FFT Analysis of Northeast Brazil Vegetation Phenology Recorded by Satellite Index[1]

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ABSTRACT

NDVI time series of monthly images for the period of July 1981 to June 1993 generated from the NOAA AVHRR GAC data were used to investigate the spatial variation of climatic impact on vegetation phenology in the northeast Brazil (NEB) using the Fast Fourier Transform (FFT) algorithm. Maps of NDVI monthly average, amplitude and phase were generated using FFT algorithm. The results showed that NDVI monthly average map delineated quite well the different vegetation types as well as climatic regimes presented in the NEB. High amplitude observed in the north center part of the NEB indicated that this region had climatic variability . The phase map indicated the peak of rainy season shifted from May in the eastern cost and northwest corner to March in north, toward February in the center and to January in the center south. It is concluded that the FFT algorithm applied to NDVI time series provides us a powerful tool to describe the progressive zonal change of climatic variability and its impact on vegetation variation in a complex climatic pattern such as the NEB climate.

1. INTRODUCTION

Time series analysis of NDVI (Normalized Difference Vegetation Index) has been used to classify global vegetation by Justice et al. (1985). Since then, NDVI generated from NOAA AVHRR data has been widely used to monitor vegetation growth conditions as well as land use dynamics. Recently, Fast Fourier Transform (FFT) algorithm has been applied to time series analysis of (NDVI) for land cover classification (Ludovic et al., 1994, Menenti et al., 1993, Verhoef et al., 1996).

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Many researchers have tried to find out the influences of the various atmospheric circulation systems originated from Pacific and Atlantic Oceans on the climatic anomalies of the Northeastern Brazil (NEB). In their studies, drought occurrences expressed by rainfall anomalies were used to correlate with ENSO events. Since we consider that NDVI time series analysis provides detailed spatial information on drought evolution, spatial analysis of phase and amplitude of NDVI obtained from the FFT may provide us a better tool for investigating the climatic impact on vegetation. In this study, FFT algorithm applied to time series of NDVI monthly images for the period of July 1981 to June 1993 generated from the NOAA AVHRR GAC data were used to investigate the spatial variation of climatic impact on vegetation phenology in the Northeastern Brazil (NEB).

2. METHODOLOGY

2.1 Data

NOAA AVHRR Global Area Coverage (GAC) monthly Maximum Value Composite (MVC) data set with a resolution of 8 km by 8 km of South American for the period of July 1981 to June 1993, provided by the GSFC/NASA (Eidenshink *et al*. 1997), was used in this study. NDVI is calculated by taking the ratio of reflectance values of AVHRR channel 1 (Ch1, 0.58-0.68 μm) and channel 2 (Ch2, 0.725 -1.10 μm) and divided by the sum of them which is expressed by the following equation:

$$NDVI=(Ch2-Ch1)/(Ch2+Ch1)$$

2.2 Study Area

An area in the northeastern region of South America, located at latitude of 2°S to 15°S and longitude of 34°W to 48°W, which covers about 1.9 million km^2, was selected for this study. The NEB with an area of 1.556 millions km^2, occupies about 82 % of the studied area. According to Hargreaves (1974), the climatic types range from very arid and arid (caatinga) at the central dry polygon, semi-arid (agreste) and wet-dry (Tropical Rain Forest) with highly irregular rainfall distribution.

2.3 NDVI time series

The NDVI time series of 144 months (07/81 to 06/93) was used to generate 72 amplitude and 72 phase maps of 72 frequencies using FFT algorithm.

A time series of NDVI-images, *y(x,y,t),* is expressed as a linear combination of elementary periodic functions (Menenti *et al*., 1993):

$$y\ (x,y,t) = \sum_{1=n}^{N} A(x,y)_n\, e^{i[(w_n t - f\,(x,y)_n\,]}$$

where: x = pixel number or longitude, y = line number or latitude,

t = time period in month, w_n = frequency,

A = amplitude, *g* = phase lag.

3. RESULTS AND DISCUSIONS

From the analysis of 72 frequency maps produced, the one year cycle of NDVI time series maps showed the most distinct phase and amplitude variation in the NEB region which agreed quite well with the distinct wet-dry rainfall distribution pattern of the NEB region. Figure 1 shows the NDVI monthly average map of the whole studied period. The colors in the map represent the variation of zero amplitude NDVI values. The predominant yellow color in the center and center north regions indicates the 12 year NDVI monthly mean value is low than 0.4. It coincides quite well with the very arid region. The area covered by light green color indicates the NDVI value of 0.4 to 0.5. The NEB dry polygon occupies mainly areas covered by the colors of green, yellow and orange (NDVI < 0.5). Although the area of over 40 % departure from normal rainfall delineated by Kousky (1979) coincided quite well with the area of NDVI monthly average lower than 0.5 shown in the Fig. 1, the NDVI average map provides us a pixelwise resolution of climatic variation.

