Study on the Statistical and Dynamic Characteristics of Rainfall in the Philippines

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1. Introduction

In 1982 and 1983, the Philippines experienced two devastating droughts which caused severe crop damages, hydroelectric power failure, depleted irrigation water supply, alteration of normal agricultural and other human activities[1]. The fact that drought is a result of some abnormal rainfall behavior has motivated this study to understand the basic dynamic features of the rainfall sequence in the Philippines. Specifically, the aim of this study is to identify the abnormal patterns in a rainfall sequence in the country and to depict their spatial and temporal characteristics.

A mathematical procedure that utilizes Kalman filtering and generalized likelihood ratio techniques is presented in this paper to identify the abnormal patterns in a rainfall sequence. Four monthly mean rainfall series typical of the four types of climate in the Philippines are analyzed.

2. Detection of Abnormal Rainfall Patterns

The system model is conceived as having two independent components: periodic and stochastic. The general periodic-stochastic model may be written in the form: $y(k)= M_y + \sum_{i=1}^{q}(A_i \sin 2\pi f_i k + B_i \cos 2\pi f_i k) + w(k)$ ...(1), where $y(k)$ is the periodic-stochastic hydrologic variable at a time instant k; M_y is the mean of the sequence; the Fourier series with necessary finite harmonics is the periodic component; q is the number of significant frequency components; f_i is the frequency component; A_i and B_i are the Fourier coefficients; and $w(k)$ is the stochastic component which is assumed to be white Gaussian noise with zero mean and variance $W(k)$. The maximum entropy method (MEM) is used to find the necessary finite harmonics to account for the periodicity in equation (1). Transformations of the rainfall data are performed to result in a periodic-stochastic model with the stochastic component being uncorrelated and normally distributed. The system parameters M_y, A_i and B_i are identified using Kalman filter.

To detect the presence of an abnormal pattern in a given rainfall time series, the transformed generalized likelihood ratio, $\phi_*(k,\ell)$, defined as the abnormality detection index, is calculated recursively at each instant k from a finite series (of length ℓ) of innovations which resulted from the Kalman filter calculations. Details of the recursive equations are given in another paper[2].

3. Characteristics of the Abnormal Rainfall Patterns

The stations selected for analysis are Vigan, Legaspi, Zamboanga and Davao. Only the results for Legaspi station are given in this paper. Figure 1 shows the time series plot of the $\phi_*(k,\ell)$-function for this station. The peaks above the threshold value, η, identify the time position and magnitude of the abnormalities. The time of occurrence of peak ϕ_* indicates the time of the onset of the rain period with identified abnormal patterns. The duration of this rain period is 15 months which is the length of the finite series of innovations. The magnitude of peak ϕ_* is the quantitative description of the pattern's degree of abnormality.

Simple visual inspection of the pattern of the observed monthly mean rainfall depths within the identified abnormal rain period relative to the pattern of the average monthly mean values shows that there are three types of abnormal patterns in rainfall sequences in the Philippines: Type A which is characterized by the dominance of rainfall depths of below the mean values; Type B which is typified by the dominance of rainfall depths of above the mean values; and Type C which is usually characterized by the short-lived high fluctuations of rainfall depths about the mean values.

Figure 2 shows the use of the decile range method[3] which is adopted to describe the rainfalls in the detected abnormal rain periods. This method is applied to the four normally distributed residual series. The decile range in which a particular residual falls gives a useful indication of the rainfall's departure from the "normal". Thus decile range one suggests abnormally dry and decile range ten abnormally wet conditions.

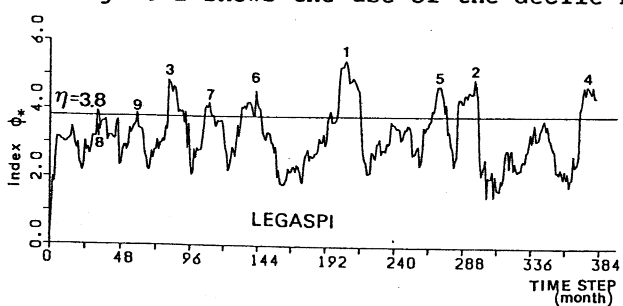

Fig. 1 Time series plot of the $\phi_*(k,\ell)$-function at Legaspi.

