Nonclassical Spectral Analysis Applied to Geomagnetic Time Series

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ABSTRACT

The south american observatories of Huancayo (Peru), Vassouras (Brazil) and Pilar (Argentina) has long uninterrupted time series of annual mean values of the geomagnetic elements. This work applies the maximum entropy spectral analysis method in determining the long period components. The component D presents a solar wave with a period of 10.3 yr. at Vassouras, 10.9 yr. at Pilar and 11.5 yr. in Huancayo. The component F presents a solar wave of 11.5 yr. at Vassouras and 11.8 yr. at Pilar. A wave 18.6 yr. appears in Huancayo F. The Z component appears with great error in the amplitudes and phases in Huancayo and Pilar but in Vassouras a 14.4 yr. wave is present.

1. Introduction.

In south america only three observatories have sufficiently long geomagnetic records to carry out a spectral analysis trying to find the longs periods present. They are Vassouras, Huancayo and Pilar, referred hereinafter VA2, HU and PI. In time series spectral analysis the maximum entropy method, hereinafter MEM, has predominated over the "classical" ones (correlogram, periodogram). In geophysics MEM has been used to study for example atmospheric pressure, temperature, rain, variation of length of day, sunspot number, among other phenomena. However despite the excellent quality of MEM, there are some problems such as frequency shift and spontaneous line splitting, the lack of a general criterion in determining the optimal length of the prediction error filter, hereinafter LPEF, and the difficulty of estimating the amplitude and phase of the periods found. Therefore there are difficulties in deciding which periods are representative and which are not.
The earth magnetic field variations are caused by internal and external sources. Hence in their study remains the problem of determining whether their periods because of external or internal phenomena.

2. Data Analysis and Results.

This work uses annual mean values of the geomagnetic elements D, H, Y, Z, and F of the earth magnetic field recorded at VA2, HU and PI. Before carrying out the spectral analysis a trend removal is done adjusting a

linear model in a least squares sense.
Between the different spectral analysis method, maximum entropy is among the best. This work uses the algorithm (FABNE) presented by *Barrodale and Erickson [1980]*. Though it is computationally inefficient, it is less sensitive to spontaneous line splitting and frequency shift than those presented by *Burg [1967, 1968]* and *Ulrych and Bishop [1975]*. The LPEF used in this work ranges from 15 to 60 per cent of the length of the time series. With the set of periods so obtained, the amplitude and phase are determined with the method discussed by *Gianibelli and Suarez [1989]*.
Variations with short periodicities were detected in the H component of HU, and in the Z component of VA2 as shown in table I. The solar cycle and the double solar cycle are present in almost all components in three observatories.

3. Discussion.

The short periodicities could be interpreted as an effect of the equatorial electrojet in the data of Huancayo, while in Vassouras the oceanic induction could be the responsible for the Z variation. The periods between 16 and 19 years might correspond to a lunar modulation with a period of 18.6 years (Mn wave) instead of the double solar cycle.

4. Conclusion.

The algorithm FABNE is appropriate to analyze short geomagnetic time series with a LPEF of 50 per cent of the original data length.
One possible classification of the periods found in the data analyzed is the following:

a) Short periods, from 2 to 8 years. They are of external origin, corresponding mainly to the modification of the magnetospheric structure.
b) Periods from 8 to 28 years. They could correspond to the solar and double solar cycles.
c) Long periods, greater than 28 years. They are of internal origin.

