Spectral Analysis of Climatological Data in Salvador, Bahia, Brazil

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Abstract

We study here the periodicity of precipitation, average temperature, pressure, humidity, insolation, minimum temperature and maximum temperature in the city of Salvador, Bahia, Brazilian Northeastern. The available time series have monthly samples during a period of 30 years, thus resulting in 360 samples. The spectral analysis indicates a strong preference for the year basis variation (1 cicle per year) for all seven quantities. The six month component is also strong (2 cicles per year) in all cases.

Introduction

The climatical variability in the Brazilian Northeastern has been approached in various aspects. Markham (1974), for instance regsitered a periodicity of 13 years in the town of Fortaleza, Ceará. Hastenrath and Kaczmarczyk (1981), showed that the precipitation variation in the Brazilian Northeastern was concentrated in diferent regions and preferably within the ranges of 2.5; 5; 10; e 13–21 years. This variability was considered as a result the great scale circulation patterns variation in Brazilian Atlantic Tropical Sector.

Kane (1998), showed that the rain characteristics between the Setentrional Brazilian Northeastern and the Oriental Brazilian Northeastern were close, but different from the Meridional Brazilian Northeastern. The Setentrional Northeastern showed periodicities of 2.03 and 2.45 years, the Oriental Northeastern showed periodicities of 2.26 and 2.60 years, while the Meridional Northeastern showed significant quasi-annual oscillations.

Kane (1998), states that these quasi-annual oscillations, as well as, the precipitation and humidity characteristics of the Brazilian Northeastern are related Atlantic Ocean parameters, like, sea surface temperature, pressure and winds. In Bastos et al. (1999), we studied the spectrum analysis of precipitation and average temperature, and in Novaes et al. (2001), we studied the spectrum analysis of pressure and humidity. Here we re-analysed these four parameters, that is, precipitation, average temperature, pressure and humidity, and we added three new parameters: insolation, minimum temperature and maximum temperature.

Data Collection

In the development of this work we have used data collected by the Instituto Nacional de Meteorologia (INMET). The data was acquired at the INMET Fourth District, and was collected at the Salvador Station, which is located at coordinates 13° 01' south latitute and 38° 31 west longitude, and the station height is 51,41m.

The available data are: precipitation (mm), average temperature (°C), pressure (hPa), humidity (%), insolation (days), minimum temperature (°C) and maximum temperature (°C).

All the data is in form of monthly values, during a period of 30 years, from 1961 to 1990, that is, each data set has 360 samples. The data whithout any treatment can be seen in Figure 1 (precipitation), Figure 4 (average temperature), Figure 7 (pressure), Figure 10 (humidity), Figure 13 (insolation), Figure 16 (minimum temperature) and Figure 19 (maximum temperature).

Spectral Analysis

The time series are analyzed at the frequency domain through the Fourier transform. Consider that a given time series is represented by a generic time function $f(t)$. Then its Fourier transform is given by

$$\mathcal{F}\{f(t)\} = F(\omega) = \int_{-\infty}^{+\infty} f(t) e^{-i\omega t} dt.$$

The available time series are not continuous functions but rather a set of discrete values. Thus we have to make use of the Discrete Fourier Transform, or from the computational poit of view we the the so called FFT or Fast Fourier Transform.

The total number of samples for the period of 30 years is $N = 360$. Each each has to samples, so that $\Delta t = 1/12$ year. The frequency interval is thus

$$\Delta f = \frac{1}{N \cdot \Delta t} = \frac{1}{360 \cdot (1/12)} = 0,0333 \text{ cicle per year},$$

being the Nyquist given by

$$f_N = \frac{1}{2 \cdot \Delta t} = \frac{1}{2 \cdot (1/12)} = 6 \text{ cicles}.$$

The Nyquist frequency, which is also called folding frequency is the frequency which value is half of the sampling frequency. The frequencies which are higher than f_N are aliased, that is, are mixed with the lower frequencies, becoming not distinguishbles, characterizing the ambiguity situation.

Applying the FFT in the time series, we obtain the amplitude spectrum, given by $A(\omega)$ =

$\sqrt{Real F(\omega)^2 + Imag.F(\omega)^2}$, where F is a complex function and the Fourier transform of the sime series given by $f(t)$.

The amplitude spectra of the time series can be seen in Figure 2 (precipitation), Figure 5 (average temperature), Figure 8 (pressure), Figure 11 (humidity), Figure 14 (insolation), Figure 17 (minimum temperature) and Figure 20 (maximum temperature).