Figure 2 shows the amplitude map of one-year frequency. The yellow, light green to deep green areas with amplitude values ranging from 0.275 to 0.175 dominate the central and northern central regions of NEB showed that these areas have high annual rainfall variability. These regions coincide quite well with the area covered by the NEB dry polygon. The areas of yellow color with an amplitude lower higher than 0.275 mostly agreed well with the areas of mean annual rainfall lower than 600 mm delineated by Kousky (1978) except the center north part which did not show up in Kousky’s study. It may indicate that although mean annual rainfall is higher than 600 mm in this region but its variability is rather high. This shows that the amplitude analysis may provide a better tool of detecting the climatic variability than the use of mean annual rainfall data.

Figure 3 shows the NDVI annual cycle phase map of the NEB region. The phase color indicates the phase angle of the month at its maximum amplitude (phase angle at 90^o). The yellow color phase angle observed at the top northwest part and the eastern cost area in the figure showed that the annual maximum NDVI occurred in June. It coincides with the maximum rainfall occurred in May since there is a one month time lag of NDVI in responding to rainfall (Liu e Ferreira, 1991). It is interesting to note that the progressive shift of peak rainy season from Summer in the west to Winter in the east cost and from the beginning of Summer in the south to the end of Summer in the north.

4. CONCLUSIONS

It is concluded that the FFT NDVI time series provides us a powerful tool to describe the progressive zonal change of climatic variability and its impact on vegetation variation in a complex climatic pattern such as the northeastern Brazil climate.

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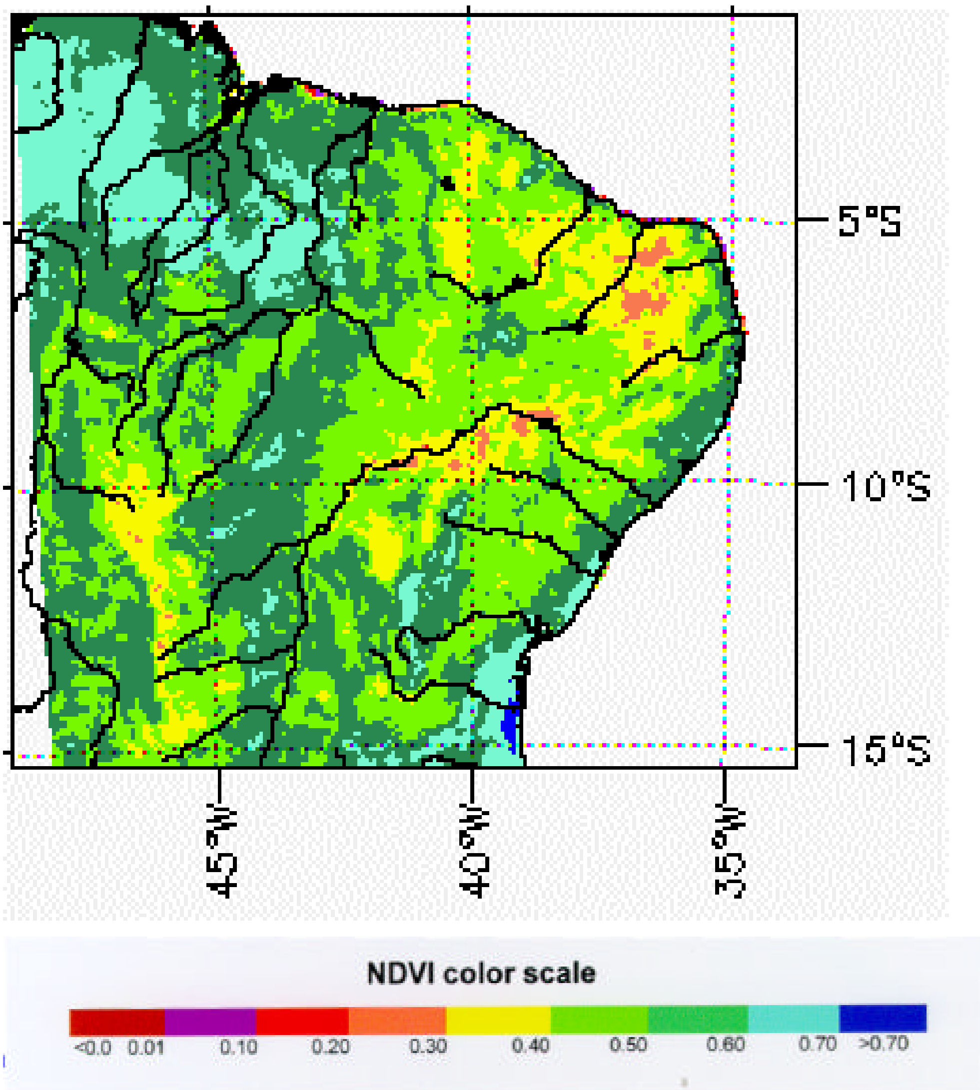

