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Diurnal Magnetic variations near the Magnetic Equator

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The diurnal variation of H at Huancayo is found to be considerably larger than that expected in such regions. McNish (1937) explained the large variation as follows. According to the dynamo theory the main electrometric forces are induced in middle and higher latitudes, which drive the current eastwards in low latitudes, where, if the geographic and geomagnetic equators coincide, it is opposed by the electromotive forces induced there, but if the two equators are apart, then in the region between these two, the electromotive forces induced there help the current flow, resulting in its enhancement. Chakravarty (1946) suggested geomagnetic control of the diurnal variation in low latitudes. Egedal (1947) showed from the data of some stations in and near the equatorial region that the diurnal magnetic variation was symmetrical about the magnetic equator. He suggested that the augmentation of the range of H in a narrow zone near the magnetic equator might be due to a varying electric current flowing in a very narrow zone of the atmosphere above the magnetic equator at a height of about 100 km. Chapman (1948) found that diurnal variation was large at places near which the magnetic equator crossed the geographic equator at a steep angle and was less at places where the change in the latitude of the magnetic equator was slow. Martyn (1949) was of the view that the distribution of diurnal range was symmetrical about an equator between the magnetic and geomagnetic equators. He mentioned that McNish's theory did not appear to account for the observed effects as although it gave approximate symmetry about the magnetic equator it did not account for the large enhancement. He thought that the enhancement was more likely to be due to an increase in conductivity of the ionosphere near the magnetic equator. Price and Wilkins (1951) from an analysis of the S_q field for the polar year 1932-33 found that the maximum variation occurred between the magnetic and geomagnetic equators in Africa and South America, and to the south of both these equators in the Far East, and that the line of maximum variation moved in a direction opposite to that of the sun.

Chapman (1951) examined the question taking into account the observations of Giesecke in South America in 1949 and presumably those of Gulatee in India in 1950. He mentioned that the observed lateral limitation of the band of abnormal H range showed that McNish's explanation, according to which the distribution of H range should be fairly smooth, was at the most a contributory cause and perhaps not the main cause. He stated in the summary : " The abnormally large range of the daily variation of the horizontal (or north) component of magnetic force over Huancayo in Peru indicates the daily rise and decline of a concentrated eastward electric current above that station, superposed on the normal current distribution responsible for the daily magnetic variation S_q. The name electrojet is suggested for this concentrated current. New investigations indicate the occurrence of the electrojet also over Africa and India. To determine the height, intensity, width and return current flow of the electrojet, it is necessary to determine the abnormality in the daily range of the vertical (and perhaps also of the east) force, at stations north and south of the electrojet. It is suggested that the Bombay and Manila daily Z variations already confirm the existence of the abnormality also in this element ". He also calculated the distribution of the diurnal range of H and Z under different conditions of height, width, form and return current flow of electrojet. These calculations will be of great help in interpreting fresh data. It is interesting to note in this connection that Singer, Maple and Bowen (1951) found experimental evidence from an Aerobee ascent of the existence of a current layer about 11·24 hrs (local time) above the magnetic equator at a height of about 100 km, but they did not find from another Aerobee ascent any such current layer about 17·24 hrs by which time such a current is expected to decline.

In the observations of Coulomb (1951), Giesecke (1951) and Gulatee (1949-50), determinations of H were made by QHM in the morning and afternoon when minima occur and just before noon when maxima occur and from these daily ranges were obtained. One of the present authors (Pramanik) arranged in 1951 for observations of diurnal variation of H at 3 places situated from 8·1°N to 9·2°N (geographic latitude). During these observations hourly determinations of H and Z were made with QHM and MBZ respectively for 6 days at each place and the diurnal ranges were obtained from the maximum and minimum values. From the analysis of the observations in the Indian region, which is far away from the crossing of the geographic and magnetic equators, Pramanik and Yegnanarayanan (1952) found that the diurnal variation of H is quite large and that the maximum variation occurs to the south of both the geomagnetic and magnetic equators.

Further observations in South India for two days at each of the nine places given in the table in the next column were arranged for by the present authors in February-March 1953.

