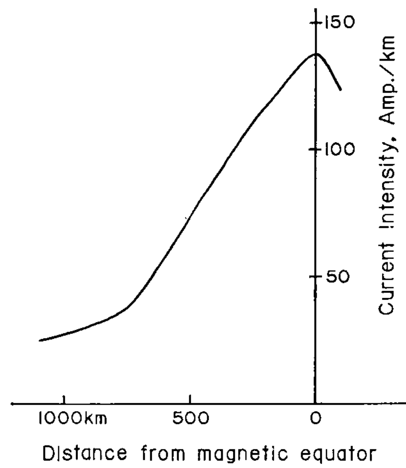

Fig. 4. Distribution of height-integrated current density around the magnetic equator, calculated from Davis *et al.* [1967].

Results of aualysis of the Sq and L fields by the method presented here will be published later.

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