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RAINFALL CHARACTERISTICS IN DIFFERENT PARTS OF NORTHEAST BRAZIL

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To reduce the effect of randomness as well as of local characteristics, rainfall data for subregions of NE Brazil were combined. The resulting series (1913-1977) was smoother and showed some general characteristics like excess rainfall during 1917, 1921, 1924, 1964, 1974 and droughts during 1915, 1919, 1932, 1953, 1958. However, these and other events seemed to occur irregularly. A spectral analysis showed significant periodicities near T = 2-3, 3-4, 5-6, 13, 26 and 50 years. But their contribution to total variance was only about 55%, leaving about 45% as random or irregular. In the future, deficit rainfall during the next few years is indicated, but the reliability of this prediction is difficult to judge.

CARACTERÍSTICAS DE PRECIPITAÇÃO PLUVIOMÉTRICA EM DIFERENTES PARTES DO NORDESTE BRASILEIRO *Para reduzir o efeito de aleatoriedade e também das características locais, dados de precipitação de chuva em sub-regiões do nordeste brasileiro foram combinados. As séries resultantes (1913-1977) foram mais suaves e mostraram algumas características gerais, tais como excesso de chuva durante 1917, 1921, 1924, 1964 e 1974 e secas durante 1915, 1919, 1932, 1953 e 1958. Entretanto, estes e outros eventos pareceram ocorrer irregularmente. Uma análise espectral mostrou periodicidades significantes em torno de T = 2-3, 3-4, 5-6, 13, 16 e 50 anos. Entretanto, suas contribuições para a variância total foi de cerca de 55%, deixando cerca de 45% de contribuição aleatória ou irregular. No futuro, carência de chuva durante os próximos anos é indicada, mas a confiabilidade desta predição é difícil de julgar.*

INTRODUCTION

Northeast Brazil has a highly variable rainfall regime. Coastal areas can have annual rainfalls exceeding 2000 mm, while in the interior, rainfalls could be as low as 400 mm. Also, different parts may have different rainfall patterns. The longest rainfall series available in NE Brazil is for Fortaleza (4°S, 39°W), Ceará, from 1849 onwards. Several publications give details of the analysis of the Fortaleza series, e.g. Markham (1974), Girardi and Teixeira (1978), Kane (1985), Morettin et al. (1985), Harvey and Souza (1987). However, Fortaleza represents only a restricted region, within a range of about 600 km. Kane and Trivedi (1988) prepared a master series (1912-1978) combining the data of 93 stations with characteristics similar to Fortaleza and reported prominent periodicities at T = 5.6, 12.3 and 47 years and a prediction of possible droughts during 1992-1994 and 2002-2006. In a recent communication, Kane and de Souza (1988) prepared average series for eight groups in NE Brazil and showed that periodicites T = 12-13 years and T = 24-26 years were prominent in several groups.

Even though the rainfall regimes are diverse in different parts of NE Brazil, one often hears of widespread droughts affecting the whole NE of Brazil. In this note, we combine data for larger portions of NE Brazil in the hope that individual characteristics will be minimized (including the random component) and characteristics of rainfall in NE Brazil as a whole will be revealed.

DATA

Data were available from "Dados Pluviométricos Mensais", Vol.I, II, III, compiled and distributed by SUDENE (Superintendência do Desenvolvimento do Nordeste) for more than 1000 locations. From these, 224 stations could be selected with reasonably complete data for 1913-1977. Firstly, data for each location were expressed as **percentage deviations** from the location mean rainfall. Then, locations **near each other** (geographically) and having roughly **similar average annual rainfalls** were grouped together as shown by the dashed boundaries in Fig. 1 (reproduced from Kane and de Souza, 1988), yielding 2 groups in Piauí (PI) (A, B), 10 groups in Ceará (CE) (A, B, C, D, E, F, G, H, I, J), 5 groups in Rio Grande do Norte (RN) (A, B, C, D, E), 4 groups each in Paraíba (PB) (A, B, C, D), Pernambuco (PE) (A, B, C, D), Alagoas (AL) (A, B, C, D) and Sergipe (SE) (A, B, C, D), 6 groups in Bahia (BA) (A, B, C, D, E, F) and 1 group in Minas Gerais (MG) (A). As shown in Kane and de Souza (1988), the correlation coefficients between these groups and Fortaleza varied widely from + 0.93 for CE (C) to 0.00 for MG (A). Keeping in mind these correlation coefficients, further grouping was done as follows:

Group 1 = PI (A) alone

Group 2 = PI (B) alone

Group 3 = CE (A, B, C, D, E, F, G, H)
RN (A, B, C)
PB (A, B)
PE (B)

Group 4 = CE (I, J)
PE (A)

Group 5 = RN (D,E)
PB (C, D)
PE (C, D)

Group 6 = AL (A, B, C, D)
SE (A, B, C, D)

Group 7 = BA (A, B, C, D)

Group 8 = BA (E, F)
MG (A)

Fig. 2 shows a plot of these eight series (rows 1-8) for 1913-1977. Black portions indicate positive percentage deviations, while hatched portions indicate negative percentage deviations. Some features seem prominent. For example, during 1913-1924, there were strong 3-4 year waves, common to Groups 1, 2, 3, 4 (Piauí and Ceará). In general, many features were common to these four groups as also to group 5. Hence, a further grouping was done to yield four series as follows:

Series 1: Groups 1, 2, 3, 4, 5 (Piauí, Ceará, Rio Grande do Norte, Paraíba and Pernambuco)

Series 2: Series 1 + Alagoas and Sergipe

Series 3: Series 2 + North Bahia

Series 4: Series 3 + South Bahia and North Minas Gerais

In Fig. 2, the ninth row is for Fortaleza alone.

