GEOMAGNETIC SECULAR VARIATION AND FIELD OSCILLATIONS OF EXTERNAL ORIGIN AT HUANCAYO, PERU

G. K. Rangarajan[1], O. Veliz[2] & B. R. Arora[1]

The long uninterrupted series of magnetic measurements made at Huancayo close to the dip equator are analysed to bring out salient features of secular variation and oscillations of external origin in the magnetic elements. It is shown that the secular change at Huancayo is largely comparable to the global models for different epochs. The secular jerk in 1969-70, noted over Europe manifests more prominantly in the vertical component. Longer period oscillations of internal origin are identified with different periodicities in H, Z and D. Solar cycle periodicity of 11 years is not distinguishable in the departures of the annual mean values from the secular trend. Quasibiennial signal is unambiguously noticed with variable amplitudes during the epoch under analysis. The modern technique of singular spectrum analysis is applied to the data to show its simple structure in terms of annual, semi-annual and 14-month periodic components. Indications of the presence of a 14-month signal in H induced by Chandler wobble are seen.

Key words: Secular variation; Secular jerk; DGRF; IGRF; Solar cycle.

VARIAÇÕES SECULARES E OSCILAÇÕES DO CAMPO GEOMAGNÉTICO DE ORIGEM EXTERNA, EM HUANCAYO, PERU - *A longa e contínua seqüência de medidas magnéticas efetuadas em Huancayo, perto do equador magnético, é analisada a fim de se obter feições de variação secular e oscilações de origem externa dos componentes magnéticos. É demonstrado que a variação secular em Huancayo é comparável a modelos globais para períodos distintos. O secular salto magnético de 1969-1970, observado na Europa, manifesta-se preponderantemente na componente vertical. As oscilações de longo período, de origem interna, são identificadas com periodicidades diferentes em H, Z, e D. A periodicidade do ciclo solar de onze anos não é perceptível nas variações do afastamento dos valores das médias anuais, em comparação com a tendência secular. O sinal quasibienal é claramente observado com amplitudes variáveis durante o intervalo de tempo da análise. A moderna técnica de análise de espectro singular é aplicada aos dados para mostrar sua estrutura simples, em termos dos componentes periódicos de seis, doze e quatorze meses. A presença do sinal de quatorze meses é identificada na componente H induzida pela oscilação de Chandler.*

Palavras-chave: Variação secular; Salto magnético secular; DGRF; IGRF; Ciclo solar.

[1]Indian Institute of Geomagnetism, Colaba, Bombay - 5, India
[2]Instituto Geofisico del Peru (IGP), Peru

INTRODUCTION

The establishment of geomagnetic observatory at Huancayo, Peru (Lat. 12°03'S, Long. 284°40'E) in 1922 was of great importance to the ionospheric physicists as it led to the discovery of the daytime equatorial electrojet current belt centred over the dip equator.

The location of Huancayo is significant from other points of view also. The lowest magnitude of total intensity (F) of the earth's magnetic field occurs over the central part of South America. Isolines of zero inclination (I) and vertical component (Z) deviate significantly from the geographic equator in the neighbourhood. Annual change in declination (D) is the largest in its vicinity while change in I is minimal with largest positive and negative annual rates of change seen on either side (Baldwin & Langel, 1993). It will, therefore, be interesting to study in detail the secular trend and shorter period oscillations of the field components at Huancayo and to compare the same with the features observed elsewhere.

Some important aspects of the secular variation in the geomagnetic field are:

(i) the geomagnetic jerk reported at several European observatories during the 1969-70 epoch (Le Mouel et. al., 1982) manifests as a change in the linear trend of the geomagnetic field and has been known to occur in different magnetic elements depending on the geographic location of the observatory (Golovkov & Simonyan, 1989);

(ii) longer period variations in the range 30 to 90 years observed with different amplitudes in different regions; and

(iii) solar cycle and solar magnetic cycle components with 11 and 22 year periodicity whose origin (internal or external) is still open to question.

In a recent study of the secular change in the geographic location of the dip equator, Rangarajan (1994b) found that the north south migration of the dip equator is minimal over Huancayo whereas just 15° to 45° further east, the swing between 1945 and 1990 was significant.

The geomagnetic field of external origin at an observatory close to the dip equator also exhibits distinct characteristics like the strong semi-annual variation in contrast to the dominance of the annual variation at low latitudes.

The local time dependence of the strength of the annual and semi-annual variations of the magnetic field at equatorial locations was discussed in detail by Bhargava (1970, 1972) and Bhargava et al. (1973). A comprehensive review of these oscillations covering all latitudes has been presented by Campbell (1989).

