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Secular variation of Geomagnetic Elements at Alibag

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ABSTRACT. Attempts are made to represent secular variations of geomagnetic elements (H, Z and D) of Alibag by fitting polynomials of third order to the observed annual mean values for the years 1905-65. The coefficients of the fitted curve account for more than 99 per cent of the total variation in case of H and D and 98 per cent in case of Z. The coefficients are compared with those computed by Moos, Pramanik and Pramanik and Ganguli for the same station. A probable change of position or intensity or both of the focus of the H-field in the region is inferred from the change in trend of H and D curves about the year 1964. The residual H, Z and D curves did not show any parallelism with solar activity as judged from sunspot numbers. H and Z residuals nearly indicated a periodicity of 3 solar cycles whereas D showed a periodicity of 2 solar cycles.

1. Introduction

The variation of the annual values of the geomagnetic field is a complex phenomenon, resulting from a number of physical processes. It is well known that the magnetic field of the earth is affected by solar phenomena and periodicities of the order of the sunspot cycle are expected to be manifested in the geomagnetic field variation. An important feature of the geomagnetic field variation however is the gradual, long period and large amplitude change, the so called secular variation, the cause of which is considered to originate within the earth.

For the Indian region a number of studies in secular variation have been reported. Moos (1910), in his extensive analysis of geomagnetic data of Colaba, fitted different equations for the annual mean parameters, *viz.*, H (Horizontal Force) Z, (vertical Force) and D (Declination) and from them deduced the residuals between the observed and calculated values. He showed a close parallelism between the residuals and the solar activity, as measured by sunspot numbers. Pramanik (1952), considering the mean annual values of the magnetic elements at Colaba and Alibag upto the year 1946, concluded that the rates of change of H, Z and D are not associated with years of increasing or decreasing sunspot activity in any definite manner. Pramanik and Ganguli (1954) reviewed the pioneer work done by various investigators in the field. They fitted different orders of the curves for H and D values for 4 stations including Colaba and Alibag data upto 1950 and concluded that in none of the residual curves of 4 stations was there a periodicity of about 11 years, nor was there any parallelism with sunspot curve.

The present study extends those of previous workers, using the data of Alibag (Geomag. Lat. 9°30′N, Geomag. Long. 143°36′E) for each of the elements H, Z and D for the period 1905-1965. The secular trend is studied by fitting a third order polynomial curve to the annual mean values and the predominant periods shown by the residual values are examined.

2. Data and analysis

The annual mean values of H, Z and D for the period 1905-1965, for Alibag have been obtained from the published observatory annual volumes or from manuscripts of the volumes to be published. The annual mean values of H, Z and D are deduced from all days monthly mean values. There were some differences from time to time in the formulation of the monthly mean values.

For this study the differences in tabulation procedure and deduction of monthly mean values are presumed not to have affected the homogeneity of the data to any appreciable extent.

For the annual mean values of each of the elements H, Z and D, a third order polynomial of the form $X = \overline{X} + At + Bt^2 + Ct^3$ is fitted where $\overline{X}$ is the mean value of the element and t is year, varying from -30 to $+30$ (1905-1965). The computations were carried out through CDC 3600 Computer at the Tata Institute of Fundamental Research, Bombay. After getting the coefficients A, B and C the value of X is calculated for each of the t values and the residual, *i.e.*, the difference between the observed and the calculated values are determined.

The values of $\overline{X}$, A, B, C and the percentage contribution of each of the coefficients to the total variance for each of the elements is given in Table 1.

The plots of the observed values of H, Z and D with the respective trends of the polynomial curves are given in Fig. 1. The residual value of H, Z and D for each of the years and Zurich sunspot number

