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ON THE CONJUGATE RELATIONSHIPS OF THE AMPLITUDES OF SSC'S AND SI'S OBSERVED AT REYKJAVIK AND SYOWA

Satoru TSUNOMURA

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Abstract

Ampiltudes of storm sudden commencements (SSC's) and sudden impulses (SI's) are compared for a geomagnetically conjugate stations pair, Reykjavik in Iceland and Syowa in the Antarctica. Local time dependences of the amplitudes of main impulses of SSC's and SI's normalized by equatorial values confirm that the difference in local times of both stations can be neglected in the correlation study of the amplitudes of SSC's and SI's. It is apparent that the amplitudes of H component are a little larger at Reykjavik than at Syowa while the relation is reversed for those of D component. The difference of induction effects of both stations may be attributed to this skew. Seasonal variations of the ratios of amplitudes at both stations, with a slight maximum in summer and a minimum in winter, especially in D component, denote that the current sources responsible for SSC's and SI's observed on the ground vary their amplitudes following the seasonal variation of the ionospheric condition.

1. Introduction

Charactistics of SSC's have been investigated with various scientific techniques since the IGY. On the basis of results obtained for about the past two decades, Araki (1977) gave a systematic interpretation about the mechanisms and the global structure of the complicated features of SSC appearances.

About SI's which are similar in wave forms with SSC's but not accompanied with subsequent storms, Sano (1964) examined a large number of events at eleven obsertvatories distributed from auroral region to the equator and concluded that SI's are essentially same with SSC's in the sense that they are the manifestations in the geomagnetic field to the sudden increase of the solar wind presure. Therefore, the characteristics of both of SSC's and SI's can be uniformly explained by Araki's model.

Araki (1977) divided geomagnetic variation fields of preliminary impulses (PI's) and main impulses (MI's) of SSC's observed on the ground into three parts, DP_{PI}, DL_{MI}, and DP_{MI}. DP $(_{PI,MI})$ fields are originated in polar region and DL $(_{MI})$ in low latitudes. About the precise description of them, refer to Araki (1977) or Araki and Nagano (1988).

The capabillity of the propagation of DP ($_{PI,MI}$) field to low latitudes is proved; theoretically by a derivation of propagative solution of TM mode electromagnetic wave in the wave guide between the ground and the ionosphere by Kikuchi and Araki (1979);phenomenologically by the characteristics of the SSC's observed at the night sideequatorial regions (Araki et al., 1985) and by the interpretations of HF doppler frequency modulations in the case of SSC's (Kikuchi et al., 1985;Kikuchi, 1986). Tsunomura and Araki (1984) estimate the distribution of amplitudes of DP_{MI} field by numerical calculation and show that the magnetic variations due to the ionospheric currents of polar origin can come to the observable magnitudes in day time low latitudes but not in night side low latitudes.

Effects of the expansion of the magnetosphere due to the sudden decrease of the solar wind pressure are treated analogously with the effects of the compression by Araki and Nagano (1988). From their conclusions, it is regarded the both phenomena are same in essence as to the variations of geomagnetic fields and the difference of them is only the sign of each DP_{MI} and DL_{MI} field producing SI^-or SI^+ and SSC in low latitudes. Therefore, SI^-'s are treated simutaneously with SSC's and SI^+'s in this paper without any special treatments to distinguish them.

A special kind of the preliminary impulses (PI) of SSC's that cannot be simply explained by Araki (1977)'s model is reported by Kikuchi and Araki (1985) where the authors do not comment that the amplitudes of the MI's are changed with respect to the wave forms of the PI's. In this paper, investigating the amplitudes of MI's of SSC's and SI's, the wave forms of PI's are ignored. Hereafter, MI's of SSC's and SI's are termed MI's for simplicity.

Conjugate relationships of MI's are the subjects investigated by many authors. Wave forms of SSC's observed simaltaneously at conjugate observatories in high latitudes are highly correlated (Nagata et al., 1966; Wilson and Sugiura, 1964; Nagano et al., 1987; Nagata, 1987) and amplitudes of them are approximately same (Nagata et al., 1966;Nagata, 1987).