In order to eliminate possible artifacts, we applied a convolutional filter in each of the amplitude spectrum. The results were reasonable providing a better interpretation. The filtered amplitude spectra of the time series can be seen in Figure 3 (precipitation), Figure 6 (average temperature), Figure 9 (pressure), Figure 12 (humidity), Figure 15 (insolation), Figure 18 (minimum temperature) and Figure 21 (maximum temperature).

Discussion

In all cases we see that two components are prominents: the annual and the semestral. The annual component is always stronger that the semestral, with one exception, in the humidity the semestral componente was larger than the annual one.

In Figure 3 (precipitation) we noticed 5 prominent frequencies. Considering a cut-off for amplitude equal to 3000, we have that: (i) amplitude 3542, frequency 4.29 years; (ii) amplitude 3279, frequency 1.76 year; (iii) amplitude 9268, frequency 1 year; (iv) amplitude 6335, frequency 6 months; and (v) amplitude 3367, 4 months.

In Figure 6 (average temparature) we noticed 3 prominent frequencies. Considering a cut-off for amplitude equal to 25, we have that: (i) amplitude 31, frequency 15 years; (ii) amplitude 142, frequency 1 year; and (iii) amplitude 29, frequency 6 months.

In Figure 9 (pressure) we notice 3 prominent frequencies. Considering a cut-off for amplitude equal to 80, we have that: (i) amplitude 287, frequency 7.5 years; (ii) amplitude 265, frequency 1 year; and (iii) amplitude 86, frequency 6 months.

In Figure 12 (humidity) we notice 5 prominent frequencies. Considering a cut-off for amplitude equal to 100, we have that: (i) amplitude 114, frequency 10 years; (ii) amplitude 125, frequency 4.28 years; (iii) amplitude 129, frequency 2.5 years; (iv) amplitude 113, frequency 1 year; and (v) amplitude 148, 6 months.

In Figure 15 (insolation) we notice 4 prominent frequencies. Considering a cut-off for amplitude equal to 1000, we have that: (i) amplitude 1241, frequency 30 years; (ii) amplitude 1304, frequency 4.28 year; (iii) amplitude 2876, frequency 1 year; and (iv) amplitude 1341, frequency 6 months.

In Figure 18 (minimum temperature) we notice 4 prominent frequencies. Considering a cut-off for amplitude equal to 30, we have that: (i) amplitude 31, frequency 15 years; (ii) amplitude 34, frequency 6 year; (iii) amplitude 120, frequency 1 year; and (iv) amplitude 29, frequency 6 months.

In Figure 21 (maximum temperature) we notice 5 prominent frequencies. Considering a cut-off for amplitude equal to 30, we have that: (i) amplitude 41, frequency 15 years; (ii) amplitude 180, frequency 1 year; and (iii) amplitude 30, frequency 6 months.

Conclusions

We analyzed the amplitude spectra of time series for precipitation, average temperature, pressure, humidity, insolation, minimum temperature and maximum temperature. This data, for the period from 1961 to 1990, was collected by INMET at its Fourth District — Salvador Station.

For each one of these seven time series, we generated the amplitude spectrum, as well as a filtered amplitude spectrum

The filtered amplitude spectra, following the above order, can be seen in Figures 3, 6, 9, 12, 15, 18, and 21. In all these seven figures we can see a strong annual component, as well as, a strong semestral one.

In the case of temperature we noticed a significant component with a periodicity of 15 years, eventually related to sunspots. It is interessting that this result was consistent with two other results displayed in this work: minimum temperature and maximum temperature.

References

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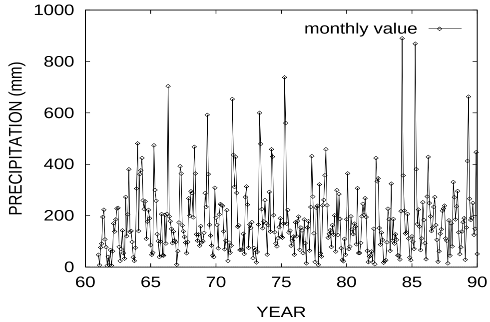

Figura 1: Monthly values of precipitation (mm) in Salvador, Bahia, Brazil, in the period 1961–1990.

