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A ROUGH ESTIMATION OF INDUCTION CHARACTERISTICS FOR GEOMAGNETIC VARIATIONS AT SYOWA AND ICELAND

Satoru TSUNOMURA

Kakioka Magnetic Observatory, 595, Kakioka, Yasato-machi, Niihari-gun, Ibaraki 315–01

Abstract: Basic characteristics of geomagnetic induction at Syowa Station are estimated by showing the induction arrows for various types of geomagnetic disturbances using one second values of geomagnetic field. It is found out that satisfactory solutions are obtained for the daytime disturbances. Induction arrows at Iceland are also obtained using the daytime disturbances. At Syowa Station, the induction arrows for the periods longer than several minutes reveal a coast line effect of Lützow-Holm Bay while island effect is apparent for shorter periods. At Iceland, the coast line effect is dominant at Isafjördur and Tjörnes but the induction effects are generally small at Husafell. The induction characteristics obtained here can be referred to as basic relationship in the analyses of geomagnetic phenomena dealing with the vertical component of geomagnetic variations.

1. Introduction

Geomagnetic variations observed on the ground are affected by induction effects due to conductivity anomalies under the ground. In middle and low latitudes, the induction effects are sucessfully estimated by deriving induction arrows from the relationships between horizontal (H and D) and vertical (Z) components of the observed geomagnetic field, *i.e.*, through a so called CA (Conductivity Anomaly) analysis (for example see the textbook of RIKITAKE and HONKURA, 1985). The CA analysis, assuming basically plane waves for incident geomagnetic variations give satisfactory solutions at middle and low latitudes where the assumption is valid to a considerable extent. But in high latitudes, where the horizontal scales of geomagnetic variations are in many cases smaller than or comparable to the height of the ionosphere from the ground, one must carefully operate CA analysis to obtain satisfactory solutions.

However, even in the auroral region, although the horizontal gradient of geomagnetic variations is large at night due to auroral jet currents, the localization of geomagnetic variations may be hopefully becomes smaller in the daytime. Checking the problem that the highly polarized events give unstable solutions because of a difficulty to separate the contributions from H and D components, HANDA and CAMFIELD (1984) tried to derive induction arrows for Canadian stations located in the auroral region, excluding the highly polarized events. They obtained satisfactory solutions to discuss the conductivity structure under the ground.

In the present study, the author checks the dependence of the stability of transfer functions on the selection of events and tried to get reasonable results for Syowa and three stations in Iceland.

2. Method of Analysis

Transfer functions are defined by the equation

$$Z=AH+BD \tag{1}$$

where, H, D and Z are geomagnetic horizontal (northward), declination (westward) and vertical (upward) components of geomagnetic variations respectively. A and B are derived as complex values after the Fourier transformation. With the real parts of them, Ar and Br, the in-phase induction arrow is defined as a vector (Ar, Br) in geomagnetic north-south and east-west coordinates which points the direction towards the region of better conductivity under the ground. The magnitudes of transfer functions depend on the sharpness of the conductivity gradient.

On the basis of three components of the geomagnetic field, sampling rates of which are one second at Syowa and two seconds at stations in Iceland, the transfer functions for periods from 8 s to 32 min band are calculated by a formula of EVERETT and HYNDMAN (1967).

For the spectrum analysis by FFT, each event is divided into 2048 s blocks of original data for shorter periods and 256 min blocks of one minute averages of original data for longer periods. Auto and cross spectra of three components for band periods around 8, 16, 32, 64, 128, 256 and 512 s are obtained from 2048 s block and those around 4, 8, 16 and 32 min from 256 min block. Spectra obtained from each block are stacked to gain the signal to noise ratio and finally transfer functions are calculated by the least square fit (EVERETT and HYNDMAN, 1967).