However, the seasonal variation of the ratios of amplitudes of MI's do not show clearly either a maximum peak in summer nor a minimum peak in winter (Nagata et al., 1966). In high latitudes, where DP_{MI} field dominates (Araki, 1977), magnetic variations of MI's are attributed to ionospheric currents and it is expected that the amplitudes of MI's vary seasonally following the seasonal variation of the ionospheric conductivity. The ionospheric conductivity at high latitudes in summer is roughly estimated a few times as large as that in winter on the basis of the global map of the foE in solstices (Rika nenpyo, 1989).

Meanwhile, the ionosheric current of MI's is regarded to change its amplitudes by local times due to the diurnal variation of the ionospheric conductivity (Tsunomura and Araki, 1984). Therefore, the comparisons of magnetic records of the geomagnetic conjugate stations local times of which are not same must be done afterthe checkof this effect.

In this paper, local time variations of amplitudes of MI's observed at Reyjavik and Syowa, which are located at the same magnetic local time but at different local times (UT−1 at Reykjavik and UT+3 at Syowa) are checked by a statistical analysis and then the ratios of them are discussed.

2. Method of analysis

Analogue magnetic records of Syowa and Reykjavik are used te determine the amplitudes of MI's. The periods of analysis are from 1974 Jan. to 1977 Jun. and from 1978 Jan. to 1979 Dec. Events are picked up on the basis of the lists of SSC's and SI's in 'REPORT OF THE GEOMAGNETIC AND GEOELECTRIC OBSERVATIONS (RAPID VARIATIONS)' (1974−1979) issued by Kakioka Magnetic Observatory.

Events without triggered substorms are selected for the analysis. Numbers of events are summarized in Table 1. Rules to determine the amplitudes of them are as follows;for SSC's and SI's without PI's the amplitudes are defined as the differences of the levels after and before MI's and for those with PI's the differences from the bottom of the PI's to the top of MI's.

Since the exclusion of scattering of data due to the amplitudes of events are desired, ampiludes thus obtained are normalized by the equatorial values which are for the first order of approximation regarded as the magnitudes of origins, that is, solar wind discontinuities responsible for the events.

In order to decide the equatorial values, magnetic records of Dst stations, Kakioka, Honolulu, San Juan and Hermanus are used. Since the DP_{MI} fields are estimated to be small at low latitudes in night side, it can be approximately

Table 1 Numbers of events v.s. wave forms

	Syowa	Reykjavik
SSC SSC	10 32	9 33
SI SI	9 26	16 19
sum.	77	77

assumed that MI's observed in this region are caused by DL_{MI} fields only and the amplitudes of them have the informations of the magnitudes of the original solar discontinuities without scatterings due to the effects of ionospheric currents. The equatorial values are then obtaind as follows;amplitudes of H component of MI's at two Dst stations local times of which are the nearlest and the second nearlest to the midnight are averaged after devided by cosine of the geomagnetic latitudes of the atations.

3. Results and discussion

Local time variations of the ampltudes of MI's at Reykjavik and Syowa normalized by the equatorial values are shown in Figure 1. The smoothing curves

