A Study of Night Time Variations during Magnetic Storms at Coastal Indian Stations.

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ABSTRACT -- The sub-surface conductivity distribution of the Indian peninsula near Alibag, Annamalainagar and Trivandrum has been investigated by analysing stormtime variations of the three components of the magnetic field. In this study only night time variations are considered in order to avoid the non-uniformity in the inducing field arising from the presence of electrojet in daytime. Spectral analysis is carried out to compute the auto and cross-spectra of the three components H,D and Z for periods ranging from 32 to 210 minutes. These are then utilised to obtain the transfer functions and subsequently the induction vectors. From an earlier analysis of continuous data of 36 hours length or more, vectors were obtained that reflected the non-uniformity of the external inducing field in day time. A comparison of these with night time vectors showed significant differences for the stations, Annamalainagar and Trivandrum

Introduction

The observed magnetic field variation on the surface is vector sum of an external and an internal part. The internal part is due to the currents induced inside the earth by the external field variations. Further we classify the internal field into normal and an anomalous component. The normal part takes into account the changes in conductivity that are functions of radius alone. This in essence would mean that the normal part of the internal field should remain the same for the same inducing field. The anomalous part is observed because of local variations in the conductivity structure beneath the earth. It has been shown that (Frazer 1974) over a stratified plane conductor the inducing and induced fields supplement each other in horizontal components but oppose each other in vertical component. Hence any irregularities in space or time of the source field will show up strongly in Z variations. Hence this provides a powerful tool to study the sub-surface conductivity contrast.

In the present study the stormtime variations are chosen to investigate the conductivity structure below the Peninsular India. The storm time variations (Lahiri and Price 1939) contain periods of wide range with measurable intensity. We report here the results from Alibag, Annamalainagar and Trivandrum. The observatories at Annamalainagar and Trivandrum come under the equatorial electrojet.

Hence in order to avoid complications that may arise because of non-uniformity of the external inducing field we have decided to use only night time variations. It has been shown (Schmucker 1964) that night time variations during bays are quasi-stationary over a latitude range of about 37°. Hence we may not be introducing much error by assuming that storm time current distributions are uniform during night time.

The formal separation of the observed field into internal, internal anomalous and external is a tedious process. Assuming that it is done with a chain of stations, still for the nature of the conductivity contrast at the tip of the Indian Peninsula, this would only be of limited utility. Instead we adopt an alternate method of transfer functions wherein we express the anomalous parts in terms of normal components. The normal part here is the sum of external and normal internal. From the transfer functions we deduce a vector called "The Induction Vector", the direction of which locates the strike of the conductor and the source of the current causing the anomaly.

Analysis

The storm time variations from Alibag, Annamalainagar and Trivandrum have been digitized manually at every 2 mm interval on time scale. Using a filter of suitable response we restricted our range of periodicities upto 300 min. Using spectral analysis, the auto and cross-spectra of H, Z and D components are determined in the period range 32 to 210 min. Schmucker observes (1970) that the Fourier transforms of the anomalous and Normal field components are linearly related by a matrix of transfer function as

$$\left.\begin{aligned} Z_{ia} &= W_{zx} X_n + W_{zy} Y_n + W_{zz} Z_n \\ Y_{ia} &= W_{yx} X_n + W_{yy} Y_n + W_{yx} Z_n \\ X_{ia} &= W_{xx} X_n + W_{xy} Y_n + W_{xz} Z_n \end{aligned}\right\} \quad \text{------- (A)}$$

where W's are the components of the transfer function matrix which are functions of frequency. X, Y and Z are the Fourier Transforms of the magnetic north, east and vertical components of the magnetic field and subscript 'n' refers to normal part and 'ia' refers to internal anomalous part. We use the following simplifying assumptions (i) that there is no correlation of Z_n with either X_n or Y_n and (ii) that the anomalous internal parts X_{ia} and Y_{ia} are negligible in comparison to normal parts. Hence we can write the relation (A) as

$$Z = AH + BD + \epsilon \quad \text{- - - - - - - - - - - (B)}$$

A and B are complex numbers and are functions of frequency. ϵ is the uncorrelated part of the vertical field. The constants A and B are peculiar to an observation point and vary from station to station. A and B are found out by minimising with respect to real and imaginary parts of A and B. Hence we get

$$A = (P_{ZH}\, P_{DD} - P_{ZD}\, P_{DH})/(P_{HH}\, P_{DD} - |P_{DH}|^2)$$

$$B = (P_{HH}\, P_{ZD} - P_{HD}\, P_{ZH})/(P_{HH}\, P_{DD} - |P_{DH}|^2)$$

In the above equation P_{HH}, P_{ZZ} and P_{DD} are the auto powers of H, Z and D respectively and P_{HD} refers to cross power of H and D etc. as obtained for each frequency. Using seven storms the values of A and B are computed at various periods and the results obtained are shown in Table I.

From the real parts of A and B (AFU and BFU) we get the induction vector $\vec{S}_R = -\vec{i}\,AFU - \vec{j}\,BFU$ where $\vec{i}$ and $\vec{j}$ are unit vectors along magnetic north and east respectively. The signs are reversed in order to conform to Parkinson's (1962) convention according to which the vector points towards the direction of induced current concentration. Similarly we obtain S_I from the imaginary parts AFV and BFV.

Results and Discussion

The values of S_R and S_I and their orientation as measured from the south clockwise are shown in Table I. These are plotted in Fig. 1. together with those values of transfer functions obtained with day and night time variations considered continuously.

We observe from Fig. 1 that the night time results show an enhancement in the value of the induction vector at all the three stations. This may be explained as follows. There is a normal part of appreciable intensity in the inducing field during day time and this may not show much correlation with variation in either H or D. At nights this normal part vanishes and so there is a better correlation of the anomalous Z variations with H and D. Hence the induction vectors are of larger magnitude at nights. Another plausible explanation may be that the assumption H_{ia} and D_{ia} are negligible in comparison to their normal parts (equation B) may not be

Period	ALIBAG				ANNAMALAINAGAR				TRIVANDRUM			
MIN	SR	SI	θR°	θI°	SR	SI	θR°	θI°	SR	SI	θR°	θI°
210	.064	.185	- 54	21	.689	.376	53	-48	.760	.494	3	8
140	.288	.202	+100	150	1.216	.787	56	-89	.841	.379	3	13
70	.589	.393	97	151	.593	.416	-11	77	.681	1.385	23	-89
53	.350	.278	240	151	1.515	1.115	41	81	.737	.479	-46	00
42	.177	.534	256	127	1.673	.343	46	-78	.677	1.254	0	-66
32	.355	.355	121	267	.579	.166	-33	0	.837	.896	- 6	24

Table.1: The values of real and imaginary parts of induction vectors for all the three stations at different frequencies.

fully justified. In another separate study we have also come to the conclusion that H and D have anomalous parts at Annamalainagar and Trivandrum; but it is still to be seen whether the anomalous parts have sufficient intensity to account for this behavior.

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