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14. Abstract/Notes

The year 1983 was an year of extreme drought in the Northeast Brazil (NEB). The 1983 precipitation in NEB in its rainy season has been observed to be only 40% of the normal by Rao and De Brito (1984). The Newfoundland Monthly mean surface pressure anomalies showed values ranging from +2 to +4 mb during the period October 1982 April 1983. These support the teleconnections between the NEB precipitation and the low level cyclonic activity in the region of Newfoundland proposed by Namias (1972). The difference between sea surface temperature (SST) anomalies north of the equator and south of the equator in the Atlantic is considered as an index to verify the effect of north-south Hadley circulation on the NEB drought as proposed by Moura and Shukla (1981). During the months of December January and February the anomaly is less than $1^{o}C$ and during March, April, and May it is even slightly negative. This shows the drought of 1983 was not due to the changes in the north-south circulations and suggests the relative importance of anomalous east-west Walker circulations, as caused by El Niño, for example.

15. Remarks *To be presented at 2nd Symposium on Tropical droughts, Fortaleza, Sept. 1984.*

TELECONNECTIONS AND SEA SURFACE TEMPERATURE ANOMALY EFFECTS ON THE DROUGHT OF 1983 IN NORTHEAST BRAZIL

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1. Introduction

Mechanisms offered to explain the interannual variations of rainfall over Northeast Brazil (NEB) are many. Namias [10] attributed these variations to large-scale atmospheric teleconnections. Hastenrath and Heller [2] showed that the strength and positioning of the Intertropical Convergence Zone (ITCZ) have a profound influence on the seasonal rainfall of this region. Moura and Shukla [8] proposed a mechanism based on the regional or local Hadley circulations generated by the sea surface temperature (SST) differences between the northern and southern tropical Atlantic Oceans. Another mechanism [5,14] involves the variability in the east-west direct thermal circulation or Walker Circulation associated with the Southern Oscillation (SO). Yet another explanation offered by Kousky [6] relates the northward penetration and number of the cold fronts from the south into NEB and the rainfall. This relation is a kind of teleconnection between the blocking situation in the higher southern latitudes and the weather in NEB.

Some of these explanations are certainly interrelated while most of them complement each other. For example, the intensity of Haddley circulation, the activity of ITCZ and the Newfoundland pressure anomalies, involved in Namias' explanation, are all closely linked. Blocking in the extratropical latitudes of the Southern Hemisphere and the northward penetration of the cold fronts into tropical South America may be related to the intensity and positioning of the Walker circulation modulated by phenomena like El Niño. For a good review of these connections see Kousky et al. [7].

Quite a few authors evolved empirical methods, based either on ill-explained mechanisms or on unexplained correlations, for the prediction of seasonal rainfall over NEB. These methods are enumerated and evaluated in the light of 1981-82 rainfall by Moura and Kousky [9]. Their evaluation showed that no method produced better forecasts than blind extrapolation of the time series.

The normalized deviation (deviation divided by S. deviation) of rainfall for the whole of NEB in the rainy season of 1983 is -1.3 as calculated by Rao and de Brito. [12]. Although drought persisted in this region almost since 1979, the year 1983 registered the severest drought in the last two decades. In the light of this fact, some of the mechanisms thought to be responsible for the rainfall variations in NEB are examined here.

2. SST Anomalies

An unclear aspect of most of the explanations offered for the variability of rainfall in NEB is the cause and effect relationship. For instance, it has not been clearly shown whether the spacial variation in SST is the cause for the regional anomalous direct thermal circulation or SST variation (at least in the same latitude belt) is a consequence of vertical motions associated with tropospheric circulations generated by a different mechanism. Figures 1 and 2 present climatological mean fields of SST minus air temperature and divergence of the wind at the surface for April (middle of the rainy season of the region) adapted from Hastenrath and Lamb [3]. In the neighbourhood of NEB, the sea surface temperature is about 0.5°C warmer than the overlying air and wind is convergent. In nonrainy months the fields tend to be the other way round (see [3]). Therefore it may be safely admitted that the SST differences are the cause and that they affect the atmospheric circulation, as is implicitly assumed in Moura and Shukla [8].