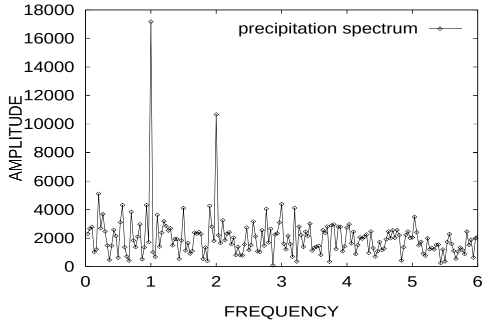

Figura 2: Precipitation spectrum in Salvador, Bahia, Brazil, in the period 1961–1990.

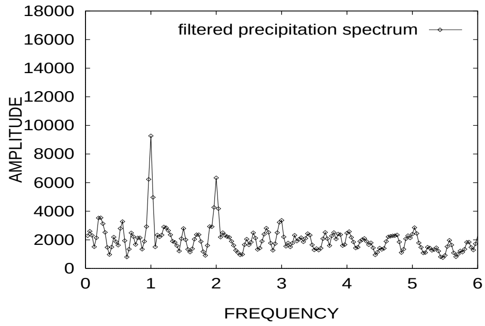

Figura 3: Filtered precipitation spectrum in Salvador, Bahia, Brazil, in the period 1961–1990.

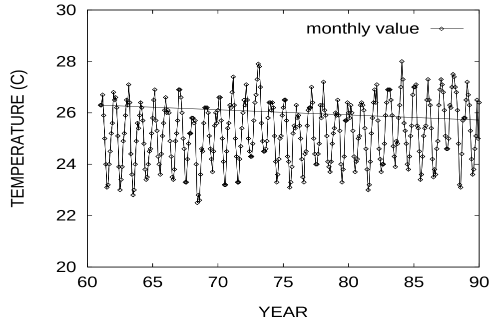

Figura 4: Monthly values of average temperature (^{o}C) in Salvador, Bahia, Brazil, in the period 1961–1990.

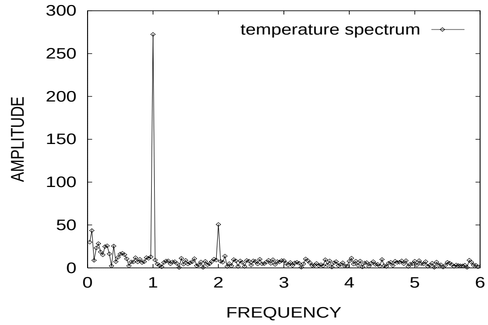

Figura 5: Average temperature spectrum in Salvador, Bahia, Brazil, in the period 1961–1990.

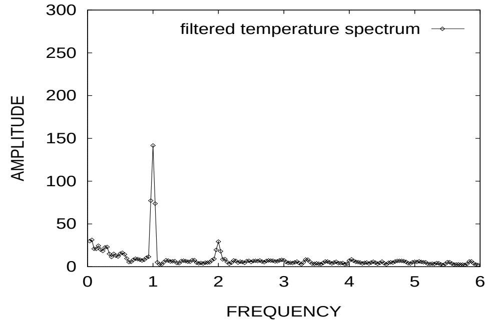

Figura 6: Filtered average temperature spectrum in Salvador, Bahia, Brazil, in the period 1961–1990.

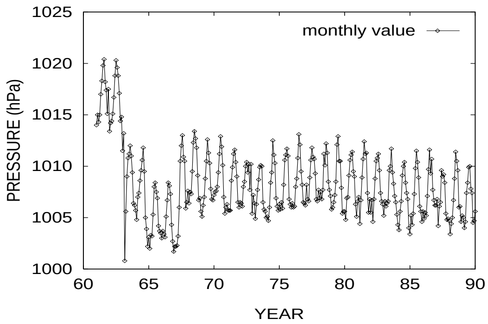

Figura 7: Monthly values of pressure (hPa) in Salvador, Bahia, Brazil, in the period 1961–1990.

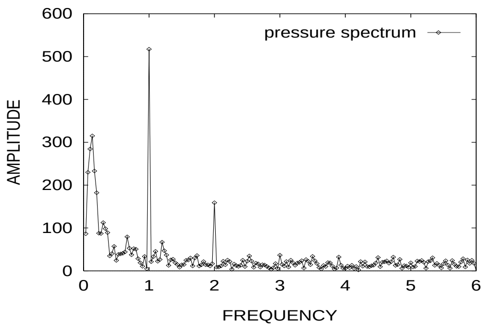

Figura 8: Pressure spectrum in Salvador, Bahia, Brazil, in the period 1961–1990.