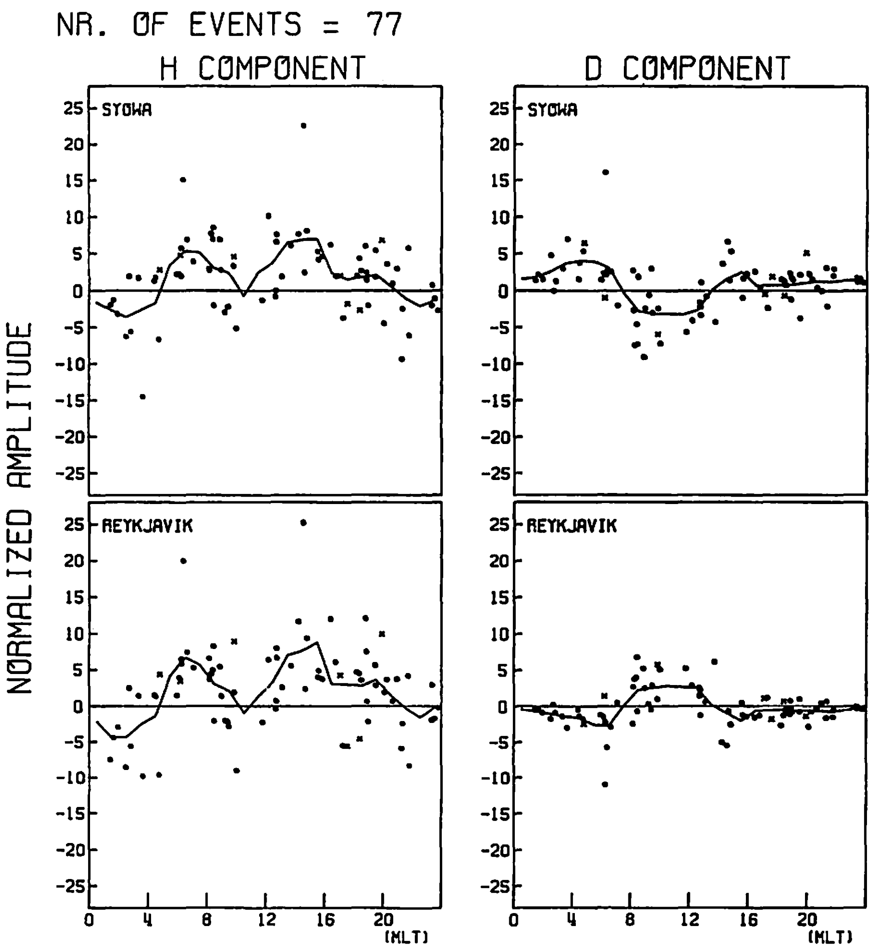

Figure 1 Local time variations of normalized amplitudes of MI's of SSC's and SI's. Circles are for SSC's and SI^+'s and crosses are for SI^-'s. Fitting lines are three hour running averages. Note that the abscissa is for magnetic local times.

showing three hour running averages are almost parallel for H component and almost antiparallel for D component. Since the data points distribute in a rather smoothed fashion, it can be mentioned that the normalization technique is effective for the present analysis.

Forms of diurnal variations of the normalized amplitudes are in agreement with the results of a numerical calculation by Tsunomura and Araki (1984) and also the results of the statistical study by Sano (1962). It is also worth to note that the data points of SI^{-}'s distribute in a same manner with those of SSC's and SI^{+}'s.

The distributions of data points for points for H component are almost parallel and those for D component are almost antiparallel with respect to magnetic local times. Therefore, it is denoted that both stations are rigidly connected by magnetic lines of force. Besides, there is no appreciable peak at four hours in lag time correlations between two stations.

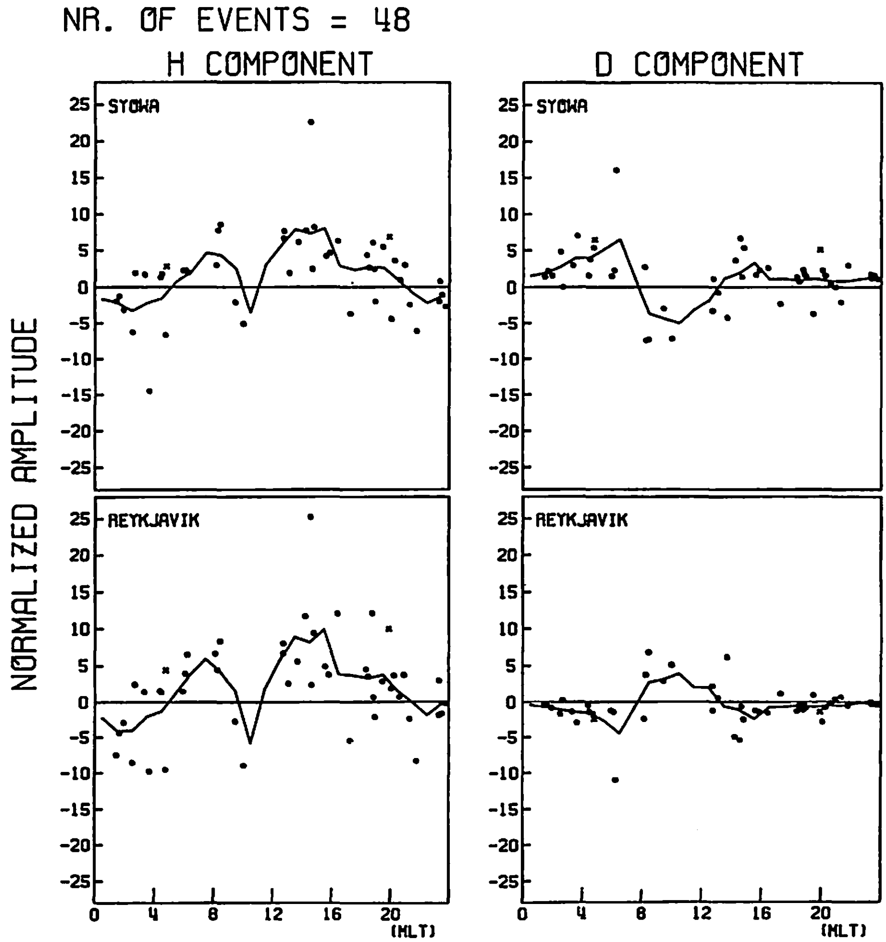

Figure 2 Same as Figure 1. for equinoctial seasons.

