CONJUGACY OF MAGNETIC FIELD FLUCTUATIONS IN THE PERIOD RANGE 2–24 HOURS

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Received May 18, 1971

(Communicated by Dr. K. R. Ramanathan, F.A.SC.)

Abstract

Conjugacy of variations in the period range 2 to 24 hours has been examined from coherence spectra of horizontal intensity at stations which are conjugate or nearly conjugate and stations which are in similar dipole latitudes but are not conjugate. The coherence spectra computed for stations located in the auroral zone, on the equatorial side of auroral zone and at low-middle latitudes suggest that, so far as the principal lines in the spectra corresponding to 24, 12 and 8 hours are concerned, *magnetic conjugacy is confined to disturbed periods and to stations in the auroral and sub-auroral zones.* In the continuum spectrum, however, the percentages of estimates, for which coherences are statistically significant, are very high for conjugate stations in the auroral zone but decrease progressively for pairs in the equator side of the auroral zone and lower latitudes.

Introduction

The phenomenon of conjugacy has received considerable attention in the last decade. Simultaneity of magnetic oscillations (Sugiura, 1961; Nagata, 1963), a high degree of similarity of records during storms (Nagata and Kokubun, 1960; Wescott, 1961, 1962), similarity of magnetic disturbance variations (Nagata *et al.*, 1962; Ondoh and Maeda, 1962; Boyd, 1963), similarity in the cosmic noise absorption events (Hook, 1962; Leinbach and Basler, 1963; Little *et al.*, 1965), simultaneity of telluric current disturbances (Mather and Wescott, 1962), F-region perturbations (Cummack, 1967) and aurora (Dewitt, 1962) at conjugate points have provided strong support to the phenomenon of conjugacy. The most notable correlations in disturbance variations at conjugate stations were noticed in the H component (Wescott, 1961). Comprehensive reviews of the magento-conjugate phenomena have been given by Wescott (1966) and Roederer (1969).

The problem of an electric linkage between the nothern and southern hemisphere by geomagnetic field lines was considered by Dougherty (1963). Earlier, it was suggested (Farley, 1960) that when the dynamo wind system is asymmetric with respect to the equator a tendency will exist for the flow of electric currents along the lines of force and that this flow will equalize the electric potentials in conjugate areas in the dymano layer. S_q variations at geomagnetically conjugate stations have been examined by Wescott *et al.* (1963). From the data of very quiet days from conjugate pair San Juan-Trelew, they, however, did not find any particular similarity in the S_q variations at these stations. In the 1961–62 programme of conjugate point observations of the U.S. Bureau of Standards, Boyd (1963) observed a close correspondence between all magnetic variations, with the exception of S_q, between stations in Quebec and their close conjugate station, Eights, in Antartica. In this communication the problem of conjugacy at diurnal and semi-diurnal frequencies has been examined from cross-spectra of series of hourly values of H from conjugate or near conjugate stations. For comparison, cross-spectra between the southern stations of the pairs and northern stations at about the same dipole latitude but well separated in longitude have been examined. The coherences have also been examined for the entire spectrum for data samples covering both relatively quiet and disturbed periods.

COMPUTATIONS AND RESULTS

Hourly values of the horizontal intensity at the selected pairs of stations were subjected to cross-spectral analysis following the procedure outlined by Blackman and Tukey (1958) and Munk *et al.* (1959). The cross-spectra yield the coherence, the degree of association between two time series, as a function of frequency. The coherence at a given frequency between the time series tend to be small or zero if the components of the series are not related to each other. It tends to be high if the components are closely related, irrespective of the magnitude of the phase difference. Conjugate stations whose hourly magnetic data have been used in the computations are listed in Table I. The power densities corresponding to 24 hr, 12 hr and 8 hr lines and coherences between the pairs are then compared with those obtained from cross-spectra of the same southern station with a northern station whose dipole latitude is almost the same but whose dipole longitude is widely different. These stations, with their dipole co-ordinates, are also given in Table I. 30-day periods over which samples of data were used for computations for quiet and disturbed intervals are shown in Table II together with respective values of the index A_p of magnetic activity averaged over the 30 days. The choice of sample was restricted by availability of continuous data, especially for San Juan—Trelew pair.

TABLE I

Station	Dipole co-ordinates		Conjugate Station	Dipole co-ordinates		Comparison Station	Dipole co-ordinates	
	Latitude	Longitude		Latitude	Longitude		Latitude	Longitude
Macquarie Island ..	61·0° S	243·0° E	College	64·6° N	256·5° E	Lerwick	62·5° N	88·6° E
Port-aux-Francais ..	57·2° S	128·(° E	Nurmijarvi	57·9° N	112·6° E	Meanook	61·8° N	301·0° E
Trelew ..	31·7° S	3·2° E	San Juan	29·9° N	3·2° E	Memambetsu	34·0° N	208·4° E

Using series of length 720 and a maximum lag of 120, the estimates were computed with reasonably high stability (11·5 degrees of freedom). High power density and low continuum level in the spectra suggest the existence of a well-defined 24-hour component and its principal harmonics. The power densities corresponding to frequencies 1/24, 1/12 and 1/8 cph at these stations for quiet and disturbed periods as also the coherence between pairs of stations at the three frequencies are listed in Table III.