In addition to the annual and semi-annual variations, low latitude geomagnetic field is known to exhibit other periodicities like the pole tide signal or Chandler wobble of 14 months (Rao & Rangarajan, 1978), quasibiennial oscillation (Sugiura 1976; Rangarajan, 1985). Rastogi (1989) has shown that the equatorial electrojet over Peru is much stronger than that over the Indian and African regions and that many ionospheric and geomagnetic features in the three longitude sectors are not immediately comparable.

It is well known that magnitudes of the disturbance components at different frequencies are enhanced during the daytime. These variations also include a component of internal origin induced by external currents whose magnitude is dominantly decided by the local and regional geology and sub-surface electrical conductivity.

In this communication, we perform an exhaustive analysis of the long series of geomagnetic data collected at Huancayo since 1922 to study both the secular variation features and oscillations of the field due to sources external to the earth.

The basic data utilised are the mean monthly values derived from observations on all days from 1922 to 1988.

FIELD OSCILLATION OF INTERNAL ORIGIN

Secular variation

Annual mean values of the magnetic elements are utilised to study the secular changes at Huancayo during the period 1922 to 1988. It is usually recommended to perform the analysis with local midnight values restricted to quiet days, as most of the field changes of external origin could be satisfactorily eliminated or their effects substantially diminished (see for e.g. Gubbins & Tomlinson, 1986). Alldredge (1976) found that the external source effect due to solar activity is better revealed in H and Z annual means than in D. Useful insight is possible when data derived from observations on all days of the year are used. Since the present analysis aims at characterizing both secular and other oscillatory signals, the monthly means obtained from all days data were considered appropriate.

To determine the nature of the smooth secular trend, polynomials of increasing order were fitted to the annual mean values by the method of propagating least squares advocated by Gangi & Shapiro (1977). The best-fit polynomials - a cubic for H, a parabola for D and a quartic for Z - and the percentage variance accounted for by successive orders are given in Table I. The fitted curves covering the epoch under analysis are shown in Fig. 1. D changes at Huancayo are by far the smoothest with almost a linear decrease since 1922. H too shows smooth trend with a point of inflexion near 1932; since then H is decreasing continuously. However, Z has a secular change characterised by a rapid increase in the initial part and an undulatory signal in the latter years. This explains why a higher order polynomial was necessary in the case of the vertical component. Residuals, determined as departures from the smooth secular trend, are known to have cyclic components which may be both of internal origin (with 30- to 80- year periodicities) or due to solar activity (11 years) or solar magnetic activity (22 years). Such periodicities have been identified at several stations by Bhargava & Yacob (1969) who found that the solar cycle response in H was larger during odd cycles indicative of a 22-year variation.

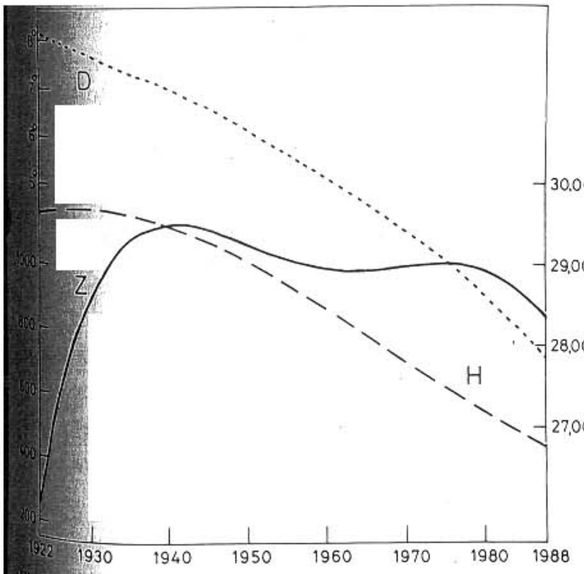

Figure 1 - Secular trend in the magnetic elements at Huancayo, derived from polynomials of best fit (see Table 1).

Figura 1 - *Tendência secular nos componentes magnéticos em Huancayo, obtida pelo melhor ajuste polinomial (ver Tabela I).*

Table 1/*Tabela 1*

H: $29611.2 + 25.59\,X - 1.9829\,X^2$

Z: $122.8 + 134.766\,X - 6.2033\,X^2 + 0.113487\,X^3 - 0.000726\,X^4$

D: $8.088 - 0.0445\,X - 0.000796\,X^2$

($X = 1$, ... 67 correspond to the years 1922 to 1988).