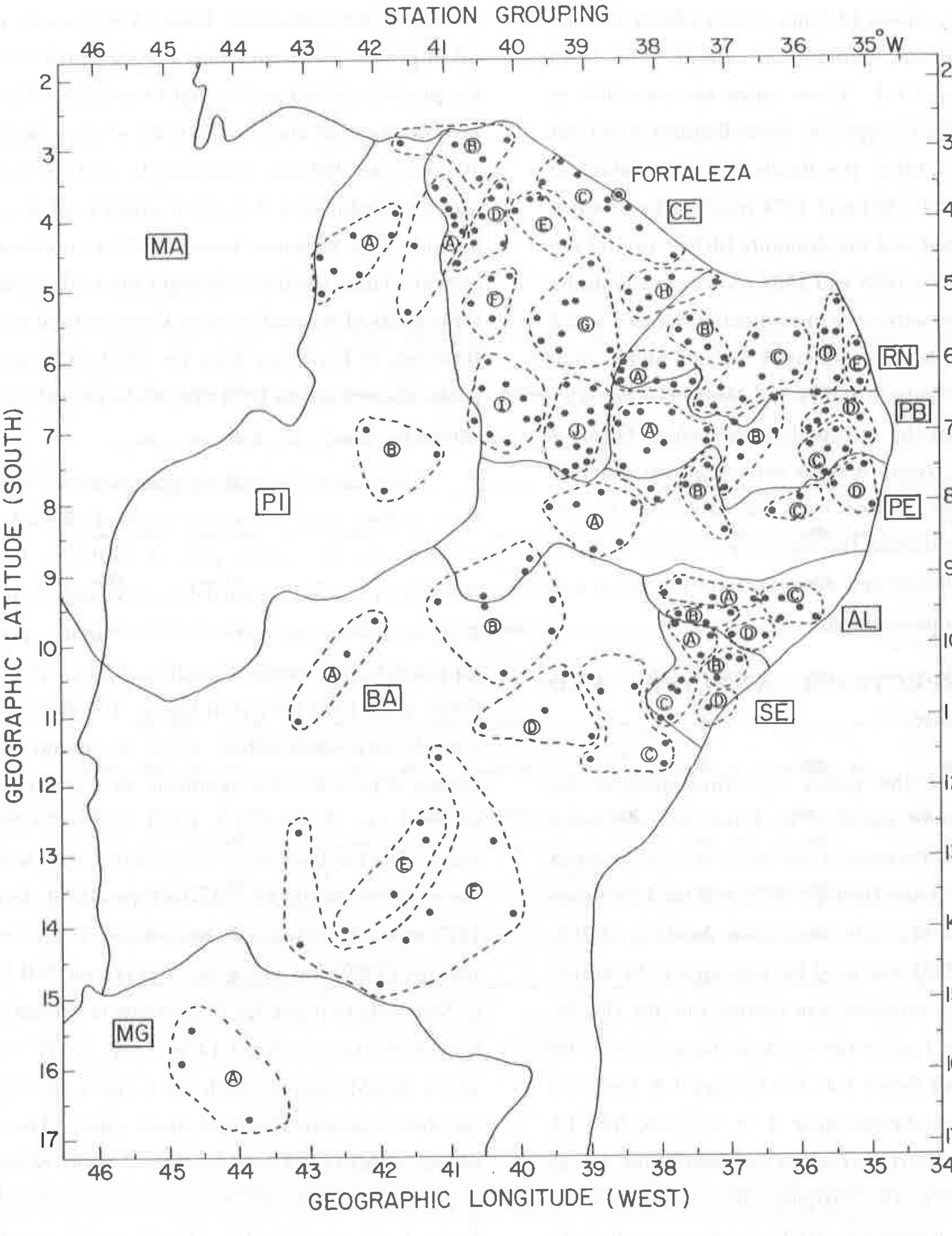

Figure 1. Grouping of 224 stations of NE Brazil into PI (A-B), CE (A-J), RN (A-E), PB (A-D), PE (A-D), AL (A-D), SE (A-D), BA (A-F), MG (A-B).

Agrupamento das 224 estações do nordeste do Brasil em PI (A-B), CE (A-J), RN (A-E), PB (A-D), PE (A-D), AL (A-D), SE (A-D), BA (A-F), MG (A-B).

The tenth row shows El Niño events (Black-Strong; Hatched-Moderate; Quinn et al. 1987). The 11-14 rows show series 1-4. These series are smoother as compared to the Groups 1-8. Some features stand out prominently, notably the floods (excess rainfall) of 1917, 1921, 1924, 1964 and 1974 (marked by upward-pointing arrows) and the droughts (deficit rainfall) of 1915, 1919, 1932, 1953 and 1958 (downward-pointing arrows). These were very prominent in Series 1 and 2 and somewhat less prominent in Series 3 and 4, indicating lesser effects in Bahia and Minas Gerais. This is obvious from the upper plots also where Group 7 and specially Group 8 show some features different from the other Groups 1-6. Fig. 3 shows the frequency distribution of the various percentages. Years of extremes (floods and droughts) are indicated and many seem to be common.

POWER SPECTRUM ANALYSIS AND PREDICTION

Results of the power spectrum analysis for Groups 1-8 were reported in Kane and de Souza (1988), where Maximum Entropy Spectrum Analysis (MESA, Ulrych and Bishop, 1975) was used for locating peaks and Multiple Regression Analysis (MRA, Bevington, 1969) was used for estimating the amplitudes. Similar analysis was carried out for the Series 1-4. Table 1 gives the spectral characteristics for Groups 1-8 and Series 1-4. For Groups 1-8, there are prominent periodicities near T = 2.1, 3.5, 5.6, 13, 26, 50 years. Each periodicity of amplitude r contributes ($r^2/2$) to the Variance. Hence, the Percentage Variance Explained (PVE) by every periodicity is ($50\ r^2/\sigma^2$), where σ^2 = Variance of the series. The last columns of Table 1 give the percentage variance explained (PVE) by peaks at 2, 3 and 4 sigma levels. As can be seen, the variance explained by peaks significant at a 2 sigma (a priori) level is only about 50%, thus leaving about 50% as a random (irregular) component. Hence, the prediction potential for these groups will be small. For the rainfall series of Fortaleza, for 1849-1976, Kane (1987) made a critical appraisal and found that the standard errors for the predicted flood and drought rainfalls at Fortaleza (average rainfall about 1430 mm) were as large as ± 400 mm and 300 mm, respectively, and the periodicities significant at a 2 sigma a priori level accounted for only 53% variance, leaving 47% as random component. Thus, predicted drought intervals could have some years of normal or even above-normal rainfalls. However, if Fortaleza data for 1914-1978 are used, peaks above 2 sigma level explain larger (about 75%) variance.

