1. Classification *INPE-COM.10/PE*
CDU: 550.38

2. Period
December 1976

4. Distribution Criterion
internal [ ]
external [x]

3. Key Words (selected by the author)
Annual and Semi-Annual Variation, Dst Currents, Magnetospheric Currents.

5. Report Nº
INPE-992-PE/052

6. Date *Fevereiro 1977*

7. Revised by
Jorge de Mesquita

9. Authorized by
Nelson de Jesus Parada
Director

8. Title and Sub-title

Annual and Semi-Annual Variation in the H-Field at Vassouras

10. Sector *CEA/GEO* Code *412*

11. Nº of Copies - *5*

14. Nº of Pages - *16*

15. Price

12. Authorship *N.B. Trivedi*
I.J. Kantor
J.M. da Costa

13. Signature of the responsible

16. Summary/Notes

Vassouras H-field data during the period 1957-68 were subjected to power spectrum analysis. The amplitudes of the annual and semi-annual components were computed. Similar computations were carried out for equatorial Dst data for the period 1957-70 and amplitudes of annual and semi-annual wave were computed. The results are discussed and compared with the results of other authors. It seems that the annual wave could have significant contribution from the currents of magnetospheric origin.

17. Remarks *Partially supported by the Fundo Nacional de Desenvolvimento Científico e Tecnológico (FNDCT), Brazil, under contract FINEP-271-CT.*

ANNUAL AND SEMI-ANNUAL VARIATION IN THE H-FIELD AT VASSOURAS*

by

N.B. Trivedi, I.J. Kantor and J.M. da Costa
Instituto de Pesquisas Espaciais - INPE
Conselho Nacional de Desenvolvimento Científico e Tecnológico - CNPq
CP 515 - São José dos Campos, SP, Brasil

ABSTRACT

Vassouras H-field data during the period 1957-68 were subjected to power spectrum analysis. The amplitudes of the annual and semi-annual components were computed. Similar computations were carried out for equatorial Dst data for the period 1957-70 and amplitudes of annual and semi-annual wave were computed. The results are discussed and compared with the results of other authors. It seems that the annual wave could have significant contribution from the currents of magnetospheric origin.

* *Partially supported by the Fundo Nacional de Desenvolvimento Científico e Tecnológico (FNDCT), Brazil, under contract FINEP-271-CT.*

ANNUAL AND SEMI-ANNUAL VARIATION IN THE H-FIELD AT VASSOURAS

INTRODUCTION

A search for periodicities in the geomagnetic elements and geomagnetic activity index has continued for a long time. Periodicities like annual and semi-annual variations in the geomagnetic elements have been studied exhaustively by several workers since Chapman and Bartels (1940), Vestine et al (1947) and Vestine (1954). Recent works are by Eckhardt et al (1963), Currie (1966, 1976), Nastrom and Belmont (1976) and Bhargava et al (1972). Currie (1966) showed from his analysis that the annual and semi-annual lines are generated by different mechanisms. His results indicated that an ionospheric dynamo action was probably responsible for the annual variation while the ring current was the likely source of the semi-annual line. Banks (1969) drew the same conclusion as that of Currie. We have investigated annual and semi-annual line in H component magnetic data from the station Vassouras (22.40°S, 43.65°W) situated in the South Atlantic magnetic anomaly region. Vassouras is also known to have marked secular variation trend (Cain and Hendricks-1967) of linear decrease of the geomagnetic field intensity.

DATA AND ANALYSIS

Monthly mean values of Vassouras H geomagnetic field for the period 1957-1968 (144 months) were used in this analysis. This time series of 144 equidistant points exhibited a linear secular variation trend of a decrease of about 60 gammas/year. Since this type of trend cannot be removed by high-pass digital filtering, a least squares procedure was employed as recommended by Bendat and Piersol (1971). The data after the trend removal were subjected to the power spectrum analysis using two different methods. The first method was that of computing the power spectrum from the autocorrelations, as described by Jenkins and Watt (1968). The second method was based on the entropy content of time series, which is termed maximum entropy method (MEM) as originated by Burg (1968, 1970). The MEM spectral estimates are proportional to the mean output power, Pm, of the series, after whitening by a filter of length M, divided by the power transfer function of the filter, i.e.,

$$P\ (f) = \frac{2\ \Delta t\ \ Pm}{\left|1 + \sum_{k} g_k e^{-2\pi i f \Delta t k}\right|^2}$$

for $0 \leq f \leq f_n$ where Nyquist frequency $f_n = 1/2\Delta t$ and g_k is the kth coefficient of the M point prediction error filter. The results are presented in terms of an amplitude spectrum, by multiplying P(f) by the bandwidth and taking the square root (Lacoss, 1971 and Currie, 1974).