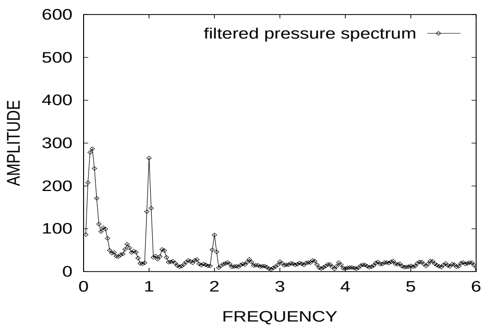

Figura 9: Filtered pressure spectrum in Salvador, Bahia, Brazil, in the period 1961–1990.

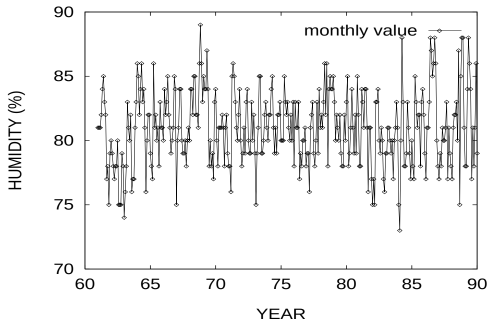

Figura 10: Monthly values of humidity (%) in Salvador, Bahia, Brazil, in the period 1961–1990.

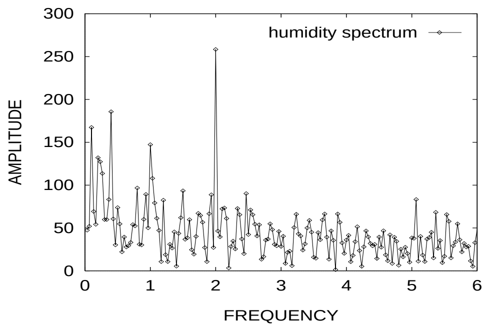

Figura 11: Humidity spectrum in Salvador, Bahia, Brazil, in the period 1961–1990.

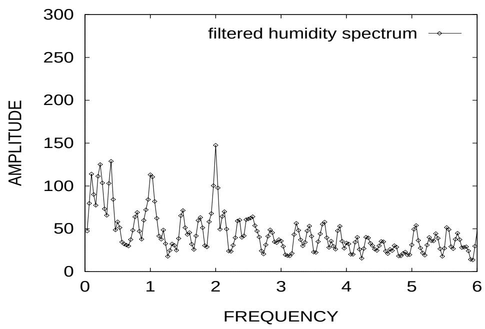

Figura 12: Filtered humidity spectrum in Salvador, Bahia, Brazil, in the period 1961–1990.

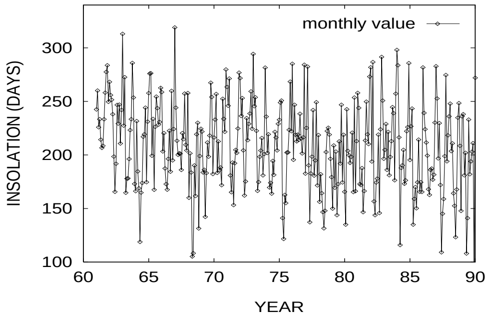

Figura 13: Monthly values of insolation (days) in Salvador, Bahia, Brazil, in the period 1961–1990.

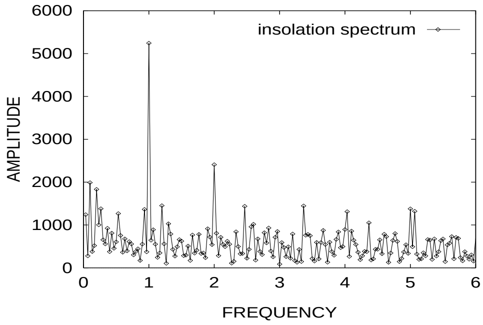

Figura 14: Insolation spectrum in Salvador, Bahia, Brazil, in the period 1961–1990.