When data for various groups were combined, the resulting four series had spectral characteristics as shown in the middle part of Table 1. The percentage variance explained by peaks significant at a 2 sigma level is still about 55%. Hence, potential for prediction is small. Fig. 4(a) shows a plot of the Series 1 for 1913-1977 (full lines). The crosses represent the **expected** values, using the amplitudes and phases of periodicities significant at a 2 sigma a priori level, viz. T = 2.4, 3.4, 4.4, 5.7, 12.7, 20.2 and 50 years. The full lines and crosses match very well. But the real test should be with **independent** data. For 1977 onwards, we do not have data. However, Hastenrath (1990) has given the average rainfall (March to September) index for 27 stations in a limited portion of Northeast Brazil (3°S - 8°S, 35°W - 41°W) which should compare with our Series 1. In Fig. 4(a), the dots represent the Hastenrath series. The resemblance with the full lines (observed values of Series 1) is good. For 1978-1987, for which observed values of Series 1 are not available, one could use the Hastenrath values as observed values, to compare with the expected values (crosses). For 1978-1987, the crosses and full dots seem to match well. Fig. 5(a) shows a plot of the observed versus expected values. The ordinate represents the expected values (crosses of Fig. 4(a)). The abscissa should have been the observed values of Series 1 (full lines of Fig. 4(a)). But since we were interested in checking prediction also,

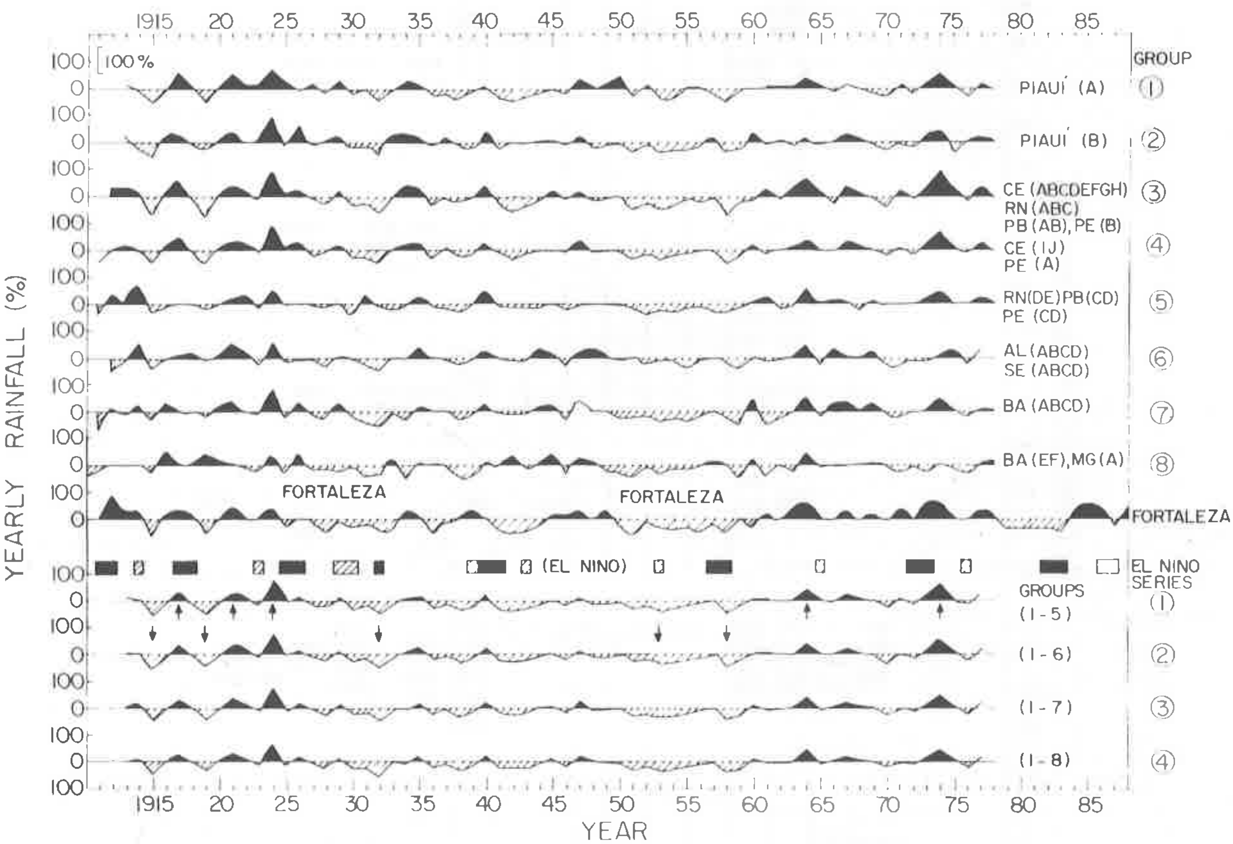

Figure 2. The annual percentage rainfall series for Groups 1-8, Fortaleza and series 1-4. Black portions show positive deviations and hatched portions show negative deviations. Some prominent events are marked by arrows (upward, floods; downward, droughts). The ninth plot shows El Niño events (full, strong; hatched, moderate).

As séries de percentagem anual de precipitação pluviométrica para os Grupos 1-8, Fortaleza e séries 1-4. Porções pretas mostram desvios positivos e porções hachuradas mostram desvios negativos. Alguns eventos proeminentes estão marcadas por setas (para cima, inundações; para baixo, secas). O nono gráfico mostra eventos do El Niño (cheio, forte; hachurado, moderado).