RESULTS

The results of the power spectrum analysis of the time series data of monthly mean H values at Vassouras for the period 1957-1968 are presented in the Figure 1. Annual and semi-annual periods were found prominent and the power at annual line was found to be more than the power at semi-annual line. The respective values were 4.877 γ^2/month and 2.59 γ^2/month.

The results obtained from the MEM power spectrum analysis, for the same data from Vassouras, are shown in the Figure 2. Once again we found annual and semi-annual periods to be prominent. The amplitude of annual line was found to be 5.6 γ and amplitude of semi-annual line was found to be 3.0 γ.

The amplitude of annual line was found greater than that of semi-annual line in the H-field at Vassouras. The values of the amplitudes of annual and semi-annual components in the H-field at stations situated approximately at the latitude of Vassouras were found to be different by Currie (1966). From the Table 1 given below, prepared using amplitude values published in Currie (1966), it can be seen that, in general, annual component is not greater than semi-annual component. And in the case of Huancayo, annual component was reported absent, whereas at Alibag, annual and semi-annual components were reported to be approximately equal.

TABLE

STATION	LATITUDE	LONGITUDE	AMPLITUDES IN GAMMAS	
			ANNUAL	SEMI-ANNUAL
San Juan	$18.12^{o}N$	$293.85^{o}E$	4.30 γ	6.06 γ
Honolulu	$21.32^{o}N$	$202.00^{o}E$	2.14 γ	5.02 γ
Huancayo	$12.05^{o}S$	$284.67^{o}E$	-	3.17 γ
Tucson	$32.25^{o}N$	$249.17^{o}E$	3.77 γ	5.21 γ
Hermanus	$34.42^{o}S$	$19.23^{o}E$	4.83 γ	7.18 γ
Alibag	$18.63^{o}N$	$72.87^{o}E$	3.81 γ	3.62 γ
Vassouras	$22.40^{o}S$	$316.35^{o}E$	5.60 γ	3.00 γ

DISCUSSION

Vestine (1954) suggested that the annual wave in the geomagnetic field elements is a seasonal effect, induced by air motions in the ionosphere. Currie (1966) and Banks (1969), from extensive analysis, offered quantitative arguments in support of Vestine's view that annual variation in the geomagnetic field has origin in the ionospheric dynamo currents, and the semi-annual variations is due to currents in the magnetosphere. Currie (1976) looked for an annual line in geomagnetic activity data from middle latitudes and could not find it. His numerical experiment indicated that strong annual term in absolute element geomagnetic data is, primarily, generated by seasonal modulation of the base line and daily variations, (Sq), themselves do not contribute significantly to the annual wave. Nastrom and Belmont (1976) concluded that long period waves in the zonal wind at dynamo levels induce long period waves in H and Z and the annual waves in H and Z at mid-latitudes and low latitudes appear to be largely of ionospheric wind origin.

However Olson (1970) demonstrated that magnetopause current system can produce annual and semi-annual variations in the earth's surface magnetic field. He showed that the strength and shape of this current system depend upon the orientation of the geomagnetic dipole axis, with respect to the direction of the solar wind. The magnetopause currents, therefore, produce seasonal as well as daily variations in the earth's magnetic field. Magnetopause currents, according to Olson's calculations, taking into consideration currents induced in the earth, accounted for 20% of the daily and seasonal variations of the surface field. Olson further stated that the ionospheric dynamo is not the only source of Sq variations and that at least two other magnetospheric current systems, the neutral sheet and ring currents, may also contribute to the quiet magnetic variations at the surface of the earth. This led us to investigate annual and semi-annual periods in the equatorial D_{st} data. The equatorial D_{st} data are computed and published by Sugiura and Poros (1971). Since the D_{st} disturbance field is interpreted (Verzariu, Sugiura and Strong, 1972) as being produced by the ring current, the tail current and the current flowing on the magnetospheric boundary, we were encouraged to investigate D_{st} data for annual and semi-annual lines.