Figure 1 - NDVI monthly average map of Northeast Brazil (NDVI data: 07/81 to 06/93).

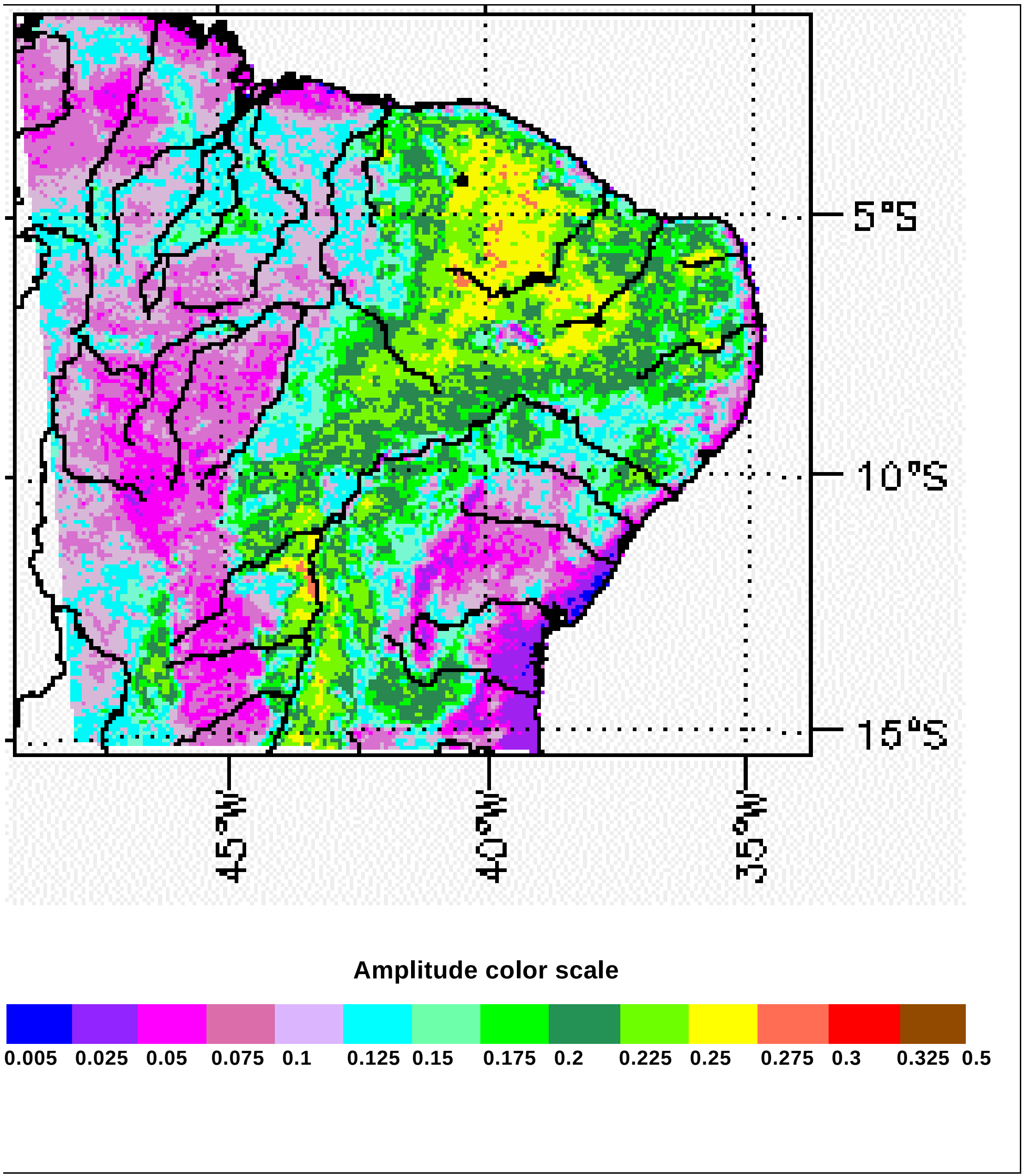

Figure 2 - NDVI annual cycle amplitude map of Northeast Brazil (NDVI data: 07/81 to 06/93).