Percentage accounted by Polynomial of degree

1 Deg.	2 Deg.	3 Deg.	4 Deg.	
96.1	99.2	99.9	-	H
6.5	55.4	78.9	95.0	Z
98.0	99.9	-	-	D

Long-term periodicities

The departures of the observed annual values from the secular trends are shown in Fig. 2. In all three elements, the residuals show fairly large amplitude undulations. In Declination, one could notice a long term periodicity of about 60 to 80 years with a maximum near 1935-40 and a minimum near 1970-75. This periodicity has been observed and analysed in great detail by the Russian scientists (see for e.g. Petrova & Burlatskaya, 1983). Langel et al. (1986) believe that the 60-year periodicity can be expected from torsional MHD vibrations. In case of Z, the cyclic component with a 30- year periodicity stands out, not necessarily as the harmonic of the 60- year variation. The residual in H, on the other hand, is complex with no well defined periodicity though two distinct maxima separated by about 40 years could be noticed. This result appears distinctly different from those shown by Bhargava & Yacob (1970) for several other stations. Alldredge (1977) noticed a periodicity close to 25 years in magnetic observatories' data and concluded that it is of internal origin due to its non-coherency in different regions. The absence of any well- defined oscillations in the vicinity of 20 years lends support to the views of Alldredge that it is not a coherent global fluctuation caused by external sources. Golovkov (1983) has attributed long period variations of internal origin to local axi-symmetric source with the motions propagating along the core surface from a single point.

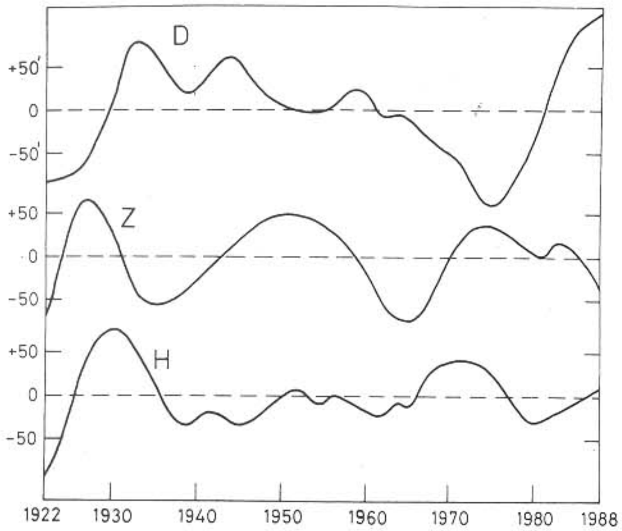

Figure 2 - Departures of observed annual mean values from the secular trend models.

Figura 2 - *Variações nos afastamentos das médias anuais observadas, em comparação com modelos de tendência secular.*

Solar cycle variations

In all the three elements, there is no discernible component with a periodicity of 11 years. If present, this could be both due to a genuine short term secular change or induced by solar cycle changes in the external part of the geomagnetic field. Demonstrating that solar cycle variation in H at Tucson was in phase opposition to the sunspot cycle, Yukutake (1965) attributed this to the effect of an increase of ring current intensities at solar maximum. However, later investigations using regional and global data sets revealed that solar cycle components varied both spatially and temporally and, when present, were not always anti-phase with sunspot cycles (Bhargava & Yacob, 1970; Rivin, 1974; and others), perhaps marking varied contributions from several sources with incoherent phases. Evaluating separately the relative strengths of the solar cycle component in the constituents of external fields, e.g. Sq and ring-current intensity (DR) modulation, Murty & Arora (1977) found solar cycle modulation in Sq and DR in H at low latitudes to be comparable in amplitude but nearly in phase opposition. It is suggested that the absence of the 11-year oscillation in the geomagnetic field at Huancayo is the result of mutual cancellation of the two effects associated with ring current and Sq due to their phase opposition.

Secular jerk

Whenever a sudden change in the slope of the smooth secular variation of the magnetic field is noticed, it is termed a secular variation impulse or simply as a 'jerk'. A significant secular jerk was noticed most clearly in the Declination of many European observatories during 1969 (Le Mouel et al., 1982). Corresponding change in H was seen in North America while Z was affected around the same period over the Australasian and Siberian regions (Whaler, 1987). According to Whaler, the most striking visual effect is seen when the first differences of observatory means are plotted. Two straight line segments with different slopes indicate a possible secular impulse. Gubbins & Tomlinson (1986) detected significant signatures of the geomagnetic secular jerk in the Y component at Apia during 1970 and at Amberley during 1972. They also indicated another jerk in the record in the beginning of 1978. Both the stations are in New Zeland in the southern hemisphere.