We subjected the equatorial D_{st} data to power spectrum analysis. We found that both annual and semi-annual waves were present. The results are shown in the Figures 3 and 4. The conventional power spectrum computations showed 6.2 γ^2/month power for the annual wave and 5.2 γ^2/month power for the semi-annual wave. The results of MEM analysis also exhibited annual and semi-annual waves and their magnitudes respectively were found to be 5.7 γs and 3.9 γs.

Annual and semi-annual lines computed from H-field data of Vassouras and equatorial D_{st} data have almost same magnitudes. These results prompt us to support Olson's view that D_{st} producing currents might have significant contribution towards both the annual and semi-annual variation in the geomagnetic field at the surface of the earth.

ACKNOWLEDGEMENTS

We thank Dr. R.G. Currie for his advice in computing amplitude from the MEM spectrum. We are grateful to the director of Observatório Nacional, Rio de Janeiro for providing us the data from Vassouras magnetic station. This work was partially supported by the Fundo Nacional de Desenvolvimento Científico e Tecnológico (FNDCT), Brazil, under Contract FINEP-271-CT.

REFERENCE

Banks, R.J. Geomagnetic variations and the electrical conductivity of the upper mantle, Geophys. J. Roy. Astron. Soc., 17, 457-487, 1969.

Bendat, J.S. and A.G. Piersol, Measurement and Analysis of Random Data, New York, Wiley, 1971.

Bhargava, B.N., A two component model of the annual line in the spectrum of the geomagnetic field, Ann. Geophys., 28, 357-361, 1972.

Burg, J.P., Unpublished paper (presented at N A T O Advanced Study Institute on Signal Processing, August 1968, Enschede, Netherlands) 1968.

Burg, J.P., Unpublished paper presented at 40th. meeting, Soc.-Explor. Geophys., November 1970, New Orleans, USA.

Cain, J.C. and S.J. Hendricks, The geomagnetic secular variation 1960-1965, NASA Report No. TM-X-55944, 1967.

Chapman, S. and J. Bartels, Geomagnetism, Oxford University Press, 1940.

Currie, R.G., The geomagnetic spectrum-40 days to 5.5 years, J. Geophys. Res., 71, 4579-4598, 1966.

Currie, R.G., Harmonics of the geomagnetic annual variation, J. Geomag. Geoelectr., 26, 319-328, 1974.

Currie, R.G., Search for an annual line in geomagnetic activity in middle latitudes, J. Geophys. Res., 81, 2935-2937, 1976.

Eckhardt, D.H., K. Larner and T. Madden, Long period magnetic fluctuations and mantle electrical conductivity estimates, J. Geophys. Res., 68, 6273-6278, 1963.

Jenkins, G.M. and D.G. Watts, Spectral analysis and its applications, San Francisco, Holden-Day, 1968.

Nastrom, G.D. and A.D. Belmont, The influence of long period dynamo region winds on the surface geomagnetic field elements, J. Geophys. Res., 81, 4800-4804, 1976.

Olson, W.P., Variations in the earth's surface magnetic field from the magnetopause current sistem, Planet. Space Sci. 18, 1471-1484, 1970.

Sugiura, M. and D.J. Poros, Hourly values of equatorial Dst for the years 1957 to 1970, G.S.F.C X-645-71-278, 1971.

Vestine, E.H., Winds in the upper atmosphere deduced from the dynamo theory of geomagnetic disturbance, J. Geophys. Res., 59, 93-128, 1954.