Moura and Shukla [8] calculated linear correlation between the average seasonal rainfall for Fortaleza and Quixeramobim and the March SST anomaly for the tropical Atlantic. The isopleths of correlation coefficient show a highly significant maximum in the mid South Atlantic and a fairly significant minimum in the North Atlantic. It is, however, desirable to see how well the rainfall of the whole region is correlated with SST. For the purpose of reassuring ourselves, linear correlations are obtained between the normalized deviation of yearly rainfall (NDR) over NEB and the SST anomalies in the two 10° latitude-longitude boxes around the maximum and minimum obtained by Moura and Shukla. The boxes are respectively bounded by 10^oS, 20^oS; 0^o,10^oW denoted by SAB (for South Atlantic Box) and 10^oN, 20^oN; 40^oW, 50^oW denoted by NAB (for North Atlantic Box). Figure 3 shows a graph of March SST anomaly in NAB and SAB, their difference and NDR as given by Hastenrath et al. [4] for 31 years starting from 1948. The SST data from 1948 to 1972 is taken from Bunker [1] and from 1973 to 1979 is taken from Servain et al. [13]. We may note that a great percentage of the yearly rainfall over NEB occurs in the three months, March, April and May.

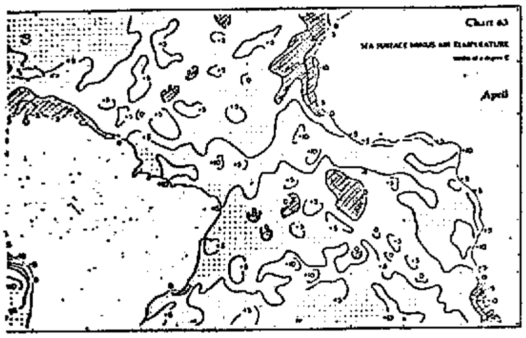

Fig. 1 Sea surface to air temperature difference in tenths of °C, climatological for April. Hatched areas indicate negative values.

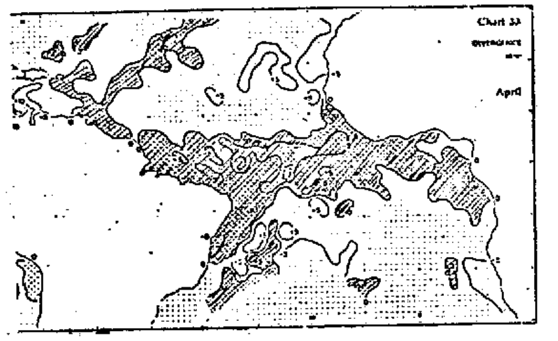

Fig. 2 Divergence field at the surface in 10^{-5} S^{-1}, climatological for April. Hatched areas indicate convergence.

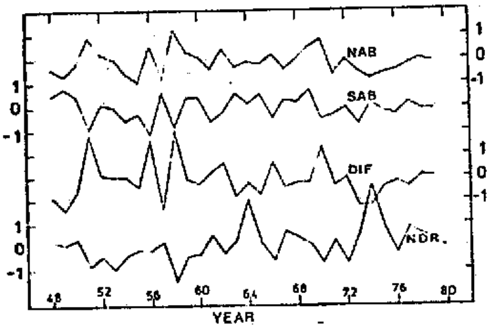

Fig. 3 March SST anomalies in North Atlantic Box (NAB), South Atlantic Box (SAB) and their difference (DIF) in °C. NDR is the normalized deviation of rainfall over Northeast Brazil.