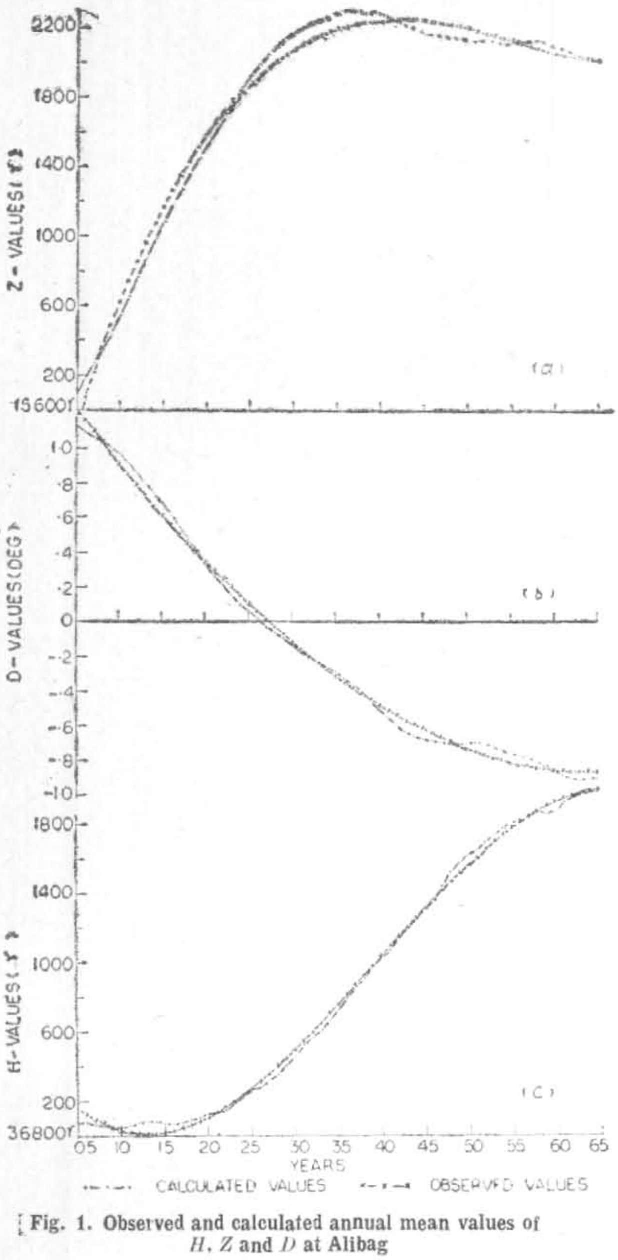

Fig. 1. Observed and calculated annual mean values of H, Z and D at Alibag

(*a*) Vertical force (*b*) Declination (*c*) Horizontal force

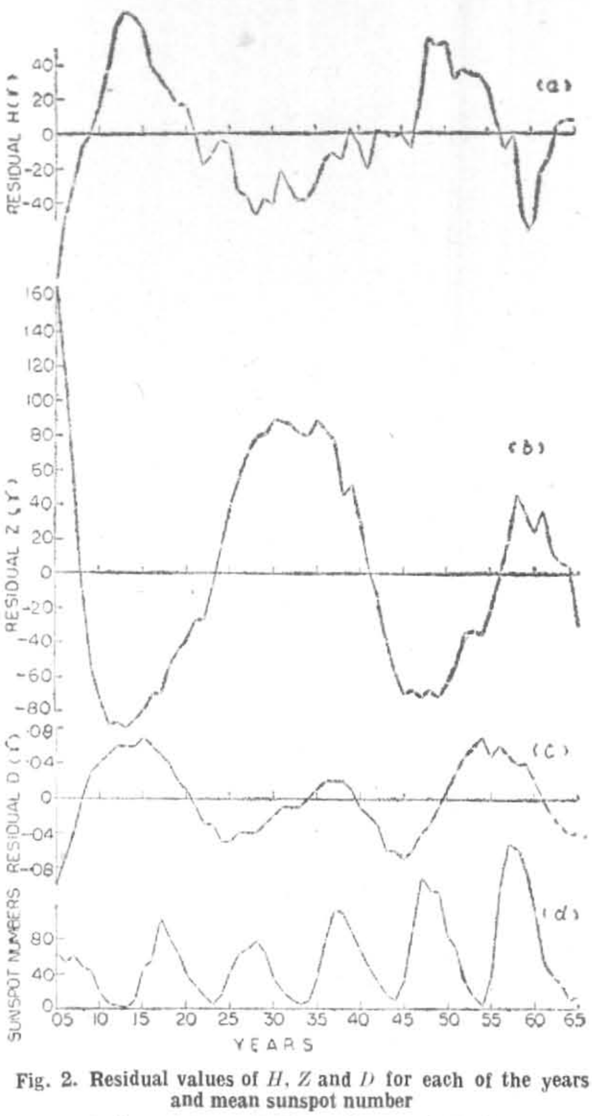

Fig. 2. Residual values of H, Z and D for each of the years and mean sunspot number