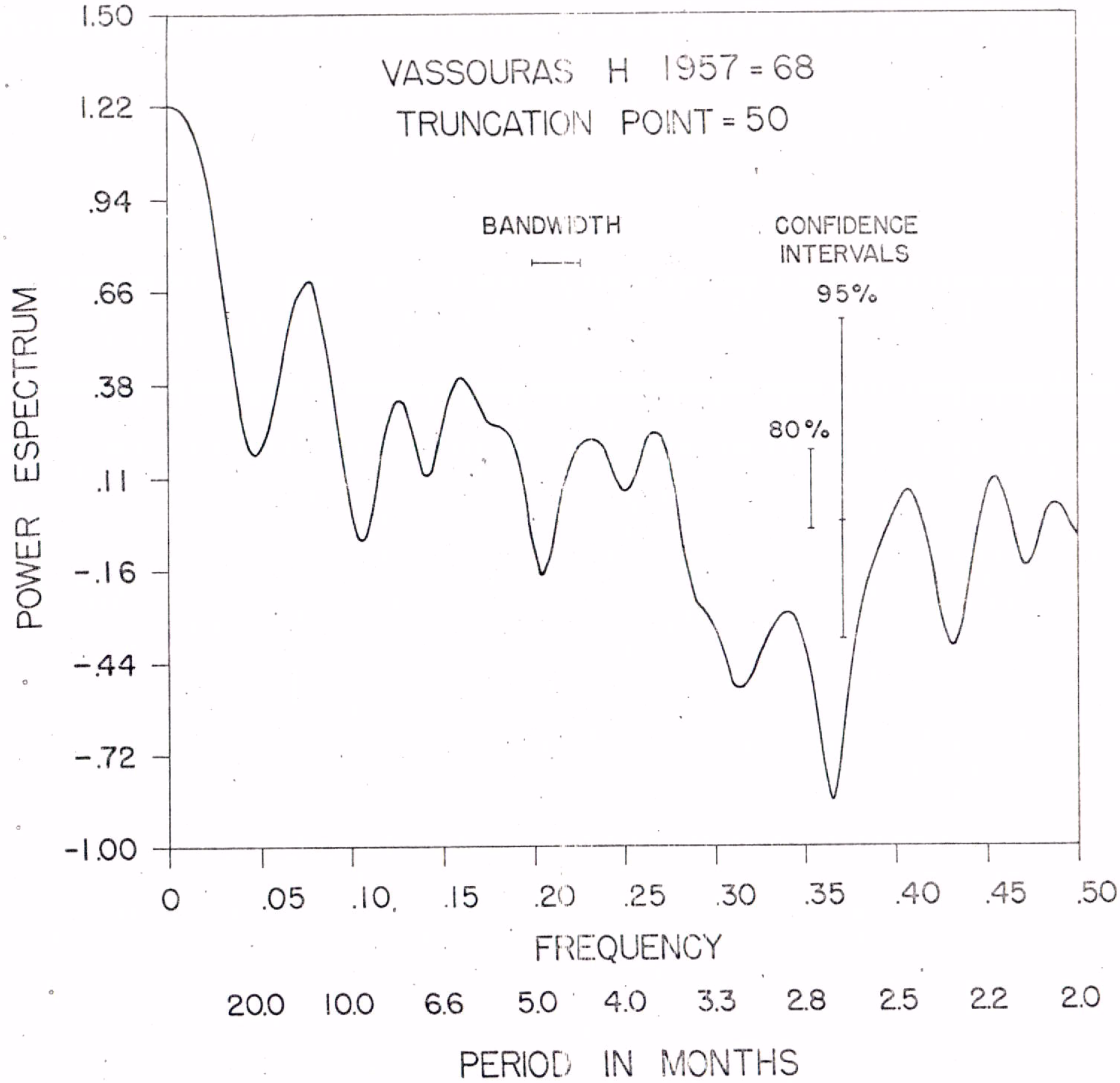

VASSOURAS H 1957 = 68
TRUNCATION POINT = 50
BANDWIDTH
CONFIDENCE INTERVALS
95%
80%
POWER ESPECTRUM
1.50
1.22
.94
.66
.38
.11
-.16
-.44
-.72
-1.00
0
.05
.10
.15
.20
.25
.30
.35
.40
.45
.50
FREQUENCY
20.0
10.0
6.6
5.0
4.0
3.3
2.8
2.5
2.2
2.0
PERIOD IN MONTHS