Events are categorized into three types. One is the disturbance in the daytime (08–16 MLT) except for lasting pulsations, the second is a substorm from evening to morning hours (typically 20–04 MLT) and the third is a kind of substorms in the nighttime associated with a sharp negative spike in H component and a brightening

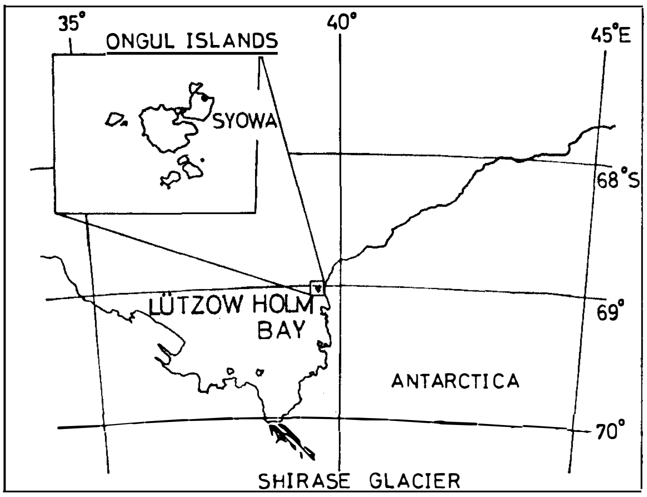


Fig. 1. The location of Syowa Station.

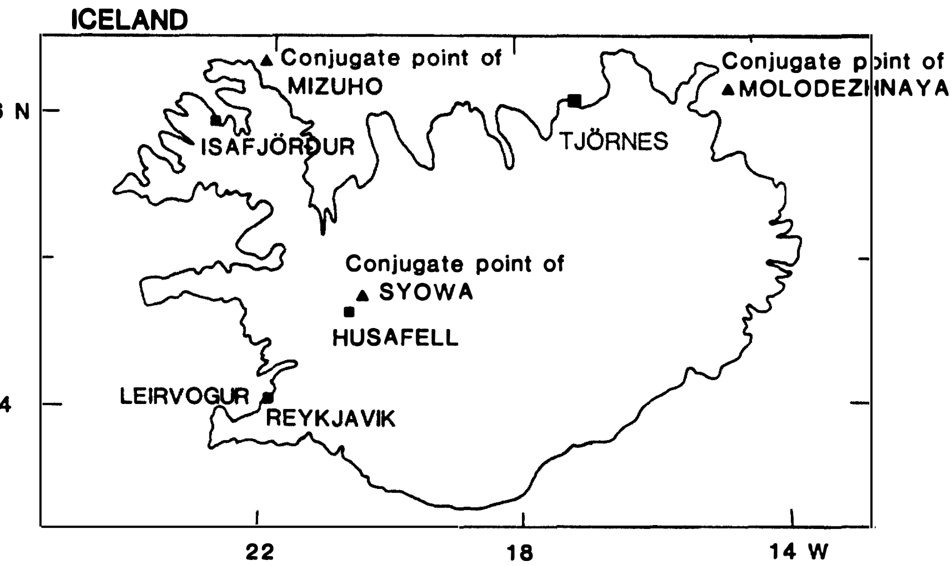


Fig. 2. The distribution of three stations in Iceland.

(more than 10 kR in the photometric observation) of 427.8 nm wavelength near the zenith. The third one is called an auroral break up event in this study and analyzed only for short periods.

Data are picked up from the records at Syowa Station taken from 1981 to 1984. Numbers of blocks for the short periods at Syowa Station are 49, 106 and 37 for the daytime disturbances, substorms and auroral break up events respectively, and for the long period block 15, 37 and 0.

Syowa Station and other three stations in Iceland are shown in the maps in Figs. 1 and 2. Syowa Station is located at the eastern coast of East Ongul Island. It is noticed that Isafjordur and Tjörnes are located at the coast lines of Iceland, where there may be a notable CA effect due to the conducting sea.