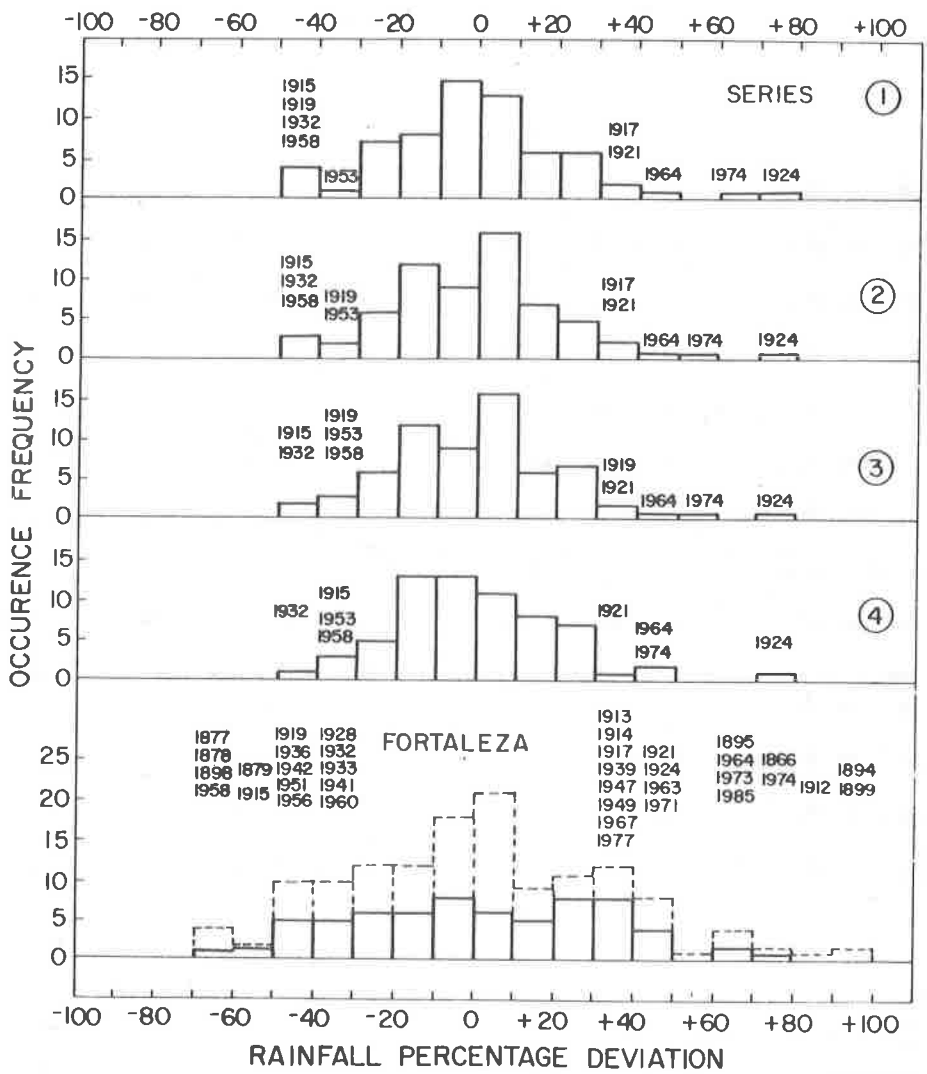

Figure 3. Frequency distribution of the rainfall percentage deviations for 1913-1977 for series 1-4, as also for Fortaleza (bottom plot), where the dashed histogram refers to 1849-1991. Some years of extreme rainfalls are indicated and most of these are common to all series.

Distribuição de freqüência dos desvios da percentagem de precipitação pluviométrica para 1913-1977 para as séries 1-4, como também para Fortaleza (gráfico de baixo), onde o histograma hachuriado refere-se a 1849-1991. Alguns anos de extrema precipitação pluviométrica são indicados e a maior parte delas é comum a todas as séries.

Table 1. Spectral characteristics of the rainfall series for various subregions and regions of NE Brazil.

Características espectrais das séries de precipitação pluviométrica em várias subregiões e regiões do nordeste brasileiro.

Group, Series	Constituted of	No. of Stations	Periodicities T(years) significant at a 2 sigma *a priori* level. * and ** represent significance at 3 and 4 sigma levels respectively													Percentage Variance Explained (PVE)		
			2.0-2.4	2.5-2.9	3.0-3.4	3.5-3.9	4.0-4.9	5.0-5.9	6.0-6.9	7.0-8.9	9.0-10.9	11.0-14.9	15.0-19.9	20-30	>30	2σ	3σ	4σ
(1913-1978) Group 1	PI(A)	7	2.4	2.6	3.2	3.6*	4.3	5.6*		8.0		13.0**		23.2*	41**	71	49	25
Group 2	PI(B)	1			3.4*			5.7			10.2		19.5		51*	40	23	0
Group 3	CE(ABCDEFGH) RN(ABC) PB(AB), PE(B)	97			3.4		4.3	5.6*				12.3**			47*	48	33	14
Group 4	CE(IJ), PE(A)	28	2.4		3.4*		4.0				10.9	12.5*		22.9*		50	32	0
Group 5	RN(DE), PB(CD) PE(CD)	24	2.4	2.7		3.6				8.5		12.7			45*	44	17	0
Group 6	AL(ABCD) SE(ABCD)	29		2.6*	3.3*	3.9	4.8					14.1		25.4**		49	33	13
Group 7	BA(ABCD)	21	2.1*	2.5	3.4	3.9					9.9			24.8**		55	25	16
Group 8	BA(EF), MG(A)	15	2.3*			3.5	4.1			7.5		11.1		24.3**		53	34	14
FORTALEZA	FORTALEZA 1849-1978	1	2.1*		3.4	3.6*	4.8*	5.7		8.8	10.2*	12.9**	17.0	25.4**	59*	61	49	24
	1849-1913		2.4*		3.4		4.9				9.8*	13.0**	17.6	21.4**		74	46	29
	1914-1978		2.1*	2.5		3.6*	4.3, 4.8	5.6		7.3	9.1	13.2**		26.0**	60*	75	48	40
	1914-1991		2.1			3.6**	4.3				9.8	13.3*		24.3*	64*	55	42	12
1913-1978 Series 1	Groups(1-5)	159	2.4		3.4*		4.4	5.7				12.7*		20.2	50*	50	31	0
Series 2	Groups(1-6)	188	2.4		3.4*	3.9		5.8				13.0*		21.1	51*	52	33	0
Series 3	Groups(1-7)	209	2.4		3.4*	3.9						13.0		21.6*	51*	55	37	0
Series 4	Groups(1-8)	224	2.4	2.6	3.4*	3.9					10.4	13.2		21.6*	52*	58	31	0
Hastenrath (1921-1987)	(3°-8°S, 35°-41°W)	27	2.4		3.4			5.6			9.6	12.5*		22.4	59	46	10	0
(1914-1975) Smoothed Series 1	Groups(1-5)	159						5.8*	6.5	8.8		12.6**		21.4**	53**	75	70	67
Series 2	Groups(1-6)	188						5.8*	6.5*	8.9		12.7**		21.9**	53**	76	74	66
Series 3	Groups(1-7)	209					4.7	5.8	6.8	8.3*	10.1**	12.6**		22.1**	54**	83	77	74
Series 4	Groups(1-8)	224					4.8	5.8	6.5*	8.1*	10.1**	12.3**		22.4**	54**	83	80	74
Hastenrath (1922-1985)	(3°-8°S, 35°-41°W)	27						5.8			9.7*	11.9**		22.1**	65**	60	55	45
FORTALEZA	Fortaleza (1915-1989)	1							6.5	8.2*	9.9**	12.3**		24.0**	70**	77	75	67
	(1915-1979)							5.6		8.3**		13.3**		26.0**	65**	75	73	73

for abscissa, we chose the Hastenrath index. In the plots, there is a good correlation (+ 0.88). The big dots represent the recent years 1978-1987. These 10 points alone are also well-correlated (+ 0.89). Since the prediction for 1978-1987 seems to be reasonably correct, we venture to predict for 1987 onwards. For 1990-1995, **below-normal rainfall is expected in NE Brazil as a whole**, and probably also for 1995-2000.

