Monsoon rains over West Africa

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ABSTRACT

Potential mechanisms producing high or low seasonal rainfall in tropical West Africa are investigated for the period 1963–74 using monthly data of precipitation, surface pressure in the South Atlantic and rawinsondes, mainly in Africa. Contrary to widespread opinion, the South Atlantic pressures yielded no correlation; the best connection was between rainfall and upper-level African observations.

Introduction

Variations in the yield of the seasonal monsoon rains have led to a drought period in the Sahel Zone of North Africa in the early 1970's (Fig. 1) which severity has not been experienced within at least 20 years or more (Strantz, 1975). The severity is enhanced by a large increase in population since earlier occurrences before 1950. Unfortunately, the causes of the large variations in yield of rain are not yet well understood. In previous studies quantities such as the departure of the Intertropical Convergence Zone (ITCZ) position have been investigated, as has the inclination of the zone with height, steering through the adjoining subtropical high pressure centers and relations with the general atmospheric circulation (Namias, 1974; Strantz, 1975).

Monsoon rains and surface pressure distribution

In this study the thought, variously uttered, has been at first explored, that the monsoon rains in western tropical Africa are related to the strength of the monsoon flow, and that the strength of the monsoon flow is correlated with the intensity of the subtropical high of the South Atlantic, or with the surface pressure gradient between about 25 S and the equator or with about the south coast of West Africa in 5 N. If valid, an increased pressure gradient would coincide with increased transport of water vapor from the South Atlantic into West Africa, hence a yield of more water—and the inverse.

It is to be noted that the heavy rains occur during very short periods related to squall lines, waves and vortices traveling westward over the continent (Asecna, 1975; Riehl, 1954). Nevertheless, charts of monthly pressure and rain might show a relationship. This contention is based on studies of Solot on Hawaii (Riehl, 1954). The rains there do show a correlation to certain pressure anomalies of the Northern Hemisphere, yet the bulk of the water is derived from a few intense passing disturbances as is true almost everywhere in the tropics. The suggestion is that long-period pressure anomalies influence the frequency of occurrence of such disturbances above or below average in any year or month.

Riehl suggested that such relations might typically hold in various tropical regions, as experienced for example in Venezuela. An attempt was made to gather observations for testing the relation over western Africa during the main rainy season of July–September.

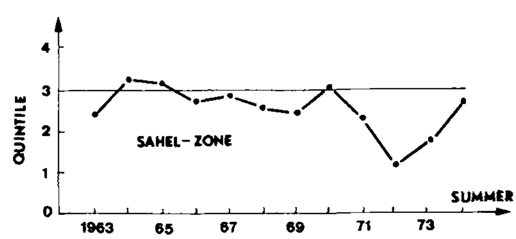

Fig. 1. Precipitation of the Sahel-zone in quintile values for each summer 1963–74.

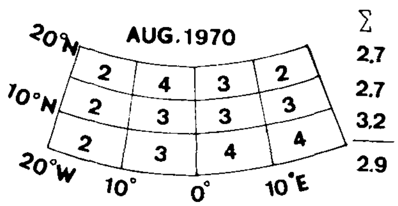

Fig. 2. Precipitation in quintile values for each area in August 1970, a sample.

Observations

The problems in obtaining relevant observations proved to be formidable, as might be expected, and various approaches were tried out. In the end, precipitation was accepted as represented by monthly quintile[1] charts published since 1963 in the *Berliner Wetterkarte*. The area of analysis (Fig. 2) was divided into 12 parts. For each month of the main monsoon season and for each whole season a quintile value was determined from the data and the published analysis. This procedure appears to be superior to the representation of Sahel precipitation by the records of 2 or 3 stations (Namias, 1974; Strantz, 1975). Even the mean of 3 stations often deviated considerably from the quintile number which was determined usually from about 100 quintile values of the area of analysis. Because of the great variability of convective rain even over short distances the best representation of Sahel precipitation would be area averages (Riehl, 1954).

Monthly surface pressure maps were taken from the Hamburg series *Die Witterung in Übersee* (Deutscher Wetterdienst). Earlier published maps from South Africa could, unfortunately, not be used because these maps were only analysed south of 10 S. However, the Australian Weather Service in Melbourne kindly placed computer-produced charts for 1972–74 at our disposal. They compared favorably with the Hamburg charts in the area in question. The problem of very sparse observations in some portions is of course therefore not eliminated.

[1] Quintile is a statistical measure: Quintile 1 corresponds to the six driest, Quintile 5 to the six most humid years, 0 means less, 6 means more monthly total precipitation than ever observed during 1931–1960.