The correlation coefficients obtained between rainfall and SST anomalies and their difference are given in Table 1. Correlations between NDR and SST anomaly in NAB are negative and between NDR and SST anomaly in SAB are positive for all months from October through April. This indicates that lower seasonal rainfall over NEB is associated with higher SST anomalies in NAB and lower SST anomalies in SAB. Seasonal rainfall over NEB is highly significantly negatively correlated with the March SST anomaly in NAB, and is significantly positively correlated with the November (of the previous year) SST anomaly in SAB. This result is somewhat different from the results of Moura and Shukla where the positive correlation coefficient between the rainfall and SST in SAB is higher than the negative correlation between the rainfall and SST in NAB for March. The negative correlation between rainfall and the difference in SST anomalies in NAB and SAB shown in column 3 are consistent. The March correlations obtained by Moura and Shukla, taking rainfall of just two stations into consideration, are much higher than the corresponding values given in Table 1. The values calculated in the present study are representative of NEB as a whole.

The correlation between the SST anomalies in NAB and SAB are insignificant except, perhaps, in March. However, the consistency of the negative sign (column 4, Table 1) may indicate a weak association between warmer waters in NAB and colder waters in SAB. The near independence between the SST anomalies in NAB and SAB leads us to doubt if the anomalous Hadley circulation operates between these two regions. This does not, however, undermine the mechanism proposed by Moura and Shukla, but leads us to consider the two SST anomalies as two independent predictors.

The SST anomalies for November 1982 and March 1983, taken from Monthly Oceanographic Summaries, are shown in Figures 4 and 5. In November there is a clear negative anomaly maximum of more than 1°C in SAB. The March SST anomaly configuration does not have a clear maximum in and around NAB, but nevertheless shows positive values of the order of 1°C in the region. These anomalies indicate a relatively dry rainfall season over NEB in 1983, according to the correlations shown in Table 1. But, yearly NEB rainfall is well-correlated with February and April negative SST anomalies in NAB and April SST anomaly in SAB also, whereas the SST anomaly charts of February and April 1983 (not given here) not only fail to show significant positive values in NAB but also give us positive anomalies throughout tropical South Atlantic.

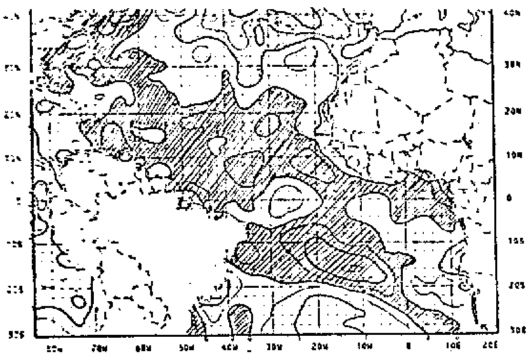

Fig. 4 November 1982 SST anomalies in ^{o}C Hatched areas indicate negative values. Isolines are drawn at intervals of $0.5^{o}C$.

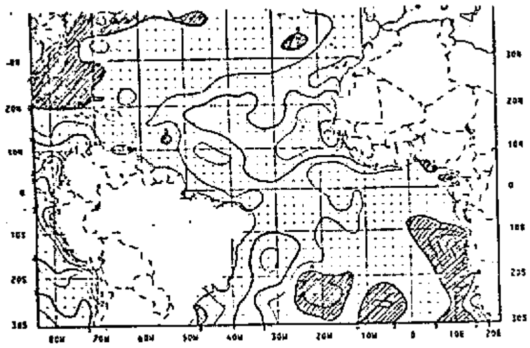

Fig. 5 Same as Fig. 4 except for March 1983.

Table 1 - Correlation Coefficient

MONTH	VARIABLES			
	SSTN vs. NDR	SSTS vs. NDR	SSTD vs. NDR	SSTN vs. SSTS
Oct.	-0.06	+0.24	-0.21	-0.11
Nov.	-0.07	+0.47*	-0.40*	-0.11
Dec.	-0.22	+0.39*	-0.43*	-0.10
Jan.	-0.07	+0.32·	-0.25	-0.21
Feb.	-0.44*	+0.26	-0.45*	-0.19
Mar.	-0.63*	+0.31·	-0.58*	-0.33·
Apr.	-0.49*	+0.33·	-0.51*	-0.19

* value significant at 99% confidence level.

. value significant at 95% confidence level.

SSTN - SST(Sea Surface Temperature) anomaly in the North Atlantic Box.

SSTS - SST anomaly in the South Atlantic Box.