What does the rainfall at Fortaleza alone indicate? Fig. 4(b) shows the plots of observed values (full lines) and expected values (crosses) using T = 2.1, 2.5, 3.6, 4.3, 4.8, 5.6, 7.3, 9.1, 13.2, 16 and 60 years, all significant at a level exceeding 2 sigma a priori. Whereas the matching is good up to 1978, the matching for 1979-1991 is poor. Thus, for some reason, Fortaleza series is not amenable to good predictions. We suspect that a variable QBO (sometimes strong, sometimes weak) spoils the prediction. Fig. 5(b) shows a plot of expected versus observed values. Whereas the correlation is high (+ 0.93), the values during 1979-1991 are not all in the main stream. In particular, the observed values for 1980, 1985, 1986 were too high and those for 1990, 1991 were too low.

Since the QBO is a disturbing and highly variable factor and is probably responsible for the **extremes** of rainfall which are irregular, it would be interesting to check whether elimination of the QBO brings more regularity and predictability. For this, running averages over 3 consecutive yearly values and then, further over 2 consecutive values, were evaluated. Effectively, this amounts to applying a 4 point filter with weight 1, 2, 2, 1. Fig. 6(a) (full lines) shows the results for the **smoothed** Series 1. The crosses represent the values expected by using T = 5.8, 6.5, 8.8, 12.6, 21.4 and 53 years, all significant at a 2 sigma a priori level. The matching is reasonably good. For 1975 onwards, we do not have data. However, the Hastenrath index is available for 1975-1985 also. The dots (Fig. 6a) represent the **smoothed** Hastenrath index. For 1976-1985, the dots and crosses run fairly parallel. For the future, deficit rainfall during 1990-2000 is indicated.

Fig. 6(b) shows similar plots (of smoothed values) for Fortaleza alone. The full lines (observed values) and crosses (expected values using T = 5.6, 8.3, 13.3, 26.0 and 65 years) match well up to 1979. However, for 1980-1989, the observed values (big dots) do not match with the expected values (crosses). Hence, prediction of a deficit rainfall for 1990-1995 may not be very reliable. If data up to 1989 are used for analysis, the matching of observed values (full lines) and the expected values (open circles) using T = 6.5, 8.2, 9.9, 12.3, 24 and 70 years is very good. For the future, deficit rainfall during 1991-1993, excess rainfall during 1994-1996 and a deficit rainfall for several years after 1997 is indicated. The reliability of these predictions is anybody's guess!

The Hastenrath index matches well with our Series 1. However, the index is available for 1921 onwards only. What does an analysis of the Hastenrath index itself show? Fig. 6(c) shows the results. Full lines represent the original index (March-September rainfall), while the dashed lines represent the smoothed index (average over 3 and 2 successive values). The crosses represent expected values, using T = 2.4, 3.4, 5.6, 9.6, 12.5, 22.4 and 59 years for the original index series and T = 5.8, 9.7, 11.9, 22.1 and 65 years for the smoothed series. For the original series, small rainfall deficits during 1992-1994 and near 2000 and 2004 are indicated. The smoothed series indicates a large deficit during 1998-2004. How reliable these predictions turn out to be, only time will show. The total PVE for the periodicities used exceeds 70%.

RELATIONSHIP WITH EL NIÑO

There seems to be a popular belief that El Niño years are coincident with droughts in NE Brazil and floods in South Brazil. Even serious works like those of Hastenrath et al. (1987) and Hastenrath (1990) are

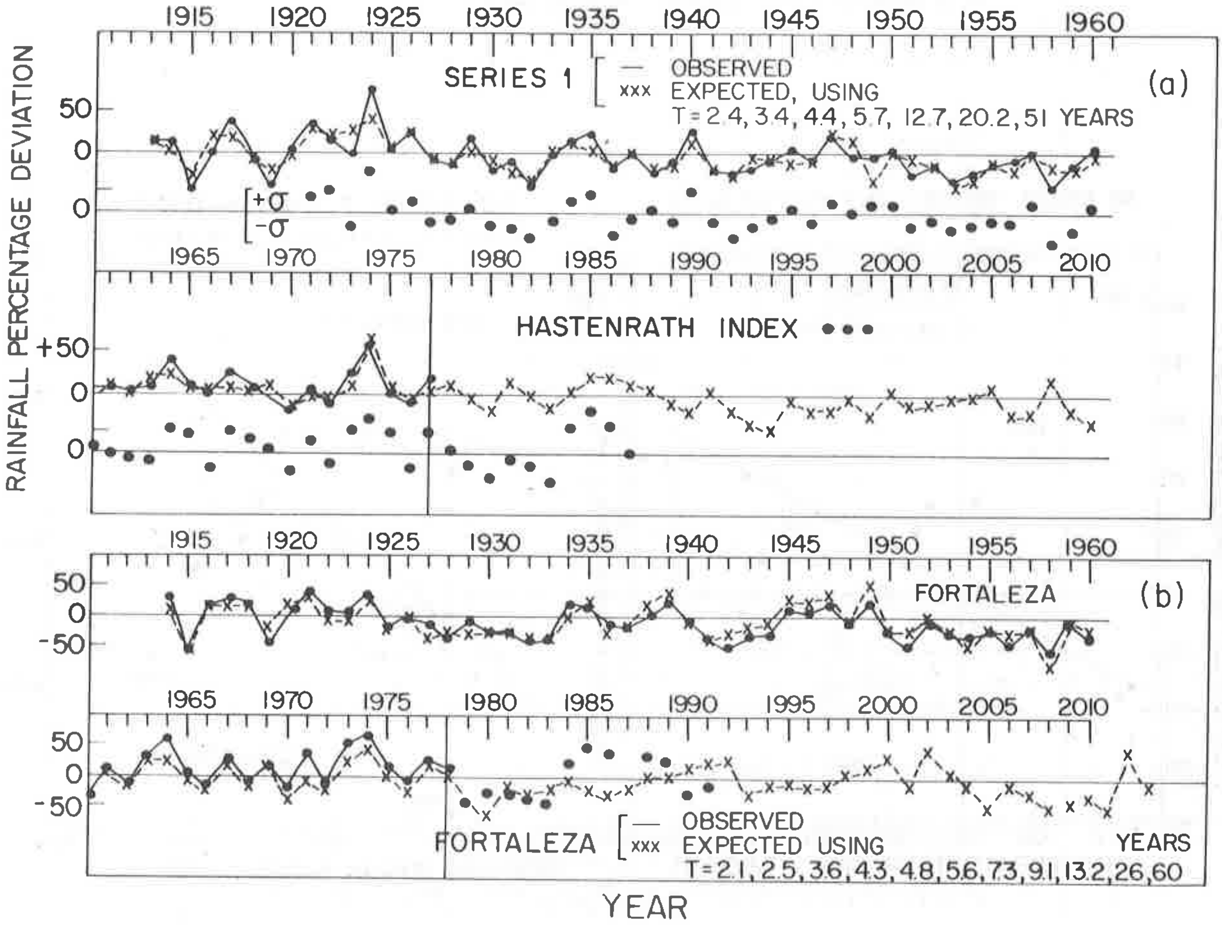

Figure 4. (a) Series 1 rainfall observed values (full lines) and expected values (crosses) using T = 2.4, 3.4, 4.4, 5.7, 12.7, 20.2 and 51 years. The dots represent Hastenrath March-Sept. rainfall index for NE Brazil (27 stations). (b): Fortaleza rainfall observed values (full lines) and expected values (crosses) using T = 2.1, 2.5, 3.6, 4.3, 4.8, 5.6, 7.3, 9.1, 13.2, 26 and 60 years.