The diurnal variation of H was determined with the help of an Askania Magnetic Field Balance (No. 50—10020), type Gf 6, designed by Adolf Schmidt, with photocell recording attachment. For obtaining the base line values, absolute values of the horizontal force were determined with the help of the QHM manufactured by Messrs Anderson and Sorenson, Copenhagen. Three QHMs (Nos. 165, 166 and 167) were used and the value of H for any particular hour was taken as the mean of the three values given by the three QHMs.

Place	Latitude °N	Longitude °E	Date of observation (1953)
Devadanapatti	10·2	77·3	Feb 23 and 24
Virapandi	10·0	77·4	Feb 26 and 27
Uttamapalayan	9·8	77·3	March 1 and 2
Kodaikanal Road	10·2	77·9	4 and 5
Palni	10·5	77·5	7 and 8
Dharapuram	10·7	77·5	10 and 11
Erode	11·3	77·8	17 and 18
Mettur	11·8	77·8	20 and 21
Bangalore	13·0	77·6	23 and 24

The values of the vertical force were obtained from observations with the BMZ (No. 58) manufactured by Messrs Anderson and Sorenson. Four observations were recorded on each day at 0700, 1000, 1200 and 1800 IST and also at 2200 IST on one day at each place. The mean value for any hour was taken as the mean of the readings obtained by using as many of the available supplementary magnets as possible in different positions. It was not necessary to use the Field Magnet for the vertical force at the stations. It was also not possible to measure the vertical force at Mettur Dam and Bangalore with the Field Magnet and supplementary magnets supplied with the BMZ (No. 58). The observations of H and Z were recorded for two complete days at each place. The QHMs and the BMZ were compared at the Magnetic Observatory at Alibag and at Kodaikanal before and after the experiments.

During the period of observations extending over 18 days, there were three magnetically calm days at Kodaikanal. Five days were moderately disturbed and ten days slightly disturbed.

In Table 1 are given the diurnal ranges of H at the nine places and their ratios to the corresponding ranges at Kodaikanal, for all the days during which observations were

TABLE 1

Diurnal range of *H* and *Z*

Month and date	Character of day	*H* Range (in γ)	*H* Range at Kodaikanal (in γ)	*H* Ratio 3 ÷ 4	*H* Mean Ratio	*Z* Range (in γ)
(1)	(2)	(3)	(4)	(5)	(6)	(7)
			DEVADANAPATTI			
Feb 23	Sa	77	86	0·8953	1·0539	30
24	Sa	97	80	1·2125		39
			VIRAPANDI			
26	Sa	153	132	1·1591	1·1855	48
	M	143	118	1·2119		20
			UTTAMAPALAYAM			
Mar 1	S	105	101	1·0396	1·0598	40
2	Mg	216	200	1·0800		32
			KODAIKANAL ROAD			
4	S	83	113	0·7345	0·7577	41
5	Sa	82	105	0·7809		21
			PALNI			
7	Sa	89	99	0·8999	0·8459	42
8	M	99	125	0·7920		18
			DHARAPURAM			
10	Sa	61	73	0·8356	0·8572	36
11	Ca	87	99	0·8788		41
			ERODE			
17	Ca	114	123	0·9268	0·8672	38
18	Ca	84	104	0·8077		26
			METTUR			
20	Sa	74	71	1·0423	0·9152	
21	Sa	67	85	0·7882		
			BANGALORE			
23	Mg	92	94	0·9787	0·9082	
24	Mg	93	111	0·8378		

recorded. The magnetic character of the days in question has been indicated against the dates. The diurnal ranges of *Z*, computed as the difference between the highest and lowest of the 4 or 5 values recorded in a day has also been given in the table. In computing the diurnal range of *H*, the maximum and minimum values have been picked out from the charts of the Askania Balance.

In Table 2 are given the mean hourly values of *H* for all the days during which observations were recorded. At the first place, Devadanapatti, complete observations were available only for one day.