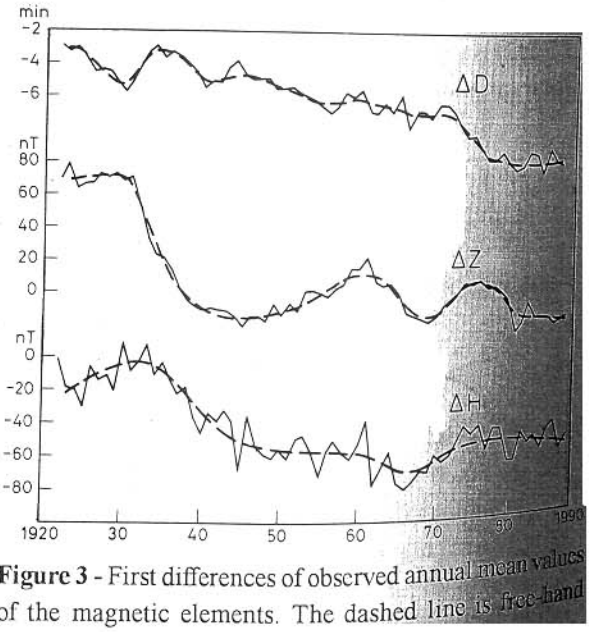

Figure 3 - First differences of observed annual mean values of the magnetic elements. The dashed line is free-hand smoothing.

Figura 3 - *Diferenças nas médias anuais observadas dos componentes magnéticos. As linhas tracejadas representam uma suavização dos dados efetuada à mão.*

To identify secular jerk at Huancayo, the first differences of the annual mean values of the magnetic elements were computed and these are depicted in Fig. 3.

The secular impulse of 1969 observed over most of the world is seen also at Huancayo but not concurrently in all the three elements. It occurs earlier in H and later in D compared to Z where the slope change is most discernible. There is no indication of a jerk near 1978 but there is a prominent indicator just after 1930 in both Z and D. Golovkov & Simonyan (1989) analysed data from 42 observatories and found that the histogram of years when inflexion was seen in the slopes, peaked in 1949 and 1969. But the earlier jerk was over much smaller geographic extent. We believe that the secular jerk noticed in Huancayo near 1930 may be restricted in its regional extent and therefore, was not seen in earlier analyses. According to Gavoret et al. (1986) only one or two jerks have occured in the 20th century. Results from Huancayo are consistent with this observations.

Comparison of the observed annual mean values with IGRF models

Spherical harmonic (S.H.) models for the main field for different epochs have been streamlined by the International Association of Geomagnetism and Aeronomy by incorporating all available data. They are now available as S.H. coefficients of degree and order 10 called Definitive Geomagnetic Reference Field (DGRF) for the epochs 1945, 1950, ... 1980, 1985 and as IGRF for 1990 (see for e.g Baldwin & Langel, 1993). They are definite in the sense that no further revision is anticipated for these coeficients even if more data become available. The reference field model gives only a global representation of the geomagnetic field and could account for only very long wavelength anomalies, as dictated by the highest degree (circumference of the earth/n.) Regional discrepancies are expected to emerge when observed annual mean values are compared with the model-derived values. Such comparison of data from Teoloyucan observatory in Central Mexico was carried out by Urrutia Fuccugauchi & Campos - Enriquez (1993). The apparent good correlation between IGRF derived-values between 1945 and 1990 and the observed annual mean values was indicative of very low secular variation anomaly in that region.

In Fig. 4 are shown the difference between observed and model-based annual mean values of the three magnetic elements for the years 1945 to 1990, every 5 years apart. Data for 1990 was extrapolated from the observed secular trend discussed earlier. It is seen that H and D have well - defined secular variation anomalies of similar nature with a notable decrease in the discrepancy between observations and model field towards the later epochs. For each epoch, the departures themselves are not too large to be termed strictly as 'anomalous'. It is tempting to ascribe the observed departure in the earlier years to less perfect observations. In contrast to the secular anomalous change in the horizontal plane, the vertical component shows a parabolic trend for the difference field with a near perfect match for the current epoch. Changes in the observed annual mean values could be attributed to the nature of the meandering dip equator in the vicinity of Huancayo (Rangarajan, 1994b). As mentioned earlier, the local characteristics of the geographic location of the dip equator as derived from IGRF is widely different over a limited longitude zone in this part of the world.