Figure 1

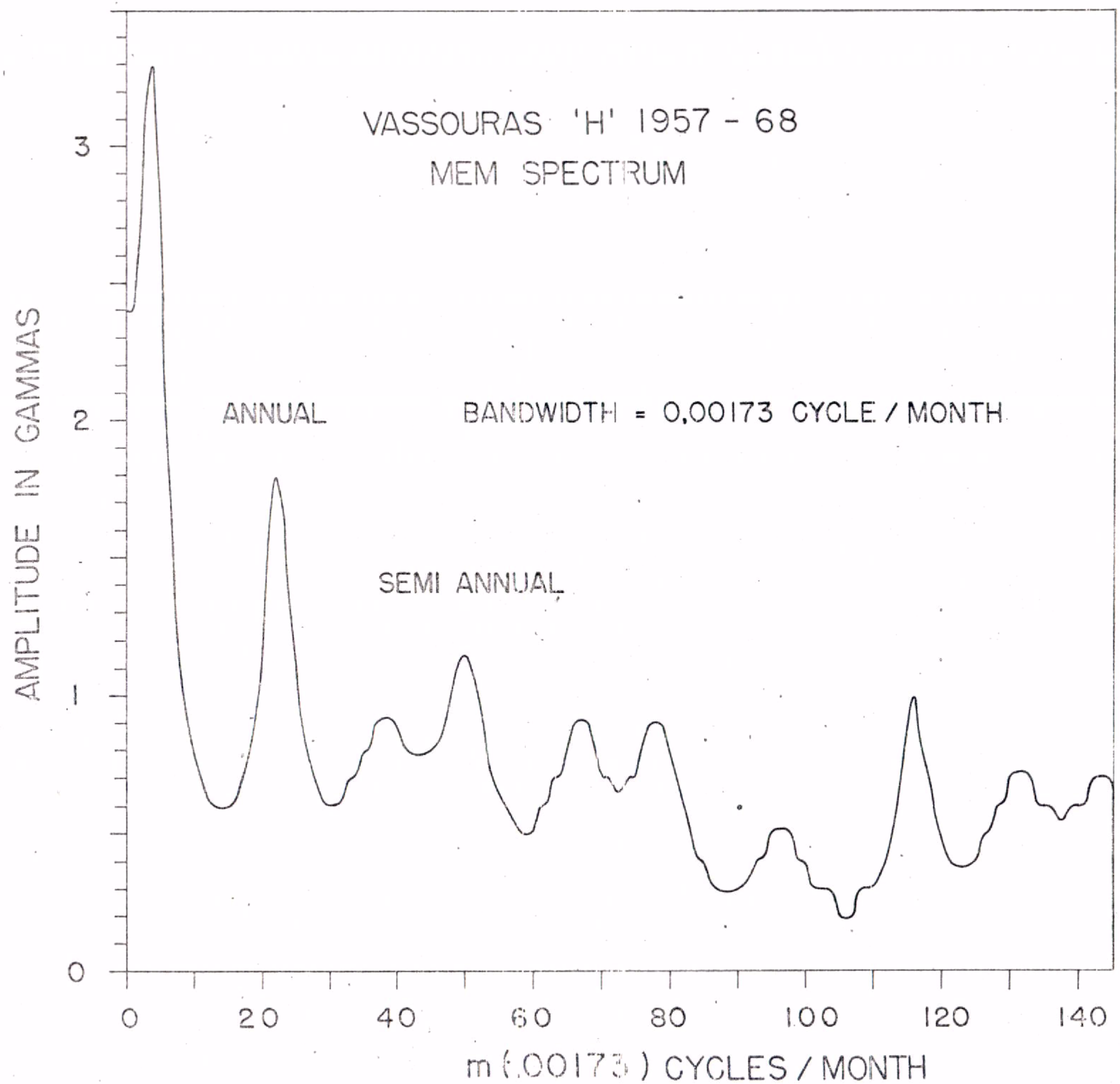

VASSOURAS 'H' 1957 - 68
MEM SPECTRUM
ANNUAL
BANDWIDTH = 0,00173 CYCLE / MONTH
SEMI ANNUAL
AMPLITUDE IN GAMMAS
0
1
2
3
0
20
40
60
80
100
120
140
m (.00173) CYCLES / MONTH