TABLE 2

Mean hourly values of H in γ (39000 +)

Station	Date	Character of day	Hours (IST) 00	01	02	03	04	05	06	07	08	09	10	11	12
Devadanapatti	23-2-53	S	548	538	536	557	557	538	548	548	560	587	583	587	587
Virapandi	26-2-53	S	536	922	919	916	918	916	930	928	928	939	942	959	948
	27-2-53	M	867	881	901	898	895	889	881	889	910	927	947	939	935
Uttamapalayam	1-3-53	S	1005	1021	1015	1012	1009	1012	1012	1014	1030	1052	1068	1075	1066
	2-3-53	M	1000	1005	1007	1016	1016	1010	1011	1008	1016	1019	1044	1041	1046
Kodaikanal-Road	4-3-53	S	1071	1071	1089	1087	1084	1077	1077	1082	1098	1110	1112	1112	1107
	5-3-53	S	1074	1074	1077	1078	1082	1080	1086	1086	1086	1104	1140	1124	1129
Palni	7-3-53	S	898	901	912	915	907	892	889	887	866	881	909	918	921
	8-3-53	M	907	889	890	895	900	903	905	910	916	914	921	921	911
Dharapuram	10-3-53	S	1217	1230	1257	1236	1241	1243	1247	1233	1230	1246	1268	1268	1249
	11-3-53	C	1239	1255	1255	1260	1265	1260	1260	1255	1266	1282	1298	1314	1306
Erode	17-3-53	C	1046	1048	1050	1064	1050	1047	1047	1054	1064	1081	1102	1105	1088
	18-3-53	C	1051	1051	1048	1050	1056	1059	1059	1062	1068	1074	1080	1080	1086
Mettur	20-3-53	S	1117	1121	1136	1136	1130	1127	1127	1127	1121	1136	1151	1151	1145
	21-3-53	S	1124	1136	1136	1130	1128	1138	1140	1143	1143	1146	1158	1146	1137
Bangalore	23-3-53	M	1336	1345	1345	1377	1355	1371	1366	1373	1373	1351	1378	1373	1344
	24-3-53	M	1361	1363	1341	1341	1346	1348	1350	1354	1354	1363	1349	1339	1355

Station	Date	Character of day	Hours (IST) 13	14	15	16	17	18	19	20	21	22	23	24
Devadanapatti	23-2-53	S	583	578	570	550	548	535	523	520	516	513	511	510
Virapandi	26-2-53	S	889	850	853	843	840	806	848	858	883	853	861	867
	27-2-53	M	894	844	824	828	828	856	864	871	883	872	876	884
Uttamapalayam	1-3-53	S	1056	1035	1000	980	974	986	992	997	999	1005	1001	1000
	2-3-53	M	1005	980	925	880	874	848	872	882	875	952	917	938
Kodaikanal Road	4-3-53	S	1114	1092	1060	1050	1044	1053	1059	1060	1070	1062	1068	1074
	5-3-53	S	1104	1082	1068	1074	1078	1074	1068	1068	1074	1062	1059	1064
Palni	7-3-53	S	898	880	858	845	837	848	860	863	869	872	872	907
	8-3-53	M	881	863	845	837	835	855	863	860	840	823	840	858
Dharapuram	10-3-53	S	1249	1233	1232	1229	1218	1215	1218	1230	1227	1234	1236	1239
	11-3-53	C	1287	1260	1244	1239	1234	1239	1244	1247	1249	1254	1258	1263
Erode	17-3-53	C	1046	1025	1009	991	994	1015	1021	1035	1045	1048	1048	1051
	18-3-53	C	1074	1050	1030	1012	1002	1002	1012	1027	1033	1042	1051	1057
Mettur	20-3-53	S	1131	1113	1095	1086	1086	1098	1104	1110	1116	1130	1130	1124
	21-3-53	S	1134	1108	1111	1114	1094	1115	1119	1126	1132	1132	1130	1118
Bangalore	23-3-53	M	1361	1349	1323	1292	1305	1294	1313	1330	1359	1336	1318	1361
	24-3-53	M	1299	1325	1885	1277	1292	1287	1287	1304	1304	1316	1326	1335

The ratios of the diurnal range of H to that at Kodaikanal for all the places at which observations were recorded in the current series as well as for the places for which these were found by Gulatee in 1950 and Pramanik and Yegnanarayanan in 1951, are plotted against the geographic latitude in Fig. 2 and a curve drawn to obtain the best fit. The locations of the places are shown in Fig. 1.