(a) Valores observados de precipitação pluviométrica da série 1 (linhas cheias) e valores previstos (cruzes) usando T = 2.4, 3.4, 4.4, 5.7, 12.7, 20.2 e 51 anos. Os pontos representam o índice de precipitação pluviométrica de março-setembro de Hastenrath para o nordeste do Brazil (27 estações). (b) Valores observados de precipitação pluviométrica de Fortaleza (linhas cheias) e valores previstos (cruzes) usando T = 2.1, 2.5, 3.6, 4.3, 4.8, 5.6, 7.3, 9.1, 13.2, 26 e 60 anos.

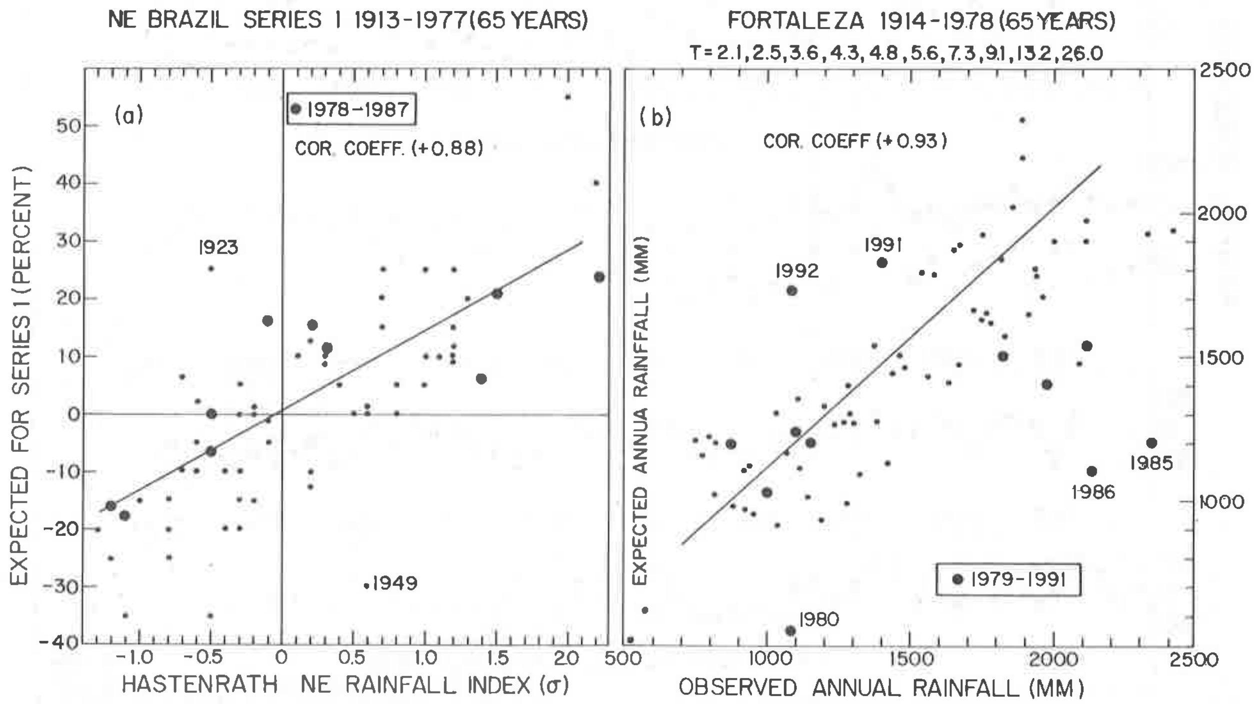

Figure 5. (a) Expected values of Series 1 rainfall versus Hastenrath March-Sept. index. (b): Fortaleza expected vs. observed values. Big dots refer to recent years.

(a) Valores previstos da precipitação pluviométrica da série 1 versus o índice de Hastenrath de março-setembro. (b) Valores previstos versus medidas de Fortaleza. Pontos grandes referem-se a anos recentes.