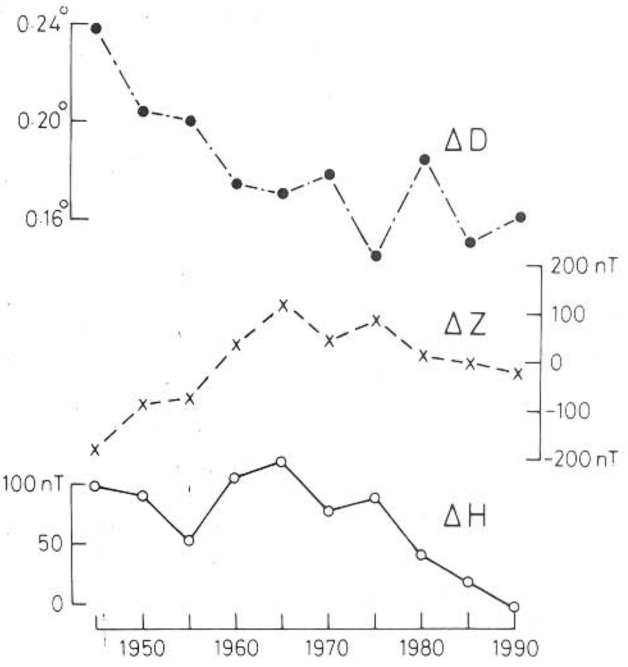

Figure 4 - Departures of the observed annual mean values (every 5 years apart) from the values derived from spherical harmonic models for the epochs 1945, 1950, ... 1990.

Figura 4 *- Variações nos afastamentos das médias anuais observadas a cada 5 anos, em comparação com valores derivados de modelos harmônico-esféricos, para o período de 1945-1990.*

In broad terms, IGRF models appear to be very good compromise to observations since 1980 for all the three elements. Results and conclusion of similar nature were also derived for North American continent by Dawson & Newitt (1982) and for West Africa by Vassal (1987).

FIELD OSCILLATIONS OF EXTERNAL ORIGIN

Quasi-biennial oscillation

The presence of a strong signal with a quasi-periodicity of two years termed Quasi Biennial Oscillation (QBO) in stratospheric parameters like zonal wind, temperature, total ozone etc. is well known. There have also been a few attempts to detect the presence of this signal in the geomagnetic field. Yacob & Bhargava (1968), from spectral analysis of long series of magnetic H component at Alibag in India showed that the QBO signal is a reality in the quiet day field and its source could well be the Sun. Applying band-pass digital filters, Rajarao & Joseph (1971) isolated the QBO in H at stations well separated in longitude to show the dependence of its amplitude on the station's location. At QBO periodicity, Sugiura & Poros (1977) showed close correlation between the solar activity indices and the geomagnetic disturbance field.

To identify the time variations in the QBO signal at Huancayo using mean monthly values derived from all days, a band-pass digital filter with unit response for 24 + 4 months was used. For immediate comparison, the corresponding H data from Alibag (18°N;72°E) in India and the sunspot number series are also processed similarly. The time evolutions of the QBO signal in the four parameters are shown in Fig. 5.

For Huancayo, the signal is stronger in H than in Z. The amplitude of the signal appears modulated but not very systematically so that it is difficult to calculate the modulating frequency, if any. The largest signals are seen before 1930, near 1945, and after 1980. Much earlier, Stacey & Westcott (1962) did not find any signal corresponding to QBO at Huancayo in the spectrum of H for the epoch 1922-1945. At first sight, it is surprising that while the present analysis shows strong QBO around 1930 and 1945, the spectral approach did not isolate QBO in almost concurrent data sets. This apparent contradiction is attributed to the phase variability of QBO and the quasi periodic nature of the different epochs. The signal strength is diluted in spectral approach where average representation is provided by the peak value in the frequency domain.

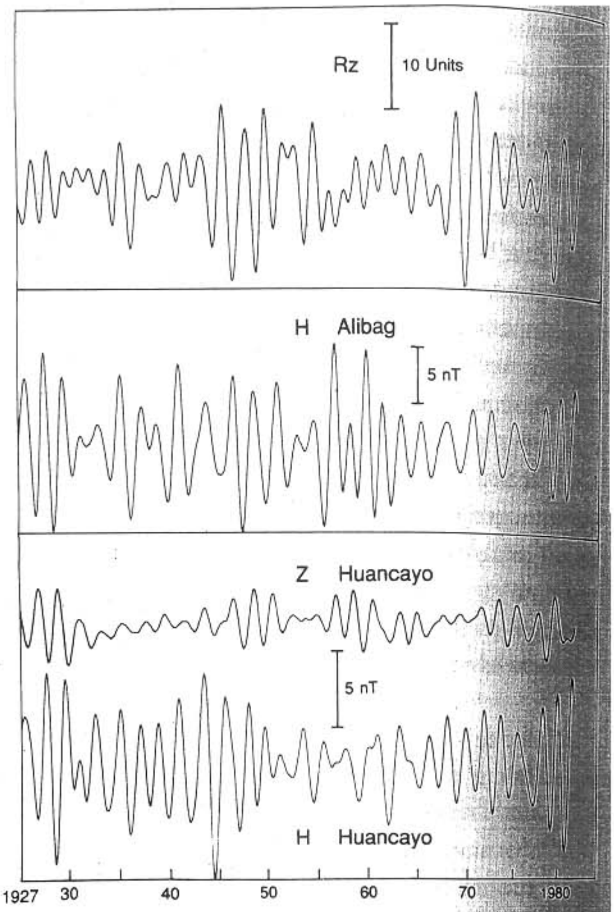

Figure 5 - Time variations of bandpass filtered (24 ± 4 months) data of H, Z at Huancayo. H at Alibag and sunspot number, Rz for quasi-biennial oscillation.