Table 1 illustrates the distribution in the ten decile ranges of the monthly residual values in the periods with

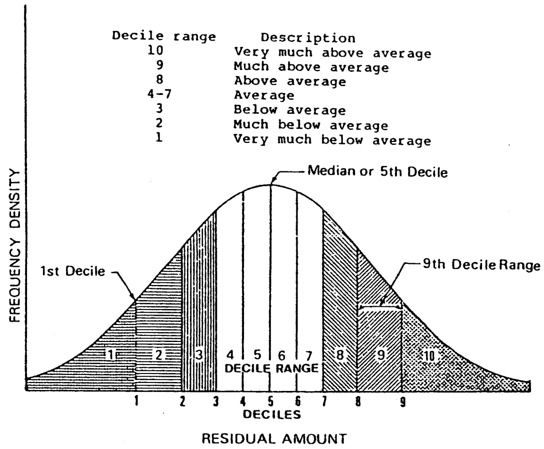

Fig. 2 Decile range method . (After Gibbs 1975)

Table 1 Characteristics Of the abnormal patterns at Legaspi.

Station name	Peak ϕ_*			Decile Range										Type
	Order	Date of Occur-rence	Magnitude	1	2	3	4	5	6	7	8	9	10	
Legaspi	1	April 1968	5.43	6	4	1	3	1			1			A
	2	Nov. 1975	4.90	1	1	2	1	3	2		1	1	4	B
	3	Oct. 1957	4.84	3	1		1	2	2	2	2	2	1	C
	4	June 1982	4.73	4	2		2	2	1	1	1	2	1	A
	5	Oct. 1973	4.70	2	2	2		2	1			3	4	B
	6	Dec. 1962	4.55	5	2		2	2	1	1	1		2	A
	7	March 1960	4.20	4	1	1	1	2	1	1	3	1	1	A
	8	Sept. 1953	3.94			4	2	1	1	1	3	1	3	B
	9	Dec. 1955	3.88	i	2	2	2	1		2	1	3	2	C

identified abnormal patterns. High frequency of occurrence of residual values in range one characterizes Type A. By contrast, the figures for Type B exhibit a dominance of residuals in ranges nine and ten. Concentrations of the residuals in Type C appear in three ways: 1) more or less evenly distributed with the presence of residuals in ranges one and ten; 2) high in range one; and 3) high in range ten. The occurrences of abnormally high (or low) rainfall depths in Type C are characterized by strong recovery of rain of average or below (or above) average depths.

Figure 3 shows that the years with abnormally low and high rainfall amounts took place in the detected rain periods with Type A and Type B abnormal patterns respectively. Those years falling in Type C appear normal because of the nature of Type C abnormal pattern. Also, the occurrence of Type C abnormal patterns can not be discerned from the annual time series.

Figure 4 illustrates that abnormal patterns of similar or different types tend to occur in the same period at certain portions of the country or at certain types of climate. Some of them appear to continue for a few years.

The two significant drought events in 1982 and 1983 are successfully identified as the occurrence of Type A and Type C abnormal patterns in Legaspi and Zamboanga and Davao respectively. These two destructive droughts are shown to be the results of major rainfall pattern abnormalities.

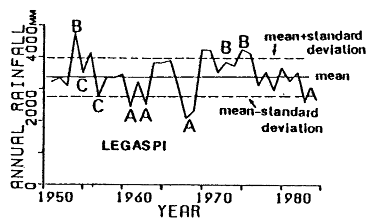

Fig. 3 Annual rainfall sequence at Legaspi.

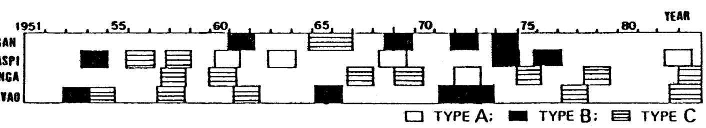

Fig. 4 Distribution of the abnormal patterns.

4. Conclusion

The presence of abnormal patterns in the four rainfall time series representative of the four types of climate in the Philippines has been successfully identified by the presented procedure which utilizes the Kalman filtering and generalized likelihood ratio techniques. The abnormality detection index has allowed an automatic and accurate estimations of the time of occurrence and magnitude of abnormality. This has made it possible to have a proper characterization of the abnormal patterns and hence an understanding of the basic dynamic behavior of the rainfall sequence in the Philippines.

References

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