DROUGHT FORECASTING FOR NORTHEASTERN BRAZIL BY HARMONIC ANALYSIS: USES AND ABUSES

By

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Introduction

This work is a summary of Nobre et al. (1982) hereafter referred to as N. Several earlier studies (Markhan, 1974, Jones and Kearns, 1976; Girardi and Teixeira, 1978; and Strang, 1979) analyzed the long time series of Fortaleza, Ceará, rainfall (1849 to present) and detected the existence of apparent periodicities of approximately 13 and 26 years in that time series. Such periodicities were used to develop drought forecasting models for Northeastern Brazil (hereafter referred to as Nordeste) as in Girardi and Teixeira (1978). The forecasts issued received a great deal of government and public attention. Jones and Kearns (1976), on the other hand, questioned the statistical significance of such apparent periodicities. In this study, we attempt to settle the question whether apparent periodicities in Fortaleza rainfall time series can reliably be utilized for drought forecasting for that region.

The first question that comes to one's mind is whether Fortaleza precipitation anomalies are representative of anomalies for a larger area of Nordeste. Fortaleza rainfall, as is the case for most of the northern Nordeste, is under the influence of the precipitation regime with peak rainfall from March through May as opposed to the precipitation regimes of coastal areas from $5^{o}S$ to $18^{o}S$ with maximum from June through August and southern Nordeste where maximum rainfall months are November and December. In N it was shown that Fortaleza rainfall can be taken as representative of the Northern Nordeste only for years of severe droughts throughout that region. Positive or near normal precipitation anomalies in Fortaleza do not bear a high correlation with precipitation elsewhere in Nordeste even for stations within a few hundred kilometers in the neighborhood of Fortaleza. However, if the goal is to forecast just the very sever and encompassing droughts for the whole region then the lack of representativeness of Fortaleza rainfall may not be a critical shortcoming.

Brief Review of Drought Forecasting for Nordeste

Walker (1928) was one of the first researchers that attempted to use scientific methods for drought forecasting in Nordeste. He developed a statistical formula, based on multiple regression analysis, relating the seasonal (Jan-Jun) rainfall in Ceará with meteorological parameters of preceding periods of this rainy season in Ceará at distant points. His formula proved to be correct in 60% of the cases, which was not satisfactory to Walker for operational purposes. Sampaio Ferraz (1929 a and b) and Serra (1956) worked along the statistical formulations of Walker even further. Sampaio Ferras (1950) was the first to find apparent pediodicities in Fortaleza rainfall series. Studying the annual precipitation series from 1849 to 1948 he found periodicities of approximately 13 and 24 years. He attempted to explain such periodicities in terms of atmospheric response to solar activity (sun spots) which exhibit a quasi-periodic behaviour. Based on this behaviour he made a forecast of an extreme drought for the mid-50's. Markhan (1974) analyzed Fortaleza rainfall series for a period of 121 years and found periodicities of approximately 13 and 26 years statistically significant at the 1% level. Jones and Kearns (1976) have shown that the series are not significantly different from white noise at the 5% level. Girardi and Teixeira (1978) forecast a period of deficient rain for Nordeste for the period 1979-1985 based on the apparent periodicities of 13 and 26 years. Hastenrath and Heller (1977) suggested the monitoring of the quasi-permanent subtropical highs of the North and South Atlantic, of the rainfall preceding the rainy season, and of the position of cloudiness and precipitation bands over the Tropical Atlantic adjacent to Nordeste for predicting the quality of the rainy season. Moura and Shukla (1981) showed high correlations between sea surface temperature anomalies over the Tropical Atlantic and preci-

pitation over northern Nordeste. Nobre (1984) has shown that anomalies of precipitation over Nordeste are linked to anomalies of the global tropospheric circulation which can be seem several months preceding the rainy season. Hastenrath et al. (1984) developed a multiple regression statistical formula to predict Nordeste's seasonal precipitation as a function of several meteorological parameters for the region and adjacent ocean.

Statistical Tests and the Sinusoidal Forecasting Model

Fortaleza, Ceará, annual rainfall series (hydrological year: November through October), comprising 130 years of data from 1849 to 1978, was submitted to various statistical tests. The autocorrelation test, Kolmogorov-Smirnov test for the periodogram, Fisher's test and the smoothed spectrum (with the Parzen-window) showed that the series cannot be considered random (more details about the statistical tests can be found in N). The Fisher's test showed the existence of two statistically significant periodicities of approximately 13 and 26 years at the 5% significance level. When the smoothed spectrum is considered (Figure 1) the periodicity of 13 years attained an a posteriori confidence level of 87% (a priori level of 99%).