Figura 5 - *Variações temporais dos dados filtrados (24 ± 4 meses) dos componentes: H e Z, em Huancayo; H em Alibag e Rz (número de manchas solares) para a oscilação quasibienal.*

It is noteworthy that while the analysis of Stacey & Westcott had failed to resolve the signal at Huancayo, the peak amplitudes for QBO were found to be well above the continuum in the spectra of Apia and Alibag. Our results, based on a longer series of data, confirm thath the QBO does exist at equatorial and low latitude stations but for most part of the time-span, the singals at two widely separated stations are not coherent. These are consistent with the observations of Stacey & Westcott (1962) who noted that while QBO's fluctuations are periodic in nature, they tend to be randomly excited. Further, since most of the signals at both the stations do not show overall coherence with QBO in sunspot numbers, it can be surmised that solar activity does not appear to be a sole cause for the observed QBO in H at low and equatorial latitudes.

Just recently it has been shown (Olsen, 1994) that the QBO in geomagnetic field could be attributed to the coupling processes between middle atmosphere and the ionosphere so that the strong QBO at stratospheric heights can leave a measurable signal at ionospheric heights. If this is so, the signal should be stronger in the quiet day field than in the disturbance field. This needs to be verified.

Annual, semi-annual and pole-tide signature

As noted earlier, in addition to the solar cycle and QBO, the low latitude geomagnetic field is known to exhibit annual, semi-annual, 14-month pole-tide and other short-period variations. It has been recently recognized that if a data base exhibits multiple time scales in its variability, the technique of Singular Value Decomposition or Singular Spectral Analysis (SSA) can be successfully applied to detect them (Reyment & Joreskog, 1993). Vautard & Ghil (1989) have highlighted how SSA provides quantitative and qualitative information about the deterministic and stochastic parts in a time series. In brief, the method consists of embedding the time series in a M - dimensional subspace by taking, as state vectors, the consecutive sequences

X (1), X (2) .... X (M)
X (2), X (3) .... X (M + 1)

....

X (N - M + 1) .... X (N)

and finding the eigen values and eigen vectors of the correlation matrix generated from this trajectory matrix. The principal components or individual modes are then obtained by treating the eigen vectors as filters operating on the time series. They, in fact, represent the projections of the original time series along the new orthogonal diretions determined by the significant principal vectors. The advantage of this method is that despite the arbitrary size of the embedding space (M), only the first few eigen values significantly contribute to the total variability so that the time series can be decomposed in terms of very few significant component variations. If there is a well-defined sinusoidal fluctuation in the time series, it manifests as a pair of eigen vectors in exact phase quadrature. A very nice illustrative example has just been provided by Schlesinger & Ramankutty (1944) who identified an oscillation of 65 - 70 years in the global climate system using this powerful methodology.

In this section, we report about the results of applying the method of Singular Value Decomposition to the mean monthly value data of H at Huancayo between 1922 and 1988. As the data series is known to be a combination of both low and high frequency components, the time series was first detrended with a digital high pass filter with unit response for periods 18 months and less. Earlier analysis (Bhargava et al. 1973) has clearly shown that the monthly values derived from all days show the influence of the disturbance field in the semi-annual and annual variations which manifests as of secondary importance during late evening or night hours. The daytime field in the equatorial region is largely of ionospheric origin and is stronger during quiet days. As we could not have access to the corresponding monthly data restricted to quiet days, we consider an alternate method for isolating the disturbance component in the time series used. For this purpose a regression analysis was performed with the monthly H data and the index Aa of geomagnetic activity (Mayaud, 1980) which represent global geomagnetic activity level over and above the ambient quiet day conditions. The regression coefficient is then used as a normalization factor to hopefully equalize the effect of disturbance in the data and make them representative of quiet day field only.

For the singular spectrum analysis a viewing window of M = 49 was chosen after several trials. The singular spectrum (square root of the individual eigen values) exhibits a noise floor beyond M = 12 or so. The resulting seven eigen vectors (EV) in descending order of importance are shown in Fig. 6. The percentage of variance accounted for by the individual modes are respectively 10.2, 10.0, 9.3, 9.2, 4.4, 4.1 and 2.8. The first three pairs of eigen vectors are in near phase quadrature indicating that they represent well defined oscillations of the field. From the number of cycles completed over the embedding space it is clear that the first pair represents semi-annual, the second pair the annual and the third pair a likely 14 month signal. The data corresponding to the 5th mode, when spectrally analysed revealed the presence of a near 14-month periodicity. Yacob & Bhargava (1968) also found such an unexpected periodicity in Alibag H but could not indicate the likely causative mechanism. Rao & Rangarajan (1978) later succeeded in precise isolation of the pole tide signal (422 days), close to the fluctuation in the length of the day due to Chandler's wobble. Singular spectrum of Huancayo H field indicates that it is fairly simple in its structure with strong semi-annual (20% variance) and annual (18%) components with the pole tide signal also being detectable.