3. Results and Discussion

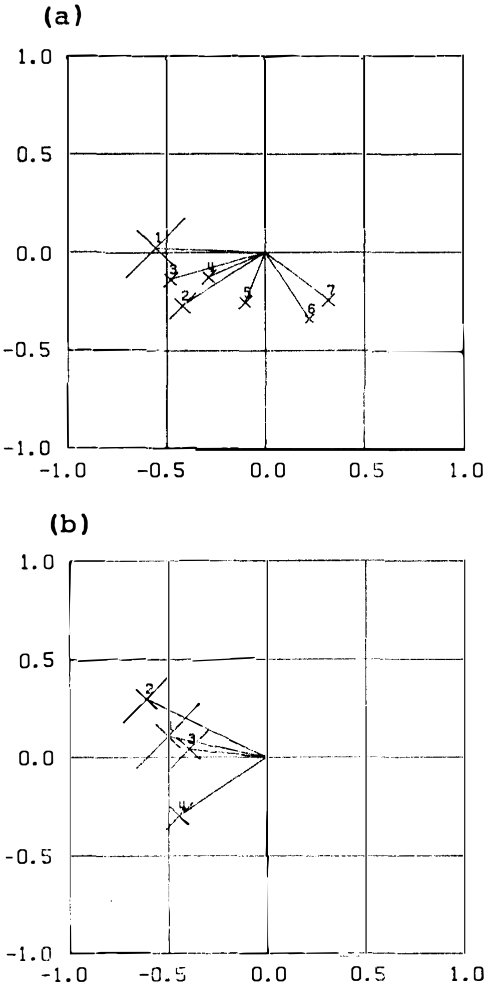
3.1. Induction arrows at Syowa

Figure 3 shows the induction arrows in geographic coordinates obtained at Syowa Station using daytime disturbances. Bars on the top of the arrows show the standard errors. A standard error for H component at a given frequency f is given as follows;

$$\mathrm{Err}\,(f)=\frac{n}{n-4}F(4, n-4;\, \alpha)\frac{(1-CohZH(f))P_Z(f)}{(1-CohHD(f))P_H(f)} \tag{2}$$

where, n is a degree of freedom, $F(4, n-4; \alpha)$ is the α percentage point of F distribution with two inputs, $CohZH$ and $CohHD$ are coherences between Z and H, H and D components respectively and P_Z and P_H are power spectra of Z and H components. Standard errors for D components are calculated replacing H in eq. (2) by D.

COHZ in Fig. 3 is a coherence between calculated Z by eq. (1) and observed Z component and *COHB* between observed H and D components. The former shows the degree of the fitness of the calculated transfer functions while the latter the degree



(a)

	(SEC)	COHZ	COHB
1	512	0.53	0.16
2	256	0.72	0.07
3	128	0.78	0.20
4	64	0.78	0.16
5	32	0.79	0.28
6	16	0.80	0.18
7	8	0.48	0.10

(b)

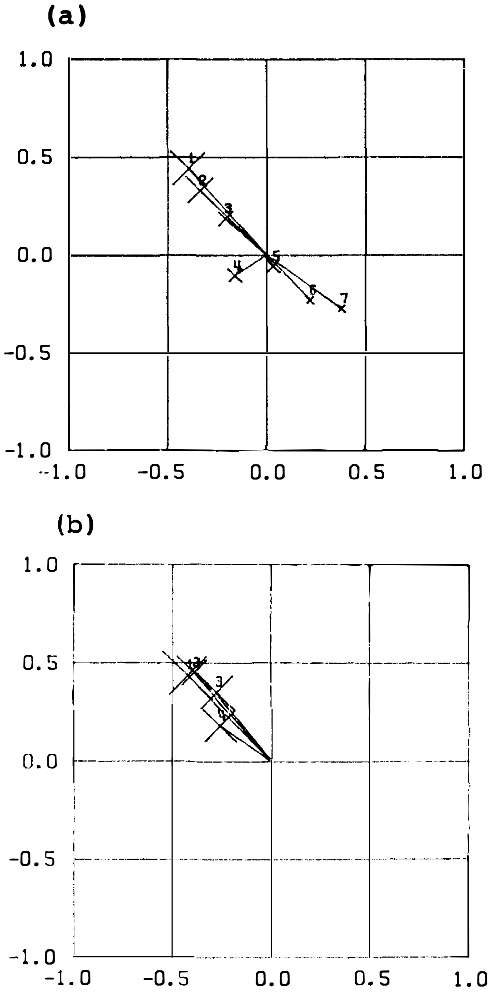
	(MIN)	COHZ	COHB
1	32	0.70	0.06
2	16	0.82	0.15
3	8	0.61	0.03
4	4	0.76	0.14