Correlation results

At first the average of the quintiles in the 12 areas of Fig. 2 was determined for each month and season. The total pressure difference was determined by averaging the pressure differences between 25 S and 5 N at 20 W, 10 W, 0 and 10 E. Although both parameters varied by factors of two in the 12 years 1963–74 considered, no relation was found for the 12 Julys, Augusts and Septembers (Fig. 3) or for the whole seasons. Other relations were tried without success, for instance the quintiles of each of the three latitude zones with total pressure difference as defined above, also pressure differences between 10 S and 5 N or 25 S and 10 S.

No relation was expected between rainfall and pressure gradient north of the ITCZ at the surface. Nevertheless, the test was made and the expectation was verified. It must be said, however, that surface pressure gradients were very weak and therefore subject to much uncertainty. Position and intensity of the ITCZ remained nearly uniform over the 12 summers of study in each month.

An investigation for a possible relation between precipitation and the 700 mb geopotential gradient, showing for the Northern Hemisphere the inclination of the ITCZ axis, unfortunately could only be made for the Northern Hemisphere. A weak relation between the position of the 700-mb high and precipitation could be seen. The drier years coincide with a more southern position of the 700-mb high than the wet years (Fig. 4) excepting 1971.

Besides in the Northern Hemisphere a strengthening of the surface anticyclone with a southward bulge is evident during the dry period of the early 1970's (Asecna, 1975; *Berliner Wetterkarte*; Strantz, 1975); in contrast the central pressure of the South Atlantic anticyclone remained virtually constant.

Monsoon rain anomalies and upper temperatures

As already stated, a weak correlation was found between the 700-mb position of the Northern Hemisphere high and the precipitation in the region of western Africa itself.

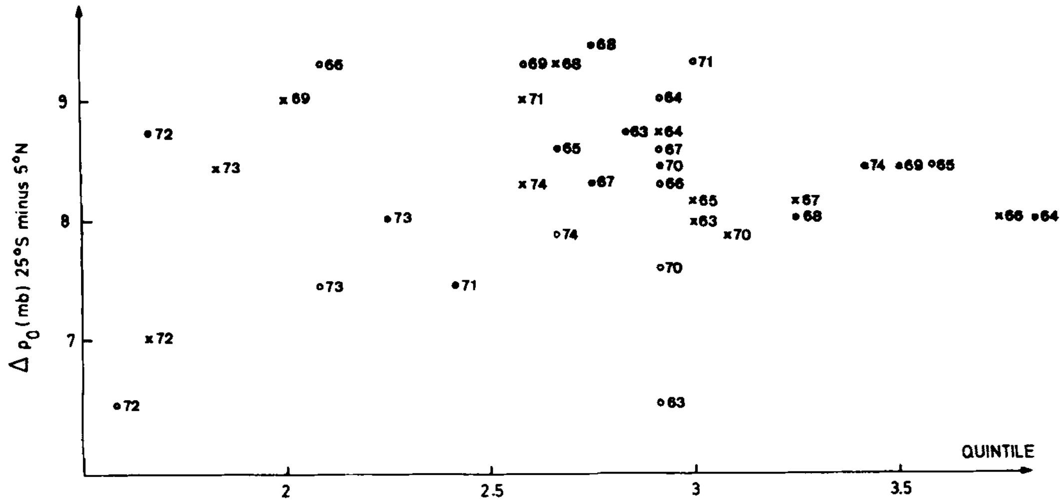

Fig. 3. Comparison between the precipitation of West Africa and the South Atlantic surface pressure gradient between 25 S and 5 N at 20 W, 10 W, 0 and 10 E for July (●), August (○), September (×), 1963–74.

The only additional effort that could be made here, was further analysis of the atmospheric structure over western Africa and extension to the upper troposphere. Only the 700- and 200-mb charts have been published with a definitive analysis in the 12 years studied; other levels appeared irregularly or were largely devoid of data.

Only temperature will be discussed. The geopotential does not offer genuine additional information because it is computed with use of the temperature; moisture at 700 mb was entered in the charts too irregularly; and the shear winds at different stations did not show a correlation with precipitation. It must be noted, however, that the aerological material published was insufficient for a definite description of the wind structure of the current, which Strantz also noted with regret—apart from climatological aerological material (Griffiths, 1972; Jackson, 1961; Thompson, 1965). Such features as a possible "easterly jet stream" and the potential role of two east wind maxima along the vertical could not be treated.