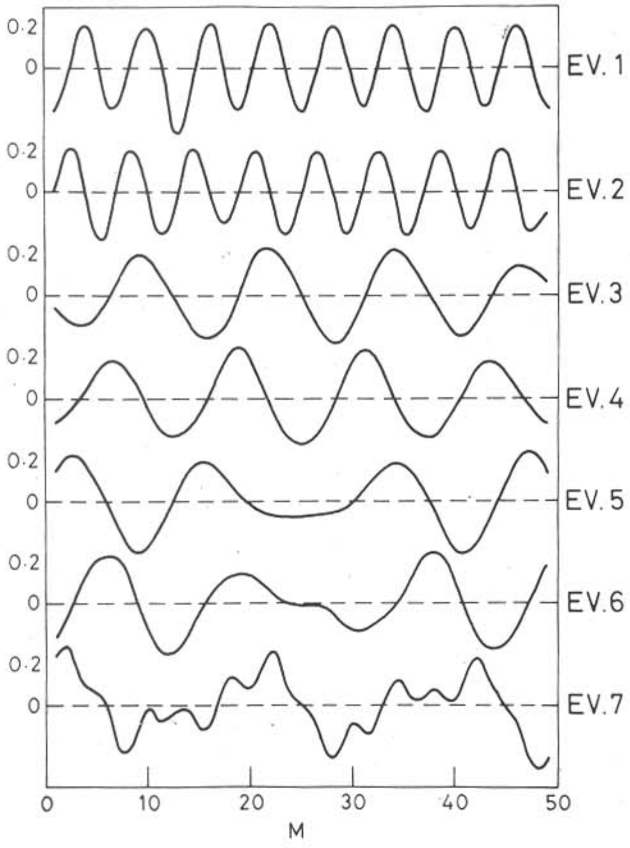

Figure 6 - First seven Eigen vectors resulting from the singular spectrum analysis of Huancayo (monthly values on all days). Note the phase quadrature in the first 3 pairs of eigen vectors, indicative of strong oscillatory signals with 6, 12 and 14 month periodicities.

Figura 6 *- Primeiros sete autovetores obtidos da análise de espectro singular em Huancayo (valores mensais todos os dias). Notar a quadratura de fase nos primeiros três pares dos autovetores, que indica o forte sinal oscilatório com periodicidades de seis, doze e quatorze meses.*

In a recent analysis carried out by Rangarajan (1994a), it was shown that the time variation in the amplitude of significant signal in a time series of Indian monsoon rainfall was exactly matching with the same derived from the technique of complex demodulation (see Banks, 1975, for details). The most salient aspect of the complex demodulation is that is represents the slow and smooth variation of both the amplitude and phase of the central frequency chosen for demodulation, covering the epoch. Fig. 7 gives the demodulates, with the top three curves corresponding to the demodulates obtained from the original filtered time series, whereas the bottom curves result from the series normalized for the disturbance effect. Due