NDR - Nonalised deviation of yearly rainfall over Northeast Brazil.

SSTD - Difference in SST anomaly (SSTN-SSTS).

3. Geopotential anomalies in Northern Hemisphere

Namias [10] obtained a high negative correlation between 700mb geopotential anomaly around Newfoundland for winter (Dec.,Jan.,Feb.) and the seasonal rainfall at Quixeramobim. A slightly lower negative correlation is obtained between the rainfall and spring (Mar,Apr., May) geopotential at the same two places. Rao and de Brito [12] used monthly rainfalls over NEB to calculate correlations with 700mb monthly geopotential anomalies all over the Northern Hemisphere. Various centers of significant correlation maxima and minima appeared in the study. The highest negative correlation center is situated over New England area, close to Newfoundland, between February geopotential and March NEB rainfall. December geopotential with March rainfall does not show any appreciable correlation in the vicinity of Newfoundland. January geopotential has even a significant positive correlation over east central North America. The highest positive correlation center is situated over Iberian Peninsula, which did not show up in the study of Namias, between January geopotential and March NEB rainfall. These descrepancies are perhaps due to the fact that Namias used just one station rainfall and seasonal geopotential anomalies whereas Rao and de Brito used monthly rainfalls of NEB as a whole and monthly geopotentials.

The monthly pressure and geopotential anomalies over Newfoundland and Iberian Peninsula, taken from the Journal of Climatology, for November 1982 through April 1983 are given in Table 2. The Newfoundland anomalies for the northern winter are systematically positive. This, according to Namias, indicates a relatively dry rainy season ahead. The high positive anomalies in January over Iberia would indicate a relatively wet March ahead for NEB, but March 1983 was relatively very dry. Therefore, we conclude that the year 1983 was different from the other dry years in the past in NEB. This shows that predictions based on simple regression relationships tend to be unreliable, because of the lack of physical basis.

However, the association between Newfoundland geopotential anomaly and NEB rainfall seems to have some real bearing.

MONTH AND YEAR	OVER NEWFOUNDLAND		OVER IBERIA	
	SURFACE PRESSURE (mb)	500mb GEOPOTENTIAL (DM)	SURFACE PRESSURE (mb)	500mb GEOPOTENTIAL (DM)
Nov. 82	+2	+1	-1	-2
Dec. 82	+4	+5	+4	+4
Jan. 83	+4	+6	+12	+11
Feb. 83	+3	+3	+4	∿ 0
Mar. 83	+1	+7	+6	+7
Apr. 83	+2	+12	-4	-6

Table 2 - 1982-83 Pressure and Geopotential Anomalies

4. Discussion and Conclusions

The year 1983 is a very anomalous year as far as South American Continent is concerned. This year has been a strong El Niño year, with an intensity of 4(measured in °C of the SST anomaly off Peru coast in January through March, Quinn et al. [11]). El Niño seems to have a profound effect on the weather of the continent. According to Stoeckenius [14] and Kousky et al. [7],more than normal SST in the eastern equatorial Pacific leads to stronger regional Hadley circulation which leads to stronger subtropical jet. This increased zonal flow carries rapidly the frontal systems into South Atlantic before they penetrate Northeast Brazil, with the effect the rainfall over NEB is reduced. Another effect of El Niño is to modify the normal Walker Circulation cells over the region. In the normal years the Walker Circulation has two cells on the equatorial Latin America and the adjoining oceans, with a common rising limb over western Amazon and with subsiding limbs over far eastern Pacific and mid Atlantic [14]. In an intense El Niño year like 1983, the Walker Circulation intensifies and, perhaps, shifts to west with a strong rising limb over the eastern Pacific and with subsidence near the Brazilian coast or even over NEB. In March 1983 (Fig. 5) we may observe that the SST anomalies in the Atlantic near the Brazilian coast are also positive with values exceeding 1°C. As we expect the warmer surface to force rising motions, the subsidence must have been over NEB annihilating the rain causing mechanisms over this region. In the same month we find that the difference between SST anomalies in the tropical North Atlantic and the tropical South Atlantic is negligible and therefore the Walker Circulation effects seem to be more important than those of Hadley Circulation in 1983.