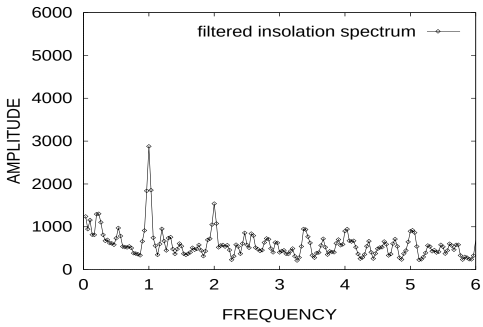

Figura 15: Filtered insolation spectrum in Salvador, Bahia, Brazil, in the period 1961–1990.

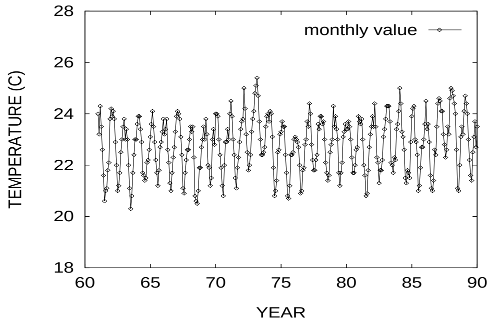

Figura 16: Monthly values of minimum temperature (°C) in Salvador, Bahia, Brazil, in the period 1961–1990.

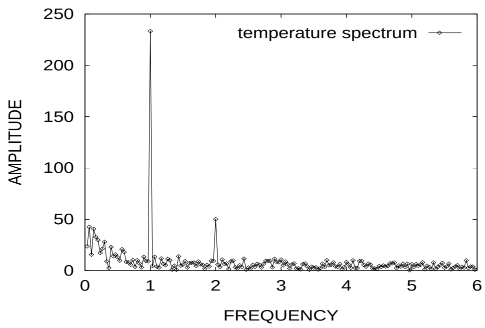

Figura 17: Minimum temperature spectrum in Salvador, Bahia, Brazil, in the period 1961–1990.

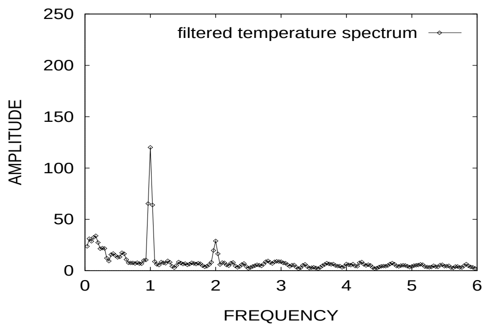

Figura 18: Filtered minimum temperature spectrum in Salvador, Bahia, Brazil, in the period 1961–1990.

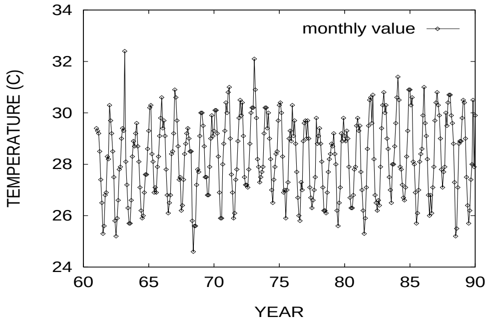

Figura 19: Monthly values of maximum temperature (^{o}C) in Salvador, Bahia, Brazil, in the period 1961–1990.

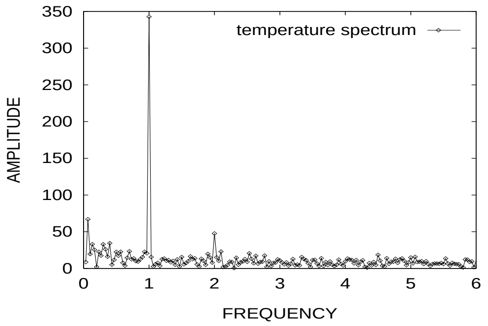

Figura 20: Maximum temperature spectrum in Salvador, Bahia, Brazil, in the period 1961–1990.

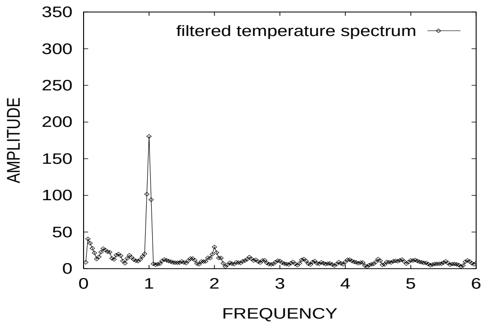

Figura 21: Filtered maximum temperature spectrum in Salvador, Bahia, Brazil, in the period 1961–1990.