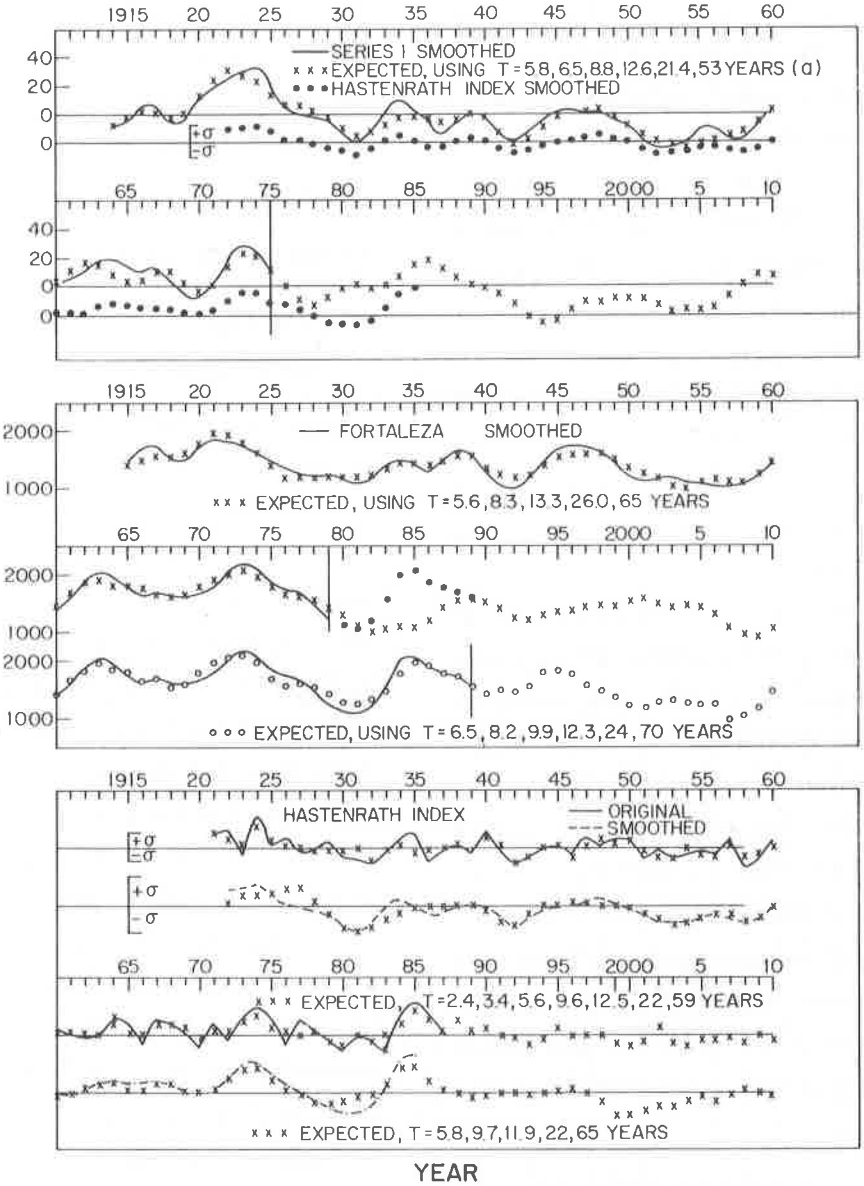

Figure 6. (a): Smoothed rainfall values for Series 1, observed (full lines) and expected (crosses) using periodicities as indicated. Dots represent Hastenrath index, smoothed. (b): Plots for smoothed values at Fortaleza. Big dots represent recent values. (c): Hastenrath index of Mar.-Sept. rainfall in NE Brazil (27 stations). Full lines, original yearly values. Dashed lines, smoothed values. Crosses, expected values using periodicities as indicated.

(a) Valores suavizados de precipitação pluviométrica para a série 1, observados (linhas cheias) e previstos (cruzes), usando periodicidades como indicado. Pontas representam o índice de Hastenrath, suavizado. (b) Gráficos para valores suavizados em Fortaleza. Grandes pontas representam valores recentes. (c) Índice de Hastenrath da precipitação pluviométrica de março-setembro no nordeste brasileiro (27 estações). Linhas cheias, valores anuais originais. Linhas tracejadas, valores suavizados. Cruzes, valores previstos, usando periodicidades como indicados.

tempted to state that NE Brazil "droughts tend to coincide with the low phase of the Southern Oscillation (SO), defined by anomalously low/high pressure at Tahiti/Darwin". The low phase of SO is certainly well-correlated with El Niños (warm water episodes in Coastal Peru). But droughts in NE Brazil are very poorly related with El Niño occurrences. We have demonstrated this in our earlier works (Kane and de Souza 1988; Kane 1992). In Fig. 2, El Niños are marked between the plots of Fortaleza and Series 1. As can be seen, El Niño years are not necessarily coincident with droughts (shaded portions) in the rainfall series. Table 2 lists the rainfall deviations from mean for Fortaleza (%), Series 1 (%) and the Hastenrath index (σ), for El Niño years El(0) and the preceding El (-1) and succeeding El (+1) years. As can be seen, in all columns, large positive and negative deviations are present, indicating that El Niños are associated with both, implying **poor** relation. The reason for this is well-known. As summarized by Hastenrath (1990), the mechanisms of rainfall in NE Brazil depend on at least three factors, viz. (1) the position of the intertropical convergence zone (ITCZ); (2) the temperature of the waters of the equatorial South Atlantic and (3) sea surface temperature (SST) contrast between a band across the tropical North Atlantic and the region south of the equator. Thus, the El Niño comes into the picture only to the extent that it affects one of these.

Fig. 7 shows the percentage rainfall deviations at Fortaleza for 102 years (1886-1987) distributed into 7 categories, viz. years when cold episodes (La Niña) occurred (first column), years of no events of any type (second column) and years when El Niños of different strengths occurred, viz. very weak, weak, moderate, strong and very strong (3rd, 4th, 5th, 6th, 7th colums). In each column, there are three subcolumns. The central one (0) refers to the year proper of the event, while the sub-columns to the left and right refer to the preceding (-1) and succeeding (+1) year. The big dots show the average values. As can be seen, large positive and negative deviations occur in all columns and the average values are near zero (±15%) for all types of events (La Niña, No events, El Niño), indicating that Fortaleza rainfall has no clearcut relationship with any of these. Similar results were obtained for the other rainfall series 1, 2, 3, 4 also.

CONCLUSIONS AND DISCUSSIONS

From the analysis presented here, the following conclusions emerge:

When rainfall data for larger and larger subregions of NE Brazil are superimposed, the resulting series show some prominent features like excess rainfall during 1917, 1921, 1924, 1964 and 1974 and droughts during 1915, 1919, 1932, 1953 and 1958. However, these events seem to occur irregularly. Periodicities of 2-3 years and 3-4 years are sometimes present and sometimes absent. Spectral analysis does reveal these and other periodicities (e.g. T = 5.6, 13, 26, 50 years) at levels better than 2 sigma (a priori). But the total variance explained is only about 55%, leaving about 45% as random (irregular) component. Part of this could be because some periodicities may be transient. But the prediction potential is affected adversely. Harvey and Souza (1987) came to a similar conclusion. In the future, deficit rainfall during the next few years is indicated. How reliable this prediction would be is difficult to assess. Academically, an unsatisfactory aspect is the lack of a physical basis for the significant periodicities T = 13 and 26 years, often encountered in these series. The T = 13 years peak is **not** the sunspot cycle. The two are significantly different.

Based on the studies of the annual cycle of circulation and climate in NE Brazil (Hastenrath and Heller 1977), Hastenrath et al. (1984) selected promising predictor candidates, viz. zonal and meridional wind components over limited areas of the equatorial Atlantic, SST in domains of the tropical North

Table 2. Rainfall deviations from mean for El Nino years.

Desvios percentuais da média de precipitação pluviométrica para anos de El Niños.