It seems reasonable that east-west circulations driven by either SST or by other heat sources play an important role in determining the interannual variations of rainfall over Northeast Brazil.

The lower tropospheric pressure or geopotential anomalies over Newfoundland and Iberia or the SST anomalies in the Atlantic could not satisfactorily explain the 1983 severe drought over NEB. The mechanism of interannual variations of rainfall is far from understood. The east-west thermal circulations associated with phenomena like El Niño seem to affect considerably the rainfall regime of NEB. The present study raises more questions than tries to answer them. One thing unclear is how November SST anomaly in the mid South Atlantic affects rainfall over Northeast Brazil which has its rainy season in March, April and May. There are strong El Niño years like 1973 when NEB had above normal rainfall and there are drought years like 1970 which are not El Niño years. Again it appears that there is no good association between El Niño and NEB drought.

Droughts in Northeast Brazil seem to be a combined effect of many physical processes, which vary from regional to global scales. In individual years some of the processes might manifest while the others do not or even contribute in the opposite sense. Therefore,it is necessary to monitor all parameters which are known to be important for reliable forecasting of seasonal rainfall of this region.

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References

1. Bunker, A., 1976: Computations of surface energy flux and annual air-sea interaction cycles of the North Atlantic Ocean, Mon. Wea. Rev., 104, 1122-1140.

2. Hastenrath, S. and L. Heller, 1977: Dynamics of climate hazards in Northeast Brazil. Quart. J. Roy. Meteor. Soc., 103, 77-92.

3. Hastenrath, S. and P.J. Lamb, 1977: Climatic Atlas of the Tropical Atlantic and Eastern Pacific Oceans. University of Wisconsin Press, Madison, USA, 97 pp.

4. Hastenrath, S., Wu, M-C and P-S. Chu, 1984: Towards the monitoring and prediction of Northeast Brazil droughts. Quart. J. Roy. Meteor. Soc., (To appear).

5. Kidson, J.W., 1975: Tropical eigenvector analysis and the Southern Oscillation. Mon. Wea. Rev., 103, 187-196.

6. Kousky, V.E., 1979: Frontal influences on Northeast Brazil. Mon. Wea. Rev., 107, 1140-1153.

7. Kousky, V.E., Kagano, M.T. and I.F.A. Cavalcanti, 1984: A review of the Southern Oscillation: Oceanic-atmospheric circulation changes and related rainfall anomalies. Tellus, (To appear).

8. Moura, A.D., and J. Shukla, 1981: On the dynamics of droughts in Northeast Brazil: Observations, theory and numerical experiments with a general circulation model. J. Atmos. Sci., 38, 2653-2675.

9. Moura, A.D. and V.E. Kousky, 1980: Um relato do regime de precipitação no nordeste Brasileiro em 1981-1982 em relação aos métodos de previsão de secas. Instituto de Pesquisas Espaciais/CNPq. INPE-2569-PRE/217 (Available from INPE, SJCampos, 12.200, SP,Brasil).

10. Namias, J., 1972: Influence of Northern Hemisphere General Circulation on drought in Northeast Brazil. Tellus, 24, 336-343.

11. Quinn, W.H., Zoph, D.O., Short, K.S.,and R.T.W.K.,Yang, 1978: Historical trends and statistics of the Southern Oscillation, El Niño, and Indonesian droughts. Fishery Bulletin, 76, 663-678.

12. Rao, V.B. and J.I.B. de Brito, 1984: Interannual variations of rainfall in northeast Brazil and their connections with the large-scale features. (To be presented at the 2nd W.M.O. Conference on Tropical Droughts, Sept. 1984).

13. Servain, J., Picant, J. and J. Merle, 1984: Compilation of sea surface temperature data for the tropical Atlantic. Laboratorie d'Oceanographic Physique, Brest, France (Unpublished charts).

14. Stoeckenius, T., 1981: Interannual variations of tropical precipitation patterns. Mon. Wea. Rev., 109, 1233-1247.