Figure 2

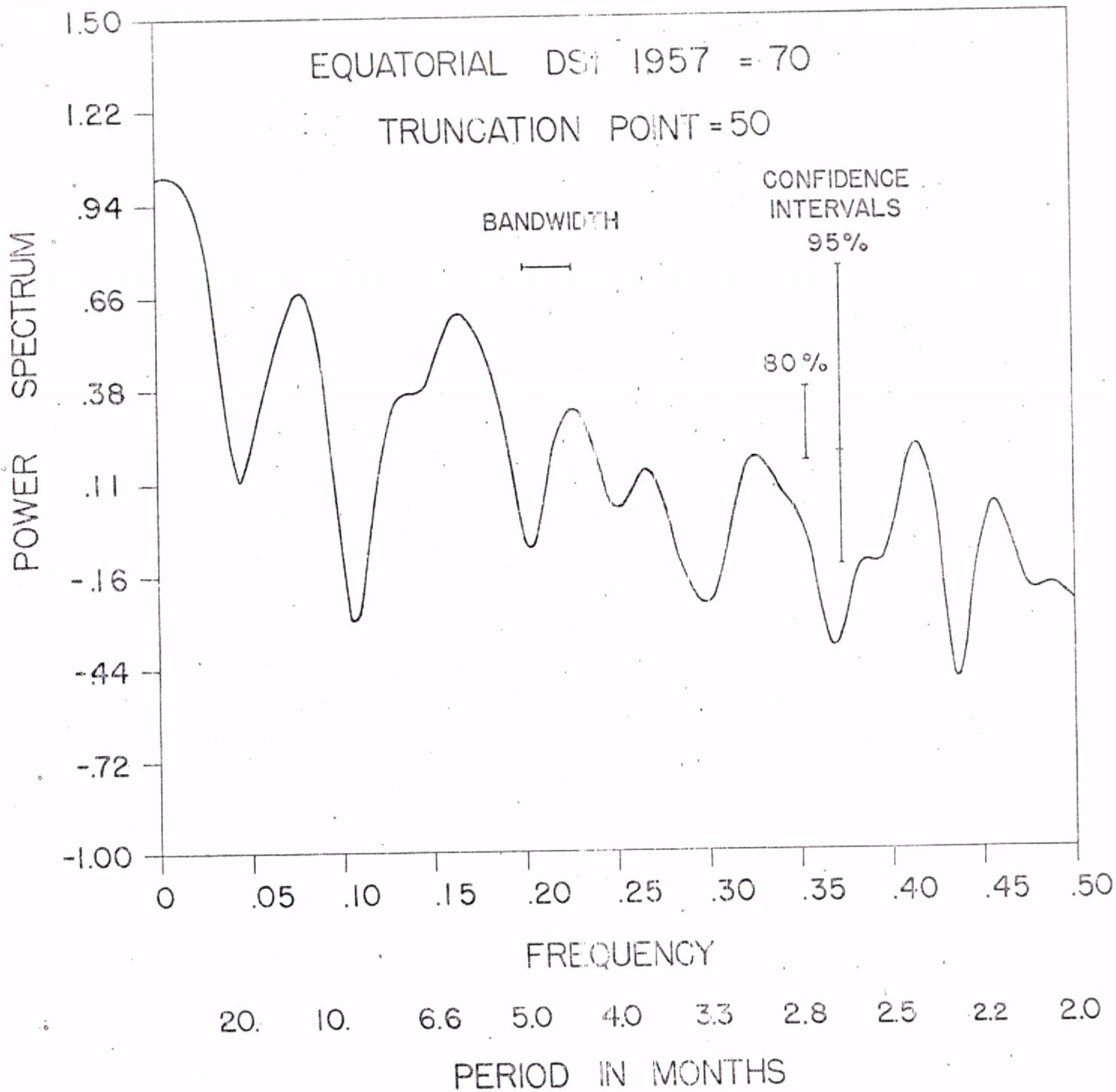
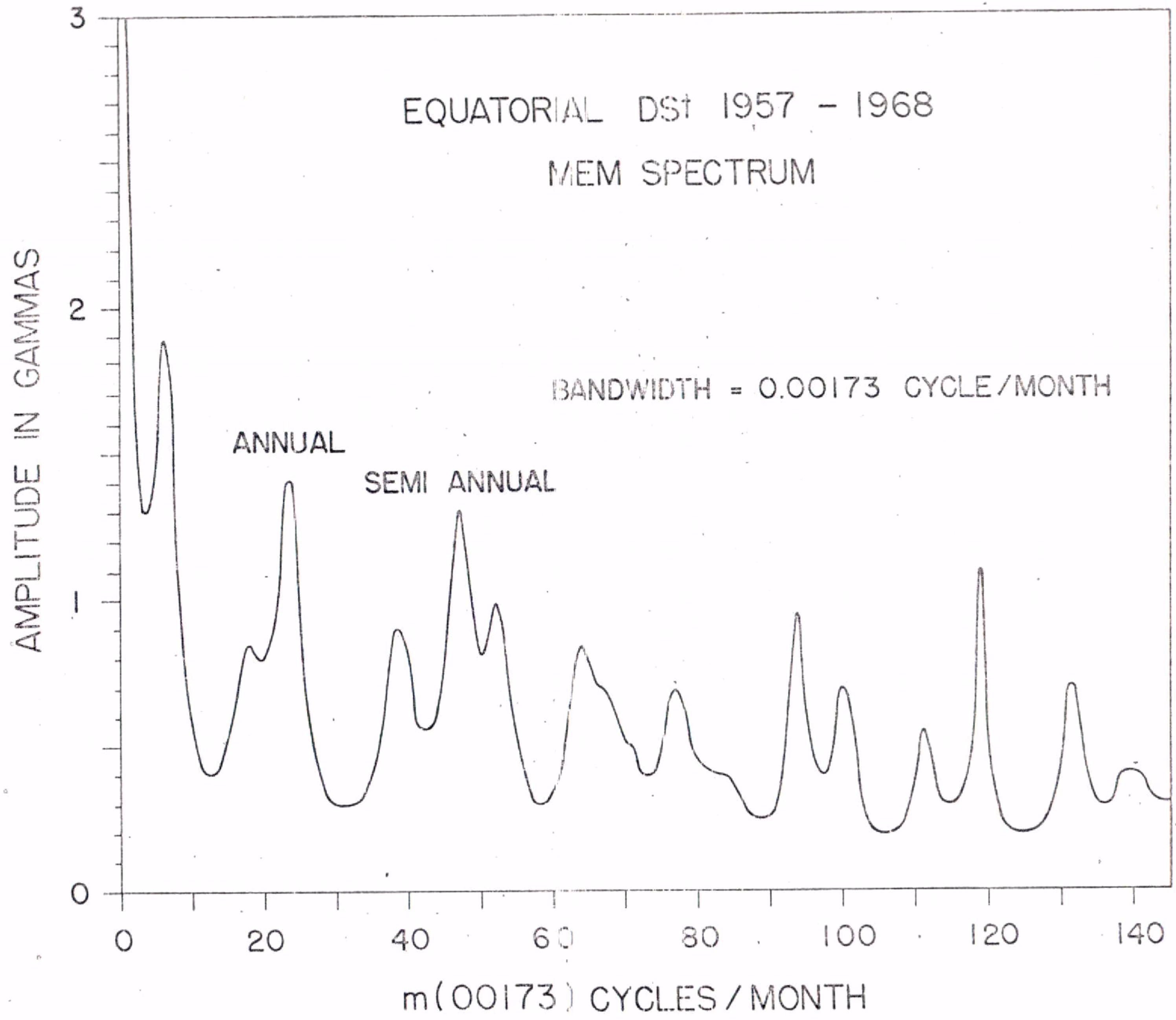

EQUATORIAL DST 1957 = 70
TRUNCATION POINT = 50
BANDWIDTH
CONFIDENCE INTERVALS
95%
80%
POWER SPECTRUM
1.50
1.22
.94
.66
.38
.11
-.16
-.44
-.72
-1.00
0
.05
.10
.15
.20
.25
.30
.35
.40
.45
.50
FREQUENCY
20.
10.
6.6
5.0
4.0
3.3
2.8
2.5
2.2
2.0
PERIOD IN MONTHS

Figure 3



EQUATORIAL DSt 1957 - 1968
MEM SPECTRUM
BANDWIDTH = 0.00173 CYCLE/MONTH
ANNUAL
SEMI ANNUAL
AMPLITUDE IN GAMMAS
3
2
1
0
0
20
40
60
80
100
120
140
m(00173) CYCLES/MONTH

Figure 4