In order to check the local time (not magnetic local time) effect clearly, similar plots for equinoctial seasons are shown in Figure 2. If the modification of electric fields due to the distribution of ionospheric conductivity was effective to the amplitudes of MI's, it might be expected that diurnal variations of amplitudes of MI's in equinoctial seasons are most influenced by such an effect. For Local times such as morning hours or evening ones at which one station is sunlit but the other is not, the diunal variations of the amplitudes may be modified from the average graphs. There is, however, no such descrepancies in Figure 2 compared with Figure 1. Therefore, it is concluded that such an effect is negligible for the correlation analysis and is justified to compare the amplitudes of MI's atReykjavik and Syowa directly.

Relations of amplitudes of MI's between Reykjavik and Syowa are shown in correlation plot diagrams in Figure 3. Absolute values of correlation coefficients reach up to 0.92.

Iinclinations of regression lines showing averages of the ratios of amplitudes are different for both components. H component is larger at Reykjavik than Syowa (factor 0.79) as is apparent in Nagata et al. (1966)'s result, while the relation is reversed for D component (factor 1.26).

It is difficult to attribute this result to the spacial structures of equivalent current systems. There is no effective mechanism to decline the zonal averages of ionospheric currents of polar origin by a cirtain angle viewing from the north to the south hemisphere. It may be natural that the difference of induction effects of the land and the sea against magnetic variations cause this matter. Here, it is

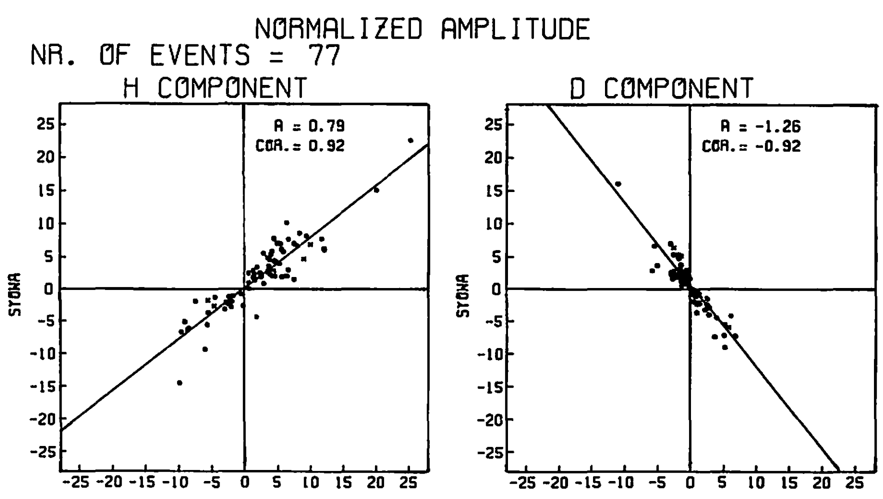

Figure 3 Correlation plots of normalized amplitudes of MI's of SSC's and SI's between Reyjavik and Syowa. Straight lines are regression lines by least squares fittings.