Over western Africa the number of stations with monthly temperature values at 700- and 200-mb entered on the monthly charts averages less than ten. These stations were dispersed from 5 N to 25 N. The variation of temperature and geopotential, as given by these stations, is predominantly meridional. However, the reporting stations vary enough from year to year so that construction of a mean meridional profile with deviations in individual years

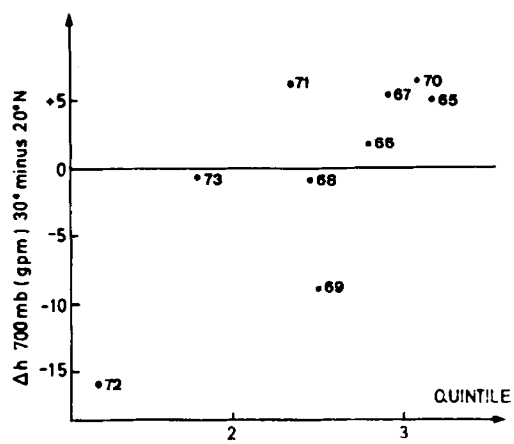

Fig. 4. Comparison between the precipitation of the Sahel-zone and the 700 mb-height gradient between 30 and 20 N at 20 W, 10 W, 0, 10 E and 20 E for each summer, 1965–73.

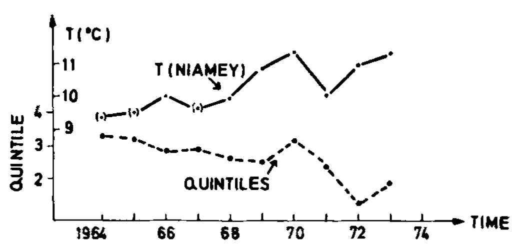

Fig. 5. Comparison between the summer average temperatures at 700 mb for Niamey and the summer quintile values of the Sahel-zone, 1964–73.

appeared to be a dangerous procedure. In preference, temperature values of four usually available stations were used individually: In Salah, Niamey, Abidschan and Dakar. Comparison was made with precipitation (*a*) at the station, (*b*) at quintile value of the corresponding zone (cf. Fig. 2), and (*c*) with the quintile values of the whole area. This was done for each month of the monsoon season and for the whole seasons (see Fig. 5 for the latter). The comparisons showed the following: (*a*) temperatures at 700- and 200-mb are correlated, (*b*) correlation is best between the temperature anomalies of the stations and the mean quintile of the zone in which they are situated, (*c*) monthly and 3-monthly quintiles of the zones in a summer have predominantly the same relation to the temperature of a month and to the temperature of the whole summer. Variations of precipitation are greater from one summer to the next than from one month to the next in the same season. The same holds for the upper temperatures, (*d*) the precipitation at each of the four individual stations analysed has no relation with the upper temperature at this station alone. This underlines the importance of dealing with a network of precipitation stations rather than with rain at any individual station.

Summary

The attempt to relate monthly gradients of sealevel pressure north of the South Atlantic subtropical high with variations of monsoon rains over western Africa was not successful.

On the other hand, the 700-mb height gradient between 20 N and 30 N at 20 W, 10 W, 0, 10 E and 20 E showed a more southerly position of the subtropical high over Africa during the dry than during the wet years suggesting control of the monsson rains by the general circulation of the Northern Hemisphere.

Considering tropospheric temperature, it could be shown for the Sahel-zone that in the three years with highest precipitation the temperature was colder than in the remaining years and that the driest summers had the warmest temperature—in agreement with what had already been stated about the displacements of the 700-mb subtropical high pressure belt. Thus, the very large scale and time averaged general circulation appears to be the most prominent factor in facilitating local convergence and divergence on short time and distance scales. This is in accord with the findings of Solot mentioned earlier and those of Riehl for Venezuela (1973).

Acknowledgement

The study was undertaken as an M.S. (Diplom) thesis under the guidance of Professor Riehl, at the Freie Universität Berlin. A copy of the full text of the thesis, of which the above is a short report, may be obtained on loan from the Meteorological Library of the University.

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МУССОННЫЕ ДОЖДИ НАД ЗАПАДНОЙ АФРИКОЙ

С использованием среднемесячных данных об осадках и давлении на поверхности в Южной Атлантике и данных радиозондирования, в основном в Африке за период 1963–1974 гг. исследуются потенциальные механизмы, вызывающие высокие или низкие уровни выпадения дождя в тропической Западной Африке

В противовес с широкораспространенным мнением, давление в Южной Атлантике не дают корреляции с уровнем осадков. Наилучшая связь имеется между выпадением дождя и данными наблюдений на высоких уровнях над Африкой.