Fig. 3. Induction arrows in geographic coordinates at Syowa Station obtained from daytime disturbances for (a) short periods and (b) long periods.

of uncertainty of the solutions. Arrows for longer periods generally point westward or south-westward, that is, perpendicularly to the coast line of Lützow-Holm Bay directing to the sea. Those for shorter periods rotate counter-clockwise with decreasing periods and for the period around 16 or 8 s, point eastward. The results are thought satisfactory with high *COHZ* values for the periods from 32 s to 32 min. Those for 8 and 16 s may be reasonable considering a tendency of continuation from longer periods, although *COHZ*s are not high.

The differences in the directions of induction arrows by periods may depend on the location of the magnetometer at Syowa Station. The sensor is set on the east side of the East Ongul Island whose horizontal extent is a few kilometers. The island is located several kilometers to the west of the coast line. Therefore, the so-called island effect may be dominant for shorter periods, while the effect of coast line of Lützow-Holm Bay about hundred kilometers extent may be dominant for longer periods.

Induction arrows obtained from substorms are in general similar to those of daytime disturbances (Fig. 4), however, the rotating tendency of induction arrows with periods cannot be seen. Considering the lower *COHZ* values than those of



(a)

	(SEC)	COHZ	COHB
1	512	0.28	0.04
2	256	0.25	0.09
3	128	0.29	0.07
4	64	0.27	0.16
5	32	0.32	0.21
6	16	0.45	0.08
7	8	0.48	0.03

(b)

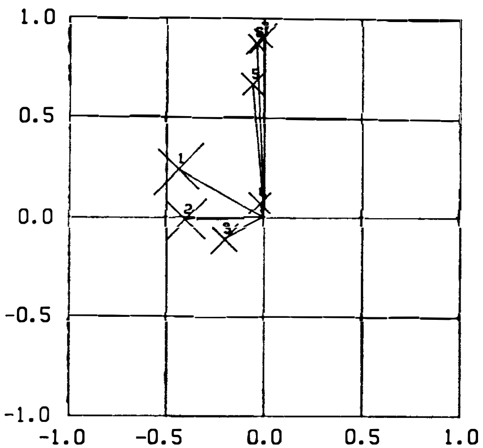
	(MIN)	COHZ	COHB
1	32	0.39	0.00
2	16	0.45	0.01
3	8	0.20	0.09
4	4	0.18	0.13

Fig. 4. Same as Fig. 3 obtained from substorms.

daytime disturbances, it is suggested that the results for daytime disturbances reflect more naturally the basic characteristics of the induction effects.

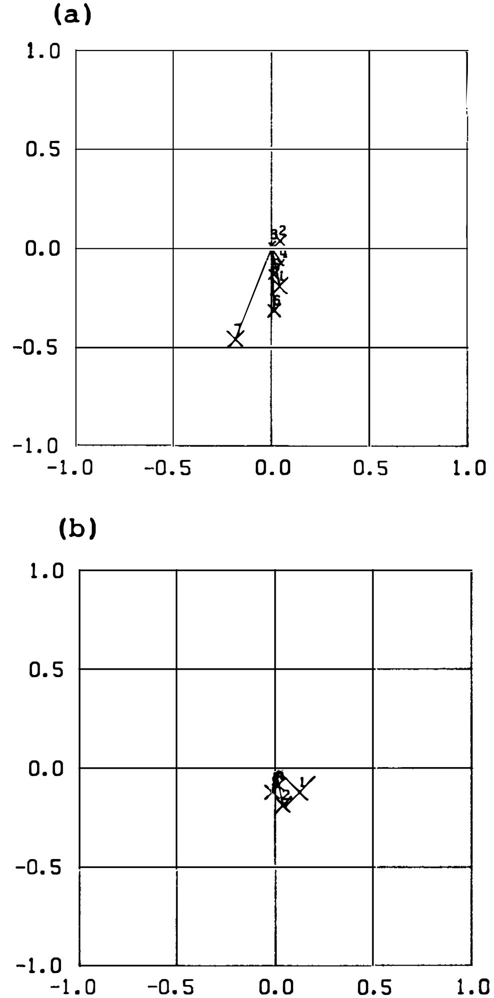
For the periods longer than 64 s, the results of the auroral break up events are similar to those of the former ones (Fig. 5) but for the periods shorter than 64 s, quite different characteristics are apparent. The arrows pointing almost northward for very short periods may be due to a rapidly varying intense current system accompanying the auroral break up. Since such current system consists of field-aligned currents and narrow ionospheric currents, it gives rise to a vertical magnetic field on the ground. From such events, the induction arrows may be very variable and arrows may be scattcrred very much. Although *COHZ* values are low, the arrows for the very short periods are determined in almost the same direction.