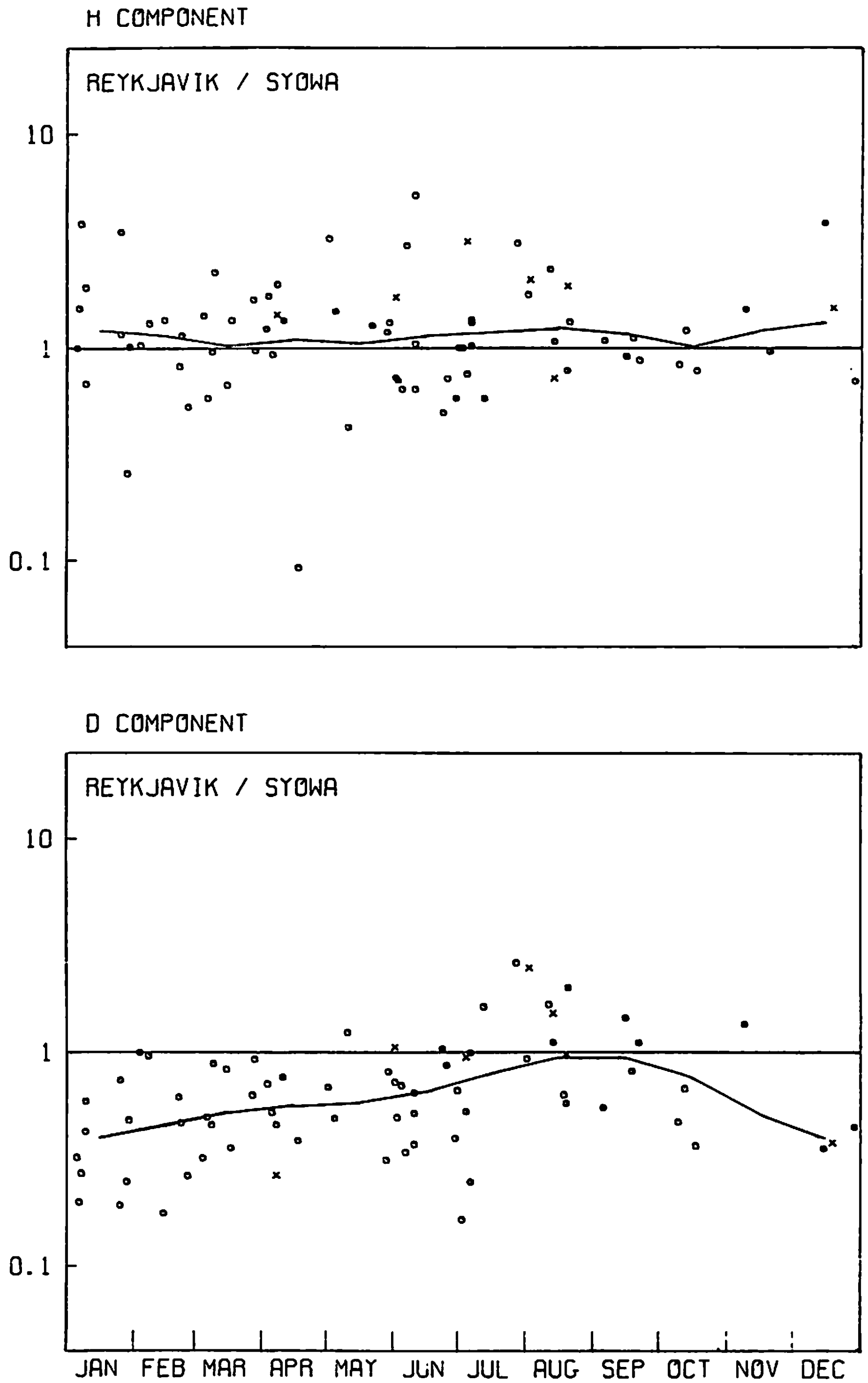

Figure 4 Seasonal variations of the ratios of the absolute values of amplitudes of MI's of SSC's and SI's. Circles and crosses are of the same meanings as Figure 1. Fitting lines are three months running averages.

impossible to calculate the precise conductivity anomaly (CA) coefficients for the author is using only analogue records. Discussions of induction effects will be performed in another paper.

Sesonal variations of ionospheric conductivity may cause those of amplitudes of MI's. To check this effect, the seasonal variations of the ratios of the absolute values of amplitudes of MI's at Reykjavik to those at Syowa for both components are shown in Figure 4. The plots of the ratios for D component show a rather clear seasonal variation with a maximum in summer and a minimum in winter. For H component, with a slight maximum in summer, a seasonal variation is not seen clearly because of the larger scattering of data points.

For the trial to inspect this feature, the effect of the disturbance level before the events are examined. Dependences of the absolute values of the ratios of the amplitudes of MI's at both stations on the K-index at Syowa for the three hour periods prior to those including the events are presented in Figure 5. Numbers of events for each K−index are listed in table 2. As can be seen in Figure 5, the ratios are almost same for the values of K from 0 to 6 witout large errors.