Assuming that the periodicities of 13 and 26 years are significant a sinusoidal model of the type $X_t = \mu + A_1\cos\omega_1 t + B_1\sin\omega_1 t + A_2\cos\omega_2 t + B_2\sin\omega_2 t + \varepsilon_t$ (1) was fitted to the data, where $\omega_1 = 2\pi/13$ and $\omega_2 = 2\pi/26$. The least square estimates of the coefficients were: $\hat{\mu}=\bar{X}=1431$mm, $\bar{A}_1=-86.3$mm, $\bar{B}_1=-243.0$mm, $\bar{A}_2=-55.4$mm and $\bar{B}_2=-204.5$mm. The original series' variance is $(488)^2$. The residual variance for the sinusoidal model is $(425)^2$ which shows that the model explain only 24% of the original series variance. Figure 2 summarizes the results of fitting the sinusoidal model to the series. At the 80% confidence level this forecasting model only indicates that for the years under the horizontal bar, annual precipitation is likely to be below (or above) average. However, it will be of little use for forecasting extreme events. If one tries to predict rainfall departures of one standard deviation (1431mm ±425mm) the confidence level would decrease to 50% for the years where the sinusoidal curve is at its minima or maxima. For the remaining years the confidence level would be even smaller. Therefore, the model is rather limited to predict large departures from the average. It would be of limited usefulness in forecasting severe Nordeste droughts since for those droughts the historical record shows that Fortaleza rainfall was below 1000mm and for this value the confidence level of the model would be 50% or smaller. Girardi and Teixeira(1978) projected the cycles of 13 and 26 years into the future and predicted a period of 7 years (1979 through 1985) with below average precipitation in Nordeste and a tendency towards the occurrence of droughts. Based on the predictions given by equation 1, the most one could have said is that at the 80% confidence level the precipitation would fall below the average in 1981, 1982 and 1983. According to Brito (1984) for northern Nordeste 1979 and 1980 were very dry years, 1981 was slightly above the average, 1982 was slightly below the average and 1983 was a extremely dry year. The rainy season in 1984 was normal or above normal for almost all Nordeste.

Use of periodicities to forecast droughts in Nordeste presents other limitations as well. Due to its inherently periodic nature this model would indicate drought periods once every 26 years. From Figure 2 one readily sees that the great drought of 1900, 1915 and 1942 would not have been predicted by the model. That is to say that it would have missed 4 out of the 5 severe droughts from 1900 to 1978. In addition, it is worth mentioning that all such statistical forecasting models are based on the continued existence of the periodicities into the future. Because the physical mechanisms responsible for such periodicities are not known, there is no assurance that any of these "hidden" periodicities will be present in the future.

Conclusion

It is conclude that the uncertanties involved in drought forecasting for northeastern Brazil based on observed periodicities in Fortaleza rainfall are very high. Therefore it does not seem justifiable to make drought forecasts based on them.

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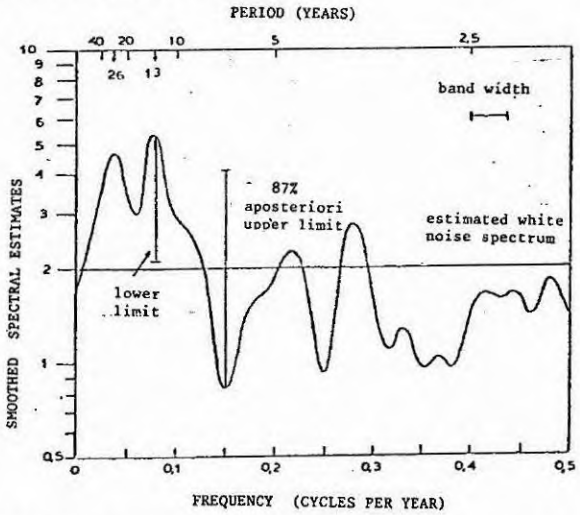

Fig. 1 - Smoothed spectral estimates for Fortaleza annual rainfall time series (1849-1978). The band width of 0.037 was chosen so as to discriminate the frequencies of 1/13 and 1/26.

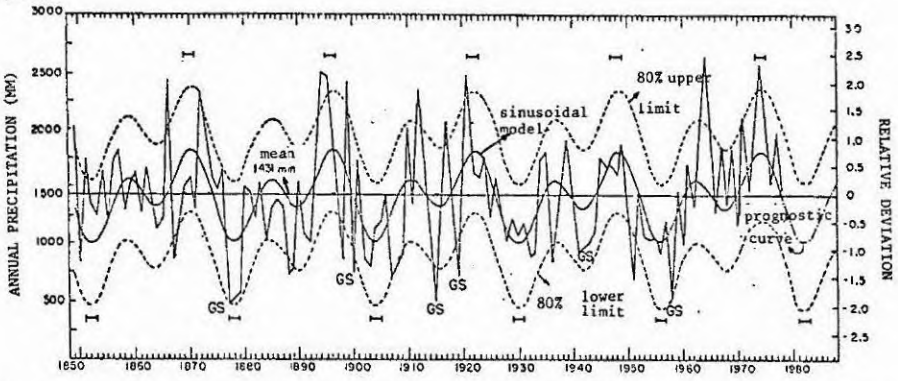

Fig. 2 - Fortaleza annual rainfall from 1849 to 1978 (yearly totals for the hydrological year: November through October). Full continuous line: sinusoidal model with periodicities of 13 and 26 years. Dashed lines: confidence intervals at the 80% level. Dash-dot line: model's prognostic curve for the period 1979-1988. Horizontal bars on the top (bottom) indicate years for which the model would predict precipitation above (bellow) the average with at least 80% of confidence. Years of extreme droughts ("Grande Seca") are indicated by GS. Relative deviation on the right-hand axis is given by annual precipitation minus the series mean divided by the standard deviation.