As the location of the auroral arc was not determined from all sky camera data for each event in this study, the result can be interpreted only speculatively as follows; when sharp negative spikes appear in the geomagnetic *H* component, the locations of the auroral arcs will be within a certain range over the observatory, so that their effects through *Z* component of geomagnetic field may be almost the same, resulting in the concentration of induction arrows for the geomagnetic variations with periods of such



	(SEC)	COHZ	COHB
1	512	0.50	0.04
2	256	0.37	0.15
3	128	0.14	0.19
4	64	0.27	0.15
5	32	0.48	0.10
6	16	0.62	0.03
7	8	0.63	0.16

Fig. 5. Same as Fig. 3 obtained from auroral break up events.



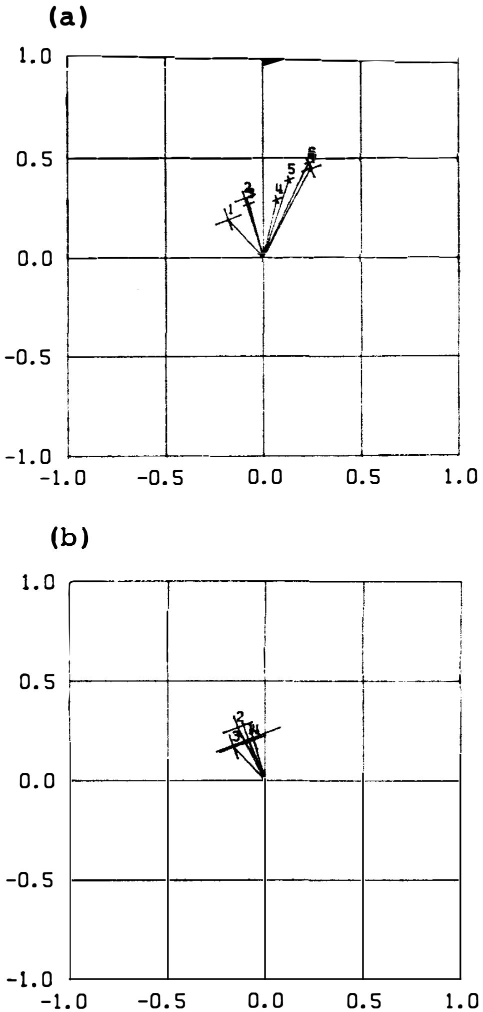
(a)

	(SEC)	COHZ	COHB
1	512	0.31	0.02
2	256	0.25	0.10
3	128	0.38	0.19
4	64	0.19	0.00
5	32	0.15	0.01
6	16	0.24	0.11
7	8	0.34	0.22

(b)

	(MIN)	COHZ	COHB
1	32	0.21	0.02
2	16	0.30	0.01
3	8	0.27	0.00
4	4	0.27	0.01

Fig. 6. Induction arrows in geographic coordinates at Husafell obtained from daytime disturbances with (a) short periods and (b) long periods.