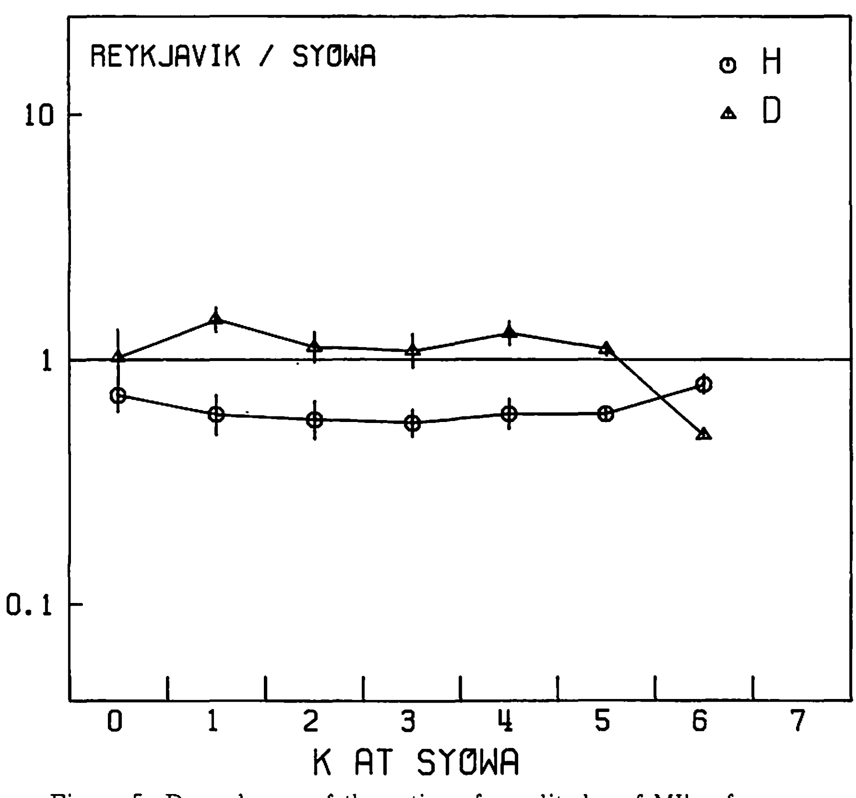

Figure 5 Dependences of the ratios of amplitudes of MI's of SSC's and SI's between Reykjavik and Syowa on the condition of disturbances. K's are for the three hour periods prior to those including the events.

Table 2 Numbers of events v.s. k index at syowa

k	0	1	2	3	4	5	6	7	sum.
No. of events	4	8	14	24	16	9	2	0	77

Thus the difference between both components in Figure 4 are not attributed to the conditions of the disturbance level of the background.

4. Conclusions

Local time variations of normalized amplitudes of MI's are examined and it is concluded that the difference in local times does not cause the difference of the ratios of MI's between Reykjavik and Syowa, that is, the connection of both stations by geomagnetic lines of force is rigid and the local time dependence due to the diurnal variation of the ionospheric conductivity is negligible for the present analysis. In order to get the self-constent model, the numerical calculation including the northsouth assymmetry with respect to the equator must be performed.

The fact that ratios of the absolute values of amplitudes of MI's between Reykjavik and Syowa are different for H and D components is the remained problem to be solved by a precise CA analysis in future.

From the patterns of seasonal variations of the ratios of MI's between Reykjavik and Syowa, it is confirmed that MI's observed in high latitudes are due to ionospheric currents the amplitudes of which vary seasonally together with ionospheric conductivity. This feature is not very much modifed for geomagnetically disturbed coditions.

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Reykjavikと昭和基地におけるSSC, SIの振幅の共役性について

角村　悟

概　要

地磁気共役点であるReykjavikと昭和基地において観測されたSSC, SIの振幅が比較された。赤道における値で規格化されたSSC, SIのメインインパルスの振幅の地方時依存性から，SSC, SIの振幅の共役性の議論に関しては，両地点の地方時の違いを無視してもよいことが確かめられた。H成分の振幅はReykjavikの方が昭和基地よりも大きく，D成分についてはその逆であった。このくい違いは，両地点における誘導効果の差によるもののようである。両地点の振幅比の季節変化は，特にD成分に，夏にゆるやかな極大，冬にゆるやかな極小を現し，地上で観測されるSSC, SIの原因となる電流源が電離層状態の季節変化に従ってその振幅を変化していることを示す。