(*a*) Horizontal force (*b*) Vertical force (*c*) Declination (*d*) Annual mean sunspot number

(taken mostly from the compilation of Chernosky and Hagan 1958) are shown in Fig. 2.

3. Discussion

3·1. *Secular variation of H* — Moos (1910), expressed the annual mean values of H of Colaba by the formula $H = a + bt + ct^2$, where a, b and c are constants and t respresents the number of years reckoned from the year 1871–1905. The constants derived from 34 years of data by the method of least squares are $a = 37237 \cdot 17\ \gamma, b = 16 \cdot 75\ \gamma$ and $c = -\cdot 35\ \gamma$. The constants given above cannot be strictly compared with the values derived by using third order polynomial given in Table 1. But it can be seen from the coefficients that the contribution of the linear coefficient is greatest suggesting that the H value at Colaba and Alibag are both increasing considerably from year to year. Pramanik and Ganguli (1954) fitted mathematical expressions for four observatories, Greenwich and Abinger, Coimbra, Cheltenham and Colaba and Alibag for the annual mean values of H and D to represent the secular trends. Whenever a linear trend failed to fit the data satisfactorily a higher degree curve was considered. In almost all cases the cubic curve explained about 99 per cent

TABLE 1

Mean value and the coefficients of H, Z and D in the equation of the fitted curve $X=\bar{X}+At+Bt^2+Ct^3$ as well as the percentage contributions of A, B and C to the variance and the total variance

Element	Mean $\bar{X}$	A	B	C	Percentage contribution of variance			
					A	B	C	Total
H in γ	37,554·88	+56·32	+0·35	—·03	95·28	1·91	2·56	99·75
Z in γ	17,803·70	+16·39	—1·38	+·02	58·82	37·40	2·06	98·28
*D in degree	—·3360	—0·03596	+·0006	+·000001	93·80	5·77	0·01	99·58

Eq. of secular trend

$$H=37{,}554\cdot 88+56\cdot 32\,t+0\cdot 35\,t^2-0\cdot 03\,t^3$$

$$Z=17{,}803\cdot 70+16\cdot 39\,t-1\cdot 38\,t^2+0\cdot 02\,t^3$$

$$D=-\cdot 3360-\cdot 03596\,t+\cdot 0006\,t^2+\cdot 000001\,t^3$$

* Easterly declination considered as +ve

of the total variations in the data. Their cubic curve for Colaba and Alibag H data for the period 1875 to 1949 accounts for 99·14 per cent. The equation given in Table 1 accounts for 99·75 per cent of the total variance.

Chapman and Bartels (1940) pointed out that there is relatively small region of increasing horizontal force with its focus in South India. The trend of H curve, given in Fig. 1 shows that the observed value has almost reached its maximum and that there is going to be a change in the direction of the curve. Thus the turning point of H suggests that there is a possible change in position or intensity or both of the focus mentioned by Chapman and Bartels.

3·2. *Secular Variation of Z* — Moos fitted the same parabolic curve as that of H for the annual mean values of V (Z) at Colaba for the period 1888-1905 and the constants obtained were: $a=13{,}700\,\gamma$, $b=60\cdot 78\gamma$ and $c=0\cdot 894\gamma$. This showed maximum linearity in the values. Pramanik (1952), unable to fit one quadratic curve to the data of Colaba and Alibag for the entire period 1888 to 1945, split it into two parts and fitted two curves. From Fig. 1, it can be seen that the values of Z were uniformly increasing at almost regular steps upto the year 1937 and from then on they are showing a decreasing trend. The coefficient of the quadratic term is negative, even though the curve in Fig. 1 is almost linear. It is surprising to have the contribution of linear term as only 59 per cent of the total variance. The percentage contribution of the quadratic term is also considerable and it is accountable for nearly 37 per cent. Altogether the fitted curve accounts for nearly 98 per cent of the total variance.