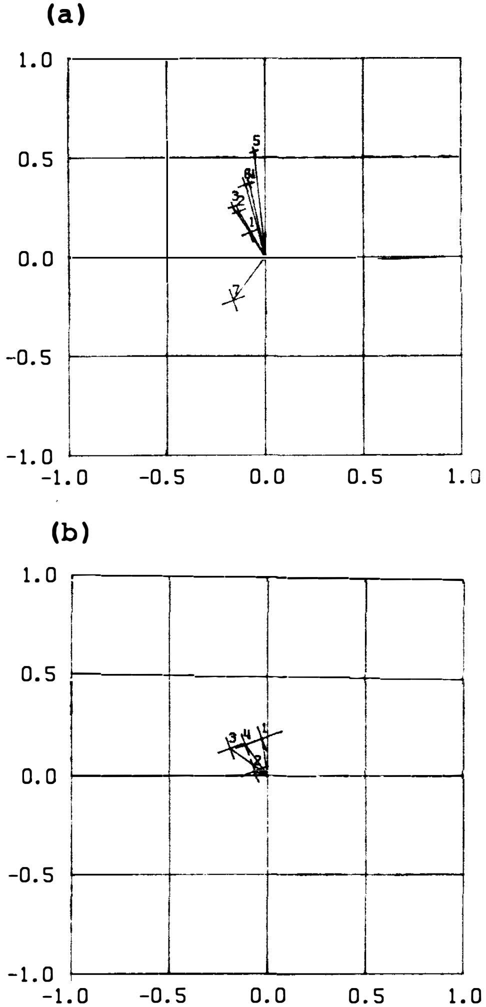
(a)

	(SEC)	COHZ	COHB
1	512	0.35	0.06
2	256	0.67	0.07
3	128	0.55	0.10
4	64	0.64	0.03
5	32	0.80	0.02
6	16	0.66	0.00
7	8	0.42	0.14

(b)

	(MIN)	COHZ	COHB
1	32	0.25	0.02
2	16	0.40	0.02
3	8	0.29	0.13
4	4	0.45	0.06

Fig. 7. Same as Fig. 6 at Isafjördur.



(a)

	(SEC)	COHZ	COHB
1	512	0.42	0.18
2	256	0.67	0.07
3	128	0.72	0.16
4	64	0.71	0.02
5	32	0.84	0.02
6	16	0.29	0.01
7	8	0.12	0.15

(b)

	(MIN)	COHZ	COHB
1	32	0.28	0.01
2	16	0.12	0.02
3	8	0.29	0.05
4	4	0.41	0.01

Fig. 8. Same as Fig. 6 at Tjörnes.

spikes.

3.2. *Induction arrows at Iceland*

As it is clarified in the previous section that daytime disturbances give satisfactory results for CA analysis, only the results for daytime disturbances are shown in this section.

The results for Husafell, Isafjördur and Tjörnes are shown in Figs. 6, 7 and 8, respectively.

For an inland station, Husafell, induction arrows are small as predicted from a noteworthy tendency that the geomagnetic Z component is usually small. For other stations near the coast, the coast line effect is dominant in a rather complicated fashion due to an irregular form of the coast lines. The magnitudes of induction arrows are a little smaller than those of Syowa Station, especially for long period geomagnetic variations.

4. Conclusion

Induction arrows for geomagnetic variations with the periods from 8 s to 64 min are calculated using a simple scheme of CA analysis method after a careful selection of observed events. Basic patterns show predicted characteristics at all stations in high latitudes. At Syowa Station the induction arrows show coast line effect for long period geomagnetic variations and the island effect for short period ones. At stations near coast lines, Isafjördur and Tjörnes in Iceland, the coast line effect is dominant, while the induction arrows are small at Husafell.

Induction effects can influence the intensity or the phase of H and D component variations. The components perpendicular to the coast lines may be increased. Especially at Syowa Station, where the transfer functions show rather large values, this skew effect may be responsible for the fine structures of polarization characteristics of geomagnetic pulsations.

The study in this paper will be an interim step for achieving a self consistent model of geomagnetic variations of upper atmospheric origin by considering the electromagnetic response of the ground against incident geomagnetic perturbations.

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