TABLE II

Station	Quiet Interval	$\bar{A}_p$	Disturbed Interval	$\bar{A}_p$
College, Macquarie Island, Lerwick	1—6-1954 to 30—6-1954	5·8	22—2-1953 to 23—3-1953	23·8
Nurmijarvi, Port-aux-Francais, Meanook	11-12-1961 to 9—1-1962	6·1	3—9-1960 to 2-10-1960	23·0
San Juan, Trelew, Memambetsu	12-11-1958 to 11-12-1958	10·2	1—6-1958 to 30—6-1958	23·8

DISCUSSION

If the coherences of the conjugate pair and the comparison pair at any frequency are nearly the same, it would imply that the periodicity is not confined to conjugate points. If, on the other hand, the coherence is significantly higher for the conjugate pair as compared to the coherence between stations which are not conjugate, a conjugacy in the variations at the parti-

TABLE III

Period (Hours)	Quiet Interval: Power densities γ^2			Quiet Interval: Coherences		Disturbed Interval: Power densities γ^2			Disturbed Interval: Coherences	
	College	Macquarie Island	Lerwick	College Mac. Is.	Lerwick Mac. Is.	College	Macquarie Island	Lerwick	College Mac. Is.	Lerwick Mac. Is.
24	66·00	6·86	96·41	·786	·794	2367·0	2273·2	110·0	·992	·869
12	24·04	12·18	25·67	·818	·915	383·9	533·1	67·5	·973	·701
8	12·30	1·32	·62	·490	·475	71·3	38·4	37·3	·822	·502
	Nurmijarvi	Port-aux-Francais	Meanook	Nurmijarvi Port-aux-Francais	Meanook Port-aux-Francais	Nurmijarvi	Port-aux-Francais	Meanook	Nurmijarvi Port-aux-Francais	Meanook Port-aux-Francais
24	4·89	41·98	21·81	·887	·488	165·2	192·8	2046·1	·847	·743
12	1·75	15·36	21·58	·776	·840	68·3	49·3	299·2	·788	·618
8	2·23	2·03	9·66	·786	·657	11·3	24·1	75·3	·831	·666
	San Juan	Trelew	Memambetsu	San Juan Trelew	Memambetsu Trelew	San Juan	Trelew	Memambetsu	San Juan Trelew	Memambetsu Trelew
24	37·23	14·37	9·58	·790	·651	17·3	43·1	56·1	·752	·948
12	5·16	17·08	18·35	·739	·786	2·2	4·9	23·7	·268	·607
8	·38	16·66	5·77	·492	·795	2·0	3·6	10·8	·575	·610

cular frequency is established. At the principal frequencies, 1/24, 1/12 and 1/8 cph, shown in Table III, the coherences between conjugate and between comparison pairs, especially during quiet periods, are of the same order, suggesting that these frequencies are global with no preference for similarity at conjugate stations. During disturbed periods, however, the coherence is noticed to be higher for the conjugate pair when compared to non-conjugate pair for the auroral and sub-auroral zones. In low and middle latitudes (San Juan-Trelew-Memambetsu) there is no magnetic conjugacy even during disturbed periods.

The spectra over the entire frequency band were next examined for significant coherences, subject to the restriction that higher frequencies where the power densities were too small for meaningful coherence were omitted. The least value of coherence to be significant should satisfy the condition $(\text{coherence})^2 > 4/\nu$ (Munk and Macdonald, 1960) and for $\nu = 11{\cdot}5$ it should be in excess of ·590. Table IV shows the percentage of estimates with significant coherences out of the total number of estimates computed. It is immediately noticed that during disturbed periods, the percentage is very high for conjugate stations. For the conjugate pair College-Macquarie Island, near the auroral zone with 117 estimates having significant coherence out of 120 computed estimates, almost the entire spectrum is similar, establishing a high degree of conjugacy of the variations between 2 hours and 24 hours

TABLE IV

Station Pair	Quiet Interval			Disturbed Interval		
	Number of coherences considered	Number of significant coherences	Percentage	Number of coherences considered	Number of significant coherences	Percentage
College, Macquarie Island	40	30	75	120	117	97·5
Macquarie Island, Lerwick	40	10	25	120	21	17·5
Nurmijarvi, Port-aux-Francais	40	15	37·5	120	94	78·3
Port-aux Francais, Meanook	40	12	30	120	45	37·5
San Juan, Trelew	40	18	45	40	32	80
Trelew, Memambetsu	40	24	60	40	27	72·5

during disturbed periods and confirming the results of Wescott (1961). For stations on the equatorial side of the auroral zone, the similarity of variations between the conjugate pair is still high but some frequencies are not common. This is indicated by reduced percentage of significant coherences. Considerably lower percentages of significant coherences for the non-conjugate pair in these two cases further confirms these results. For the low latitude stations, the percentages are nearly the same for both conjugate and comparison pairs. This suggests that variations during disturbances in low latitudes are not confined to magnetic conjugate points but are discernible at other stations in the same latitude. During quiet period, a pronounced similarity of occurrence is confined to conjugate stations in and near the auroral zone. For low and middle latitude stations the principal components of the quiet day variations have no preference for conjugate stations and confirm the results of Wescott *et al.* (1962) and Chikovani (1970).

CONCLUSION

Diurnal and shorter period variations ($> = 2$ hours) in low latitude conjugate stations show nearly the same characteristics as stations in the same latitude belt but which are not conjugate, during quiet as well as disturbed conditions. Near the auroral zone, conjugate stations are linked by field lines both during quiet and disturbed periods. Coherences between stations for 24-hour line and its harmonics suggest a conjugacy during disturbed conditions but little conjugacy during quiet periods. For the conjugate stations on the equator side of the auroral zone also, the conjugacy is restricted to disturbed conditions. There is a progressive decrease in the percentage of significant coherences during disturbed conditions from auroral zone through equatorial side of auroral zone to low-middle latitudes.

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