3·3. *Secular variation of D* — Moos fitted a curve $Y=AX+B-(CX^2+DX+E)$, for annual mean values of declination, D, for the period 1862–1894. The coefficients A, B, C, D and E were calculated and were in good agreement with the observed values. Pramanik (1952), fitted a straight line $D=mt+a$ to the annual mean values of D for the period 1887 to 1946. Pramanik and Ganguli (1954), fitted Colaba and Alibag D values from 1875 to 1949 in a linear, quadratic and cubical curves along with data of other stations. In all, the cubic curve was found to account for more than 99 per cent of the total variance.

Though the D curve given in Fig. 1 shows more or less linearity for most of the earlier years, it is felt a cubic curve of the same order as in case of H and Z will account for the secular variation of D. The D value at Alibag was easterly upto the year 1926 and it was westerly for 1927. The change occurred in the year 1927. Here the easterly D was considered positive. The coefficients of the fitted curve are given in Table 1. It can be seen that the coefficient of the linear term is negative showing the downward trend of the curve. As is in H, here also the coefficient of the linear term is having higher magnitude. The contribution of linear and quadratic coefficient themselves are accountable for more than 99 per cent of the variance. A close inspection of the D observed curve in Fig. 1 shows an indication of change in the trend of the curve from the year 1964 as in case of H. This may support the view of change in position or intensity or both of H focus in South India, as both H and D combined together gives the resultant force in the horizontal plane.

3.4. *Solar activity contamination in the residuals*—Chapman and Bartels (1940), mentioned that the transient magnetic disturbances, on the average, lower the value of H. The 11-year cycle in the frequency of magnetic disturbances similar to the sunspot cycle, therefore, causes the value of H near the sunspot maximum to be systematically lower than near sunspot minimum. This affects the rate of annual change in H, and in years of increasing sunspot number and increasing magnetic activity, the rate will be algebraically less than in years of decreasing sunspot numbers. Moos (1910) has plotted the differences between the theoretically fitted curve values and observed values against sunspot number published by Wolfer. He got a close parallelism for H, V (Z) and D between the departure values and the sunspot cycle curve and could clearly indicate the 11-year periodicity. Pramanik (1952), found that there was no parallelism between the sunspot curve and the curve of differences between observed and calculated values in any of the elements H, Z or D. The analysis of Pramanik and Ganguli (1954), also confirms that there was no parallelism between the residuals and the sunspot curve not only in Colaba, and Alibag data but also in the data from other stations, or any tendency for coincidence of maxima and minima of the residuals with the minima and maxima of sunspots. They also emphasised that there was little suspicion of 11-year periodicity in the H values upto 1900 but later there was no indication of any.

In Fig. 2 are given the values of residuals for each of the elements H, Z and D. At the bottom of the figure is given the mean sunspot curve for the same period. It can be readily seen that there is no parallelism as such in any of the curves. A close inspection by drawing a smooth curve one can notice periodicity of 35 years in the residual H-curve, Z-curve shows a periodicity of 34 years nearly equal to that of H, and D shows an average period of 20 years (nearly 2 solar cycles). The graphical analysis thus clearly shows that there is no 11-year periodicity but a rough periodicity of 3 solar cycles in case of H and Z and 2 solar cycles in case of D. This result confirms Pramanik and Ganguli's suspicion of about 30 to 40 years periodicity in H and if there is any priodicity present, it is definitely longer than the sunspot cycle. But, however, D periodicity here is differing by one cycle from that of Pramanik and Ganguli.

4. Summary

1. The third order polynomial equation accounts for nearly 99 per cent of the total variance in all the three elements. Hence a good fit of the observed and the calculated curves can be seen in Fig. 1.

2. The South Indian positive focus of H has a change in its position or intensity or both.

3. The residual values of H, Z and D show a periodicity of nearly 3 solar cycles in case of H and Z and nearly 2 solar cycles in case of D.

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