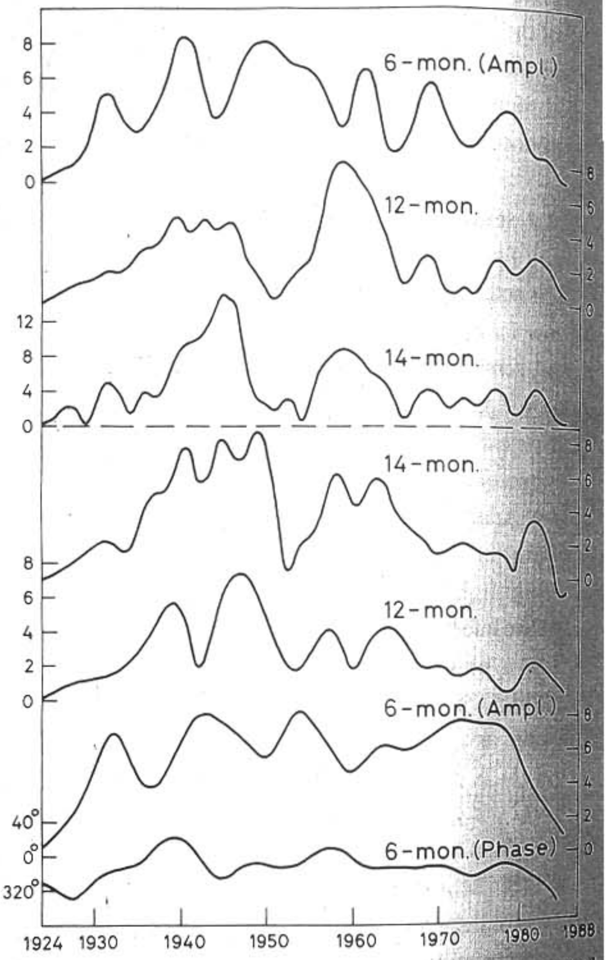

Figure 7 - Complex demodulates of H at Huancayo centred at periods corresponding to 6, 12 and 14 months. The top three curves pertain to results of analysis of observed data and the bottom curves correspond to results after normalization for geomagnetic activity levels. Phase of the 6-month wave is also included in the lower band to demonstrate its constancy over the entire period of the analysis.

Figura 7 *- Demodulação complexa do componente H, em Huancayo, centrada em períodos correspondentes a seis, doze, e quatorze meses. As três curvas do topo resultam da análise dos dados observados, e as curvas de baixo correspondem aos resultados após uma normalização para os níveis de atividades geomagnéticas. A fase de onda de seis meses é também incluída para demonstrar sua consistência no período de análise dos dados.*

to the method of analysis, the first and last 10 percent of the total duration will not be correctly represented. After accounting for this, it can be seen that all through the period, the phase of the semi-annual variation is constant with a phase angle indicative of equinoxial maximum as would be expected. The amplitudes, of both the annual and semi-annual components, exhibit cyclicity of nearly 11 years but not always in phase with the maximum of the solar cycle. It is also worthy of note that the annual component is considerably weaker in comparison to the semi-annual component but the pole tide signal, over certain segments, exhibits significant amplitudes while at other intervals it is close to zero. Most significant effect of the normalization procedure adopted is seen for the annual component.

CONCLUSIONS

The earth's magnetic field components, close the dip equator in the American sector, are shown to exhibit several interesting features of internal and external origins. The secular change in the magnetic field at Huancayo is largely comparable to the model field, generated by Definitive Geomagnetic Reference Field (DGRF) for different epochs. The vertical component indicates the signature of the 1969-70 secular jerk noticed most prominently over Europe and Australia. Solar cycle signal in the magnetic field measured as departure of annual mean values from the secular change models in the three elements are not easily distinguishable. In sharp contrast, a quasi-biennial oscillation of the field with variable amplitudes is clearly identified. Singular value decomposition of the time series clearly indicates the fairly simple structure of the field variations of external origin.

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NOTAS SOBRE OS AUTORES
NOTES ABOUT THE AUTHORS

Prof. G.K. Rangarajan

Prof. G.K. Rangarajan did his graduation and post-graduation in Mathematics and followed it up with his Ph.D in Physics (Geophysics) of Bombay University, India. His areas of specialization includes data-based analysis using modern techniques of signal processing, studies related to solar-wind-magnetosphere-low latitude geomagnetic field interactions, geomagnetic instrumentation and observatory practice.

He is presently a Professor at the Indian Institute of Geomagnetism.

Prof. B. R. Arora

Prof. B.R. Arora did his graduation in Physics followed up with Master's Degree and Ph.D. in Geophysics. He leads the group on Geomagnetic Deep Sounding through magnetovariational methods and has carried out extensive surveys. He is also an active participant in a coordinated programme on seismicity and seismotectonics of the Himalayan region and is also involved in Magnetic Petrology Studies. He is presently a Co-Chairman of the Inter Divisional Commission on Developing Countries (ICDC) of IAGA for the years 1995-1998. He is a member of the editorial board of the Brazilian Journal of Geophysics.

NOTÍCIAS/*NEWS*

IV COLAGE - Realizou-se entre 22 e 26 de abril de 1996, em San Miquel de Tucumán, Argentina, a IV Conferência Latino Americana de Geofísica Espacial (IV COLAGE). A Conferência contou com especialistas de diversos países da América Latina, Estados Unidos, Africa do Sul, Alemanha, França, Itália, Japão e Rússia. O Brasil esteve presente com a participação de 21 pesquisadores e alunos de pós-graduação. Os Drs. Walter Gonzalez e Inez S. Batista do INPE, São José dos Campos, proferiram palestras convidadas. Durante a IV COLAGE houve eleição para a diretoria da ALAGE (Associação Latino Americana de Geofísica Espacial). O Dr. Walter D. Gonzalez-Alarcon foi eleito para a Vice-Presidência e a Dra. Inez S. Batista foi indicada para o Comitê Assessor.