5. Bibliography.

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Component H

T (yr)	Vassouras r (nT)	σ (nT)	φ (°)	σ (°)	Huancayo r (nT)	σ (nT)	φ (°)	σ (°)	Pilar r (nT)	σ (nT)	φ (°)	σ (°)
3.8					4.2	2.8	352.4	38.5				
8.7					5.2	3.1	342.2	37.7				
10.2									7.6	5.3	331.9	44.9
10.8	7.9	5.0	287.0	44.4								
11.7					4.3	3.4	27.0	9.5				
24.3									36.9	5.7	148.3	10.2
25.7					58.4	5.5	324.2	6.7				
28.4	27.8	5.8	36.0	0.3								
33.3					61.5	5.9	316.4	6.9				
58.9					242.5	4.2	259.5	0.8				
67.5	177.4	5.6	152.0	2.0								
76.5									174.2	8.6	353.1	3.1
143.3									90.0	12.0	152.3	6.5

Component Y

T (yr)	Vassouras r (nT)	σ (nT)	φ (°)	σ (°)	Huancayo r (nT)	σ (nT)	φ (°)	σ (°)	Pilar r (nT)	σ (nT)	φ (°)	σ (°)
9.2					12.6	3.8	5.5	14.4				
11.9									4.3	1.9	288.8	30.8
14.5	16.8	9.7	101.8	38.0								
16.2					8.5	4.7	153.6	35.5				
16.6									6.0	1.9	106.4	21.1
24.8					19.2	4.2	11.1	8.5				
42.7									52.9	2.8	220.6	0.2
45.4					61.2	5.5	108.0	6.1				
53.3	50.3	11.7	135.0	15.7								
61.6									88.1	2.5	109.2	2.0
77.8					55.9	6.5	58.0	3.0				

Component Z

T (yr)	Vassouras r (nT)	σ (nT)	φ (°)	σ (°)	Huancayo r (nT)	σ (nT)	φ (°)	σ (°)	Pilar r (nT)	σ (nT)	φ (°)	σ (°)
4.7	6.6	4.7	280.9	46.8								
8.7	16.5	4.7	78.8	13.5								
14.4	13.6	4.2	182.4	16.4								
16.6									33.4	11.7	193.6	11.8
46.3					169.7	26.4	82.8	7.8				
54.1									145.5	12.5	19.0	2.1
69.6	130.4	7.0	77.8	2.5								
128.7	37.3	10.3	154.1	18.1								

Table I

Total Magnetic Field F

	Vassouras				Huancayo				Pilar			
T (yr)	r (nT)	σ (nT)	φ (°)	σ (°)	r (nT)	σ (nT)	φ (°)	σ (°)	r (nT)	σ (nT)	φ (°)	σ (°)
2.5									2.2	1.6	282.3	48.8
3.8	4.1	3.4	266.7	45.2								
3.9									2.6	1.7	17.7	16.9
5.3	5.1	4.5	141.6	60.5								
6.8	4.5	4.1	161.7	55.5								
9.8									6.0	1.6	13.1	9.5
11.8	7.2	4.3	335.6	37.3					4.0	1.6	350.6	23.1
11.9												
18.6					12.1	5.9	0.9	27.7				
24.2									29.1	2.3	9.6	3.7
31.6									24.2	4.2	216.8	0.2
36.0	25.4	4.3	184.6	8.6	76.5	8.7	165.8	6.3				
45.2									13.1	5.4	315.3	29.6
51.3	71.6	5.4	119.3	5.3								
58.6					298.1	8.3	352.8	1.3				
66.1									72.3	4.4	314.8	4.1

Declination D

	Vassouras				Huancayo				Pilar			
T (yr)	r (′)	σ (′)	φ (°)	σ (°)	r (′)	σ (′)	φ (°)	σ (°)	r (′)	σ (′)	φ (°)	σ (°)
4.0									0.26	0.16	30.5	4.2
6.1					0.70	0.60	349.7	51.5				
8.8									0.26	0.14	346.3	32.7
10.9									0.43	0.16	213.0	1.5
11.5					1.23	0.67	70.6	21.5				
15.2	0.68	0.58	190.6	30.6								
15.7									0.72	0.16	298.9	15.3
44.1	10.04	0.53	5.2	2.5								
48.2									11.29	0.15	249.4	0.5
76.5					5.6	1.03	281.4	12.0				
113.1	1.73	0.17	223.1	1.1								

Table I (cont.)