El Niño Years	Fortaleza(%)			Series 1			Hastenrath Index (σ)		
	El(-1)	El(0)	El(+1)	El(-1)	El(0)	El(+1)	El(-1)	El(0)	El(+1)
1911	+44	+4	+87						
1912	+4	+87	+34						
1914	+34	+34	+41	+18	+11	-46			
1917	+21	+38	+27	+1	+38	-1			
1918	+38	+27	-44	+38	-1	-42			
1923	+18	+10	+41	+17	-1	+78	+1.3	-0.5	-2.2
1925	+41	-16	+2	+78	+5	+22	+2.2	+0.3	+0.7
1926	-16	+2	-10	+5	+22	-7	+0.3	+0.7	-0.4
1929	-34	-8	-22	-12	+18	-25	-0.1	+0.4	-0.6
1930	-8	-22	-29	+18	-25	-9	+0.4	-0.6	-0.8
1932	-20	-38	-33	-9	-42	-2	-0.8	-1.1	-.03
1939	+11	+33	+2	-24	-13	+28	+0.2	-0.3	+1.2
1940	+33	+2	-36	-13	+28	-22	-0.3	+1.2	-0.3
1941	+2	-36	-44	+28	-22	-28	+1.2	-0.3	-1.2
1943	-44	-28	-23	-28	-19	-9	-1.2	-0.6	-0.1
1953	-3	-25	-27	-16	-35	-27	-0.2	-0.7	-0.5
1957	-43	-14	-64	-9	+2	-44	-0.4	+0.6	-1.3
1958	-14	-64	+5	+2	-44	-16	+0.6	-1.3	-0.8
1965	+70	+15	-9	+42	+8	-2	+1.2	+1.0	-0.6
1972	+47	-9	+64	+8	-12	+28	+0.8	-0.3	+1.2
1973	-9	+64	+77	-12	+28	+63	-0.3	+1.2	+2.0
1976	+25	0	+36	+3	-9	+23	+1.2	-0.5	+1.1
1982	-23	-29	-38				-0.1	-0.5	-1.2
1983	-29	-38	+39				-0.5	-1.2	+1.4
1986	+62	+50	-19				+2.3	+1.5	+0.2
1987	+50	-19	+48				+1.5	+0.2	
Average	+10	+1	+4	+7	-3	-2	+0.4	0.0	+0.1

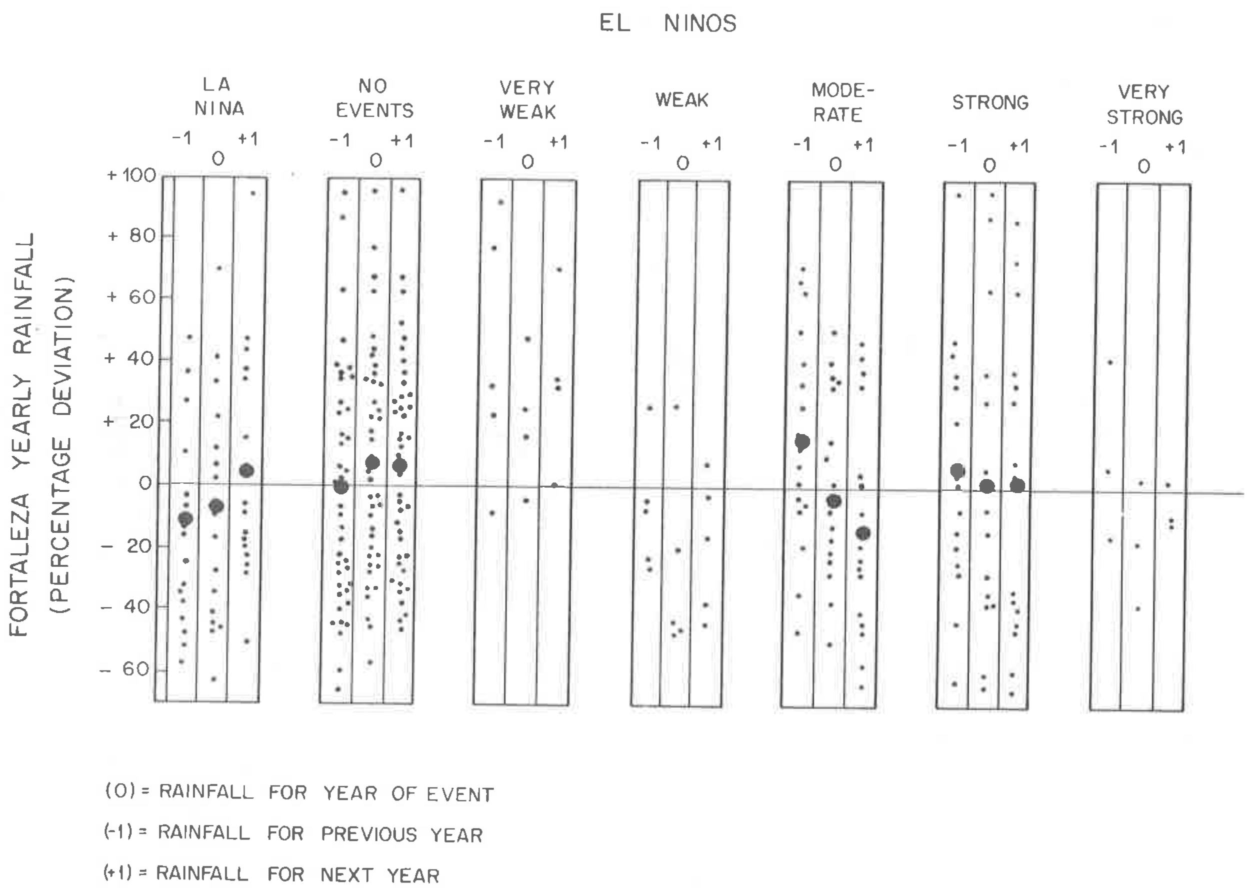

Figure 7. Percentage deviations from mean of Fortaleza annual rainfall for 102 years (1886-1987), separated in 7 categories, viz. years of La Niña (cold episodes), years of no events and years of very weak, weak, moderate, strong and very strong El Niños. Big dots represent averages. Column (0) refers to the events and columns (-1) and (+1) represent years previous and succeeding to the event concerned.

Desvios percentuais da média da precipitação pluviométrica anual de Fortaleza para 102 anos (1886-1987) separados em 7 categorias, a saber, anos da La Niña (episódios frios), anos sem eventos e anos de El Niños muito fraco, fraco, moderado, forte e muito forte. Grandes pontas representam médias. Coluna (0) refere-se aos eventos e colunas (-1) e (+1) representam anos antecedendo e sucedendo ao evento considerado.

and South Atlantic, Southern Oscillation index and, preseason rainfall in NE Brazil. They used these in a regression model to predict rainfall for 1958-1972. Recently, Hastenrath (1990) extended the study to record beyond 1972 and reported that preseason rainfall (Oct.-Jan.) was the most powerful predictor, accounting for 52% variance, while surface Atlantic meridional wind and SST in the equatorial Pacific added another 19%. Operationally, there are two major difficulties, viz. real-time monitoring of the surface wind field is difficult and the relative weights of the various factors in the regression scheme seem to change with time.

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