It will be seen from the curve that for the approximate meridian of Kodaikanal (77·5°E) the diurnal variation is maximum near the magnetic equator and that it decreases rapidly on either side. It should be mentioned that the values used in preparing the graph were based on observations during three years, mostly during the months of February and March. The values have been reduced to reference station (Kodaikanal) but are uncorrected for variation with sunspots and for annual and lunar variations. The period of observation varies from two to six days at each station, but as a fairly large number of stations have been used, it is expected that the graph would give a fair representation of the diurnal variation in the region, particularly during February-March.

In Fig. 3, the ratios of the diurnal ranges of H, at the field stations to those at the respective places where the highest variations have been observed (Huancayo for the southern hemisphere and Cape Comorin for the northern hemisphere), have been plotted making use of the available Indian observations for the northern hemisphere latitudes and South American observations of Giesecke for the southern hemisphere latitudes. There is good similarity between the graphs for the latitudinal belt north of the equator in the Indian area and that south of the equator in South America. It is also seen that they fit into a continuous pattern across the geographic equator.

It will be seen that the observations are not available in Indian regions further south than 6°N, *i.e.*, about 3° from the magnetic equator, and in South America further south than 16·2°S or about 3° from the magnetic equator. In the case of Indian region it is not possible to have observations further south

Fig. 1. Locations of places with observations of diurnal range of H

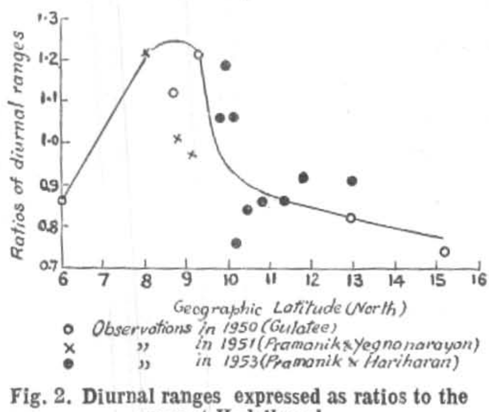

Fig. 2. Diurnal ranges expressed as ratios to the range at Kodaikanal

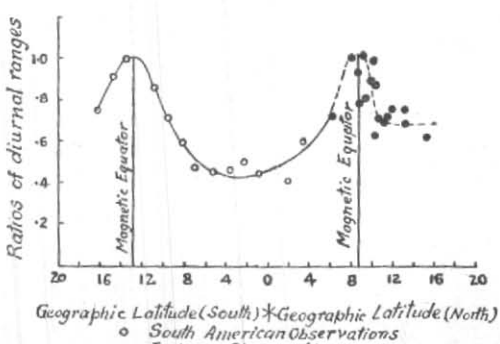

Fig. 3. Diurnal ranges expressed as ratios to those at Huancayo and Cape Comorin respectively

because of the sea, but it would be helpful if some observations were taken at a few places south of latitude 16·2°S in South America. The portions of the curve in the Indian region and South America being similar, one may be able to get an idea of the variation in the Indian region south of 6°N from the corresponding South American portion of the curve, and of the variation in South America south of latitude 16°S from the corresponding portion of the Indian curve. In this connection it will also be interesting to have observations at some places between the geographic equator and 15°N along a meridian, say between 15°E and 38°E in Africa.

It should be mentioned here that in both the Indian and the South American regions the magnetic equator is widely separated from the geographic equator. The nature and extent of the variation in regions where the two equators are close together are not known, and it will be interesting to have observations from some places in these regions.

Conclusions

From the above study the following conclusions may be drawn regarding the diurnal ranges of *H* in the neighbourhood of the magnetic equator in South America and India.

(1) The maximum diurnal range of *H* occurs near the magnetic equator.

(2) The high diurnal ranges occur over a narrow belt extending over about 5° to 6° of latitude.

(3) The diurnal range near the magnetic equator is about double that outside the narrow belt of high ranges.

(4) The diurnal range increases rapidly on approaching the magnetic equator.

(5) Although the actual ranges are different, the curves of the ratio of the ranges at places to the north and south of the magnetic equator in India and South America are similar.

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