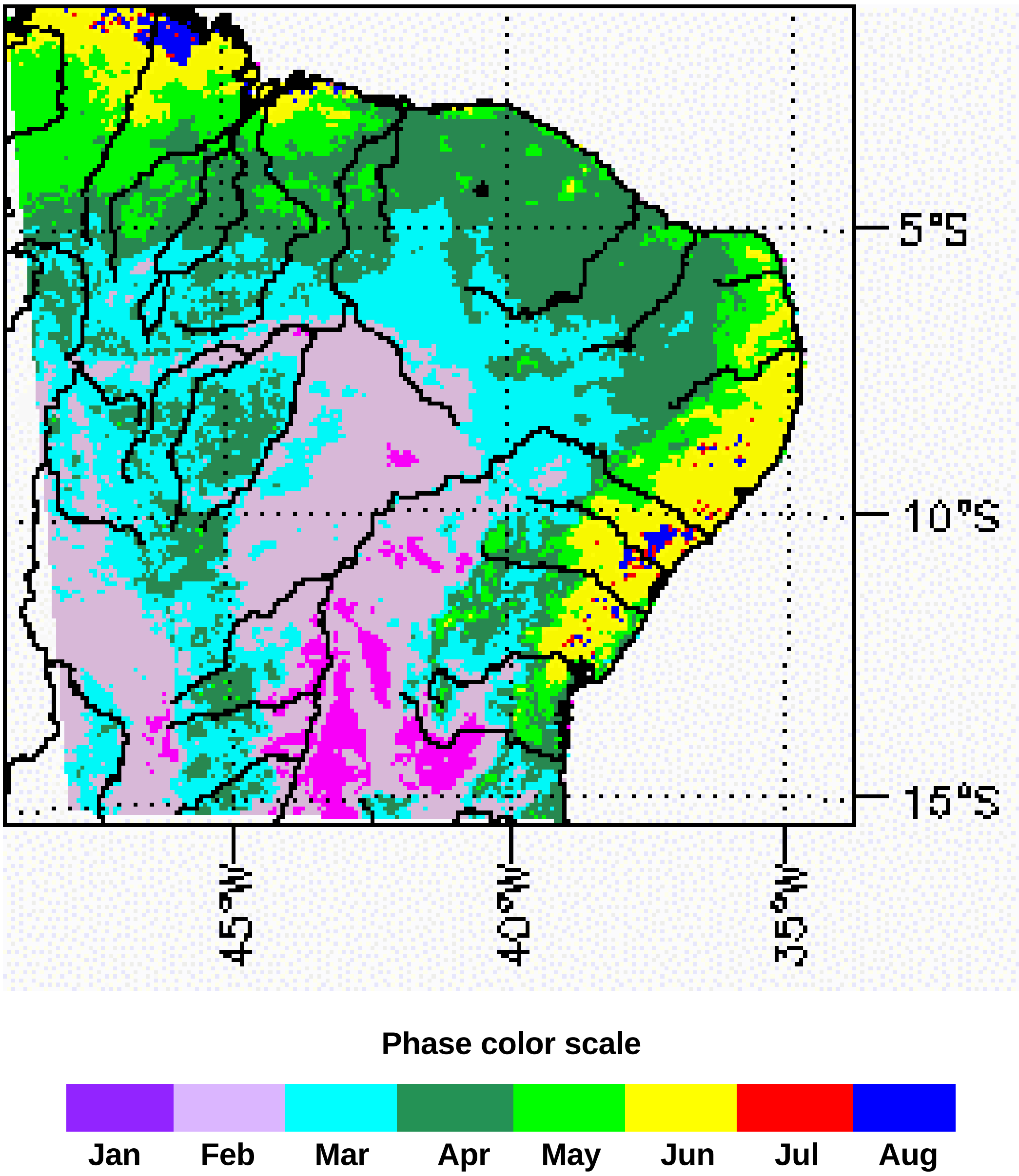

Figure 3 - NDVI annual cycle phase map of Northeast Brazil (NDVI data: 07/81 to 06/93).