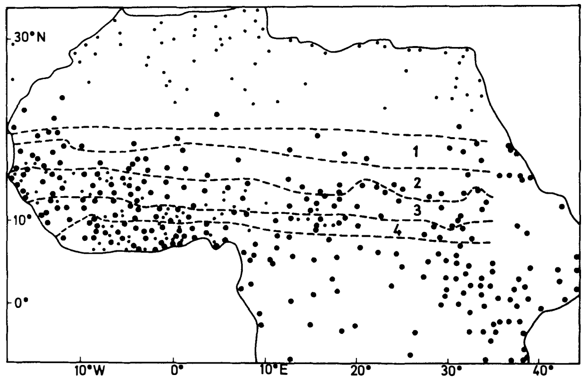
STATISTICAL TYPING OF RAINFALL ANOMALIES IN SUBSAHARAN AFRICA

With 7 figures and 1 table

SHARON E. NICHOLSON

Zusammenfassung: Statistische Typisierung von Niederschlagsanomalien im subsaharischen Afrika

Für die Jahre 1901–1973 wurden aus den Zeitreihen der normierten jährlichen Niederschlagsabweichungen vom langjährigen Mittel Niederschlags-Anomalietypen für die afrikanischen Tropen und Subtropen mit Hilfe räumlicher Korrelationen hergeleitet. Diese Typen stellen i. w. bevorzugte Raummuster der Niederschlagsabweichungen während Jahren mit außergewöhnlichen Niederschlagsbedingungen in der semi-ariden Sahel- und Sudanzone dar, aus denen einige Charakteristika des Sahel-Sudanklimas zu entnehmen sind. Die angegebenen Variationsweisen belegen eine gewisse Komplexität des Klimas dieser Region und seine Fernverbindungen mit anderen Gebieten Afrikas.



1 SAHELO-SAHARA 2 SAHEL 3 SOUDAN 4 SOUDANO-GUINEAN

Fig. 1: Network of rainfall stations: large dots denote stations used in both correlation (Section III) and the maps (Section IV) and small dots denote stations omitted in correlation but used in constructing the maps.

I. Introduction

The extreme climatic fluctuations which occur in semi-arid subtropical Africa have recently aroused the interest of several scientific disciplines and researchers have offered numerous causal explanations for fluctuations on scales ranging from millenia to decades. On the longer scale, the Saharan desert advanced as much as 500 km southward during the last (Würm) glacial 18,000 years ago, while during the subsequent warming increased rainfall led to the formation of tremendous lakes in the present central and southern Sahara and in the semi-arid Sahel and Soudan zones further south. Lake Chad expanded to cover an area nearly as large as the United Kingdom, sixteen times the lake's present size. During the present century, these regions experienced less marked but ever so significant fluctuations in rainfall. During the 1950's zonally-averaged rainfall tended to be 24% to 50% above the twentieth-century mean in the Sahelo-Saharan and Sahel zones (Fig. 1) and 10% to 15% above the mean in the Soudan zone, with generally higher departures at individual stations. Such conditions probably characterized much of the sixteenth through eighteenth centuries and late nineteenth century (NICHOLSON, 1978). By contrast, rainfall often totaled only 40% to 50% or less of the mean during the droughts c. 1968–73 and between 1910 and 1920 (NICHOLSON, 1979b). Similar droughts plagued the Sahel for even longer periods of earlier centuries.

Suggested explanations of these changes tend to simplify the responsible climatic mechanism. A basic latitudinal shift of circulation features and climatic zones, including the semi-arid Sahel and Soudan, is often assumed for Ice Ages as well as for the recent droughts. Relevant hypotheses (WINSTANLEY, 1973, BRYSON, 1974) suggest, for example, that an equatorward displacement of the Atlantic Subtropical High suppresses the northward summer migration of the Intertropical Convergence Zone (ITCZ) and thereby reduces rainfall in these regions south of the Sahara: rainfall in these semi-arid regions is considered a function of ITCZ position. In the cases of both Ice Age aridity and the recent droughts, the observed rainfall changes do affect the entire east-west extent of the climatic zones in question; hence there is some justification for assuming large-scale latitudinal shifts. However, other lines of evidence (NICHOLSON, 1978, 1979b, KLAUS, 1975, 1978) suggest that the present latitudinal climatic zones in the African subtropics do not consistently respond as an entity to climatic forcing and that the fluctuations they experience do not bear a consistent relationship to conditions in other parts of Africa. In other words, climatic variation in the sub-Saharan regions involves more complex mechanisms and several modes of rainfall fluctuation might be involved.

In recognizing this complexity, KLAUS (1978) uses eigenvector analysis to describe rainfall variation in West Africa, with the derived eigenvectors representing characteristic modes of rainfall variability, i.e., typical rainfall departure patterns. This method, used also by KIDSON (1975) to describe tropical rainfall variability, contains two inherent limitations: (1) "reflection", which classifies the negative of each eigenvector as a realistic departure type, and (2) orthogonality, which requires that modes of variation represented by the eigenvectors be statistically independent. Because observed climatic departure patterns are not orthogonal and do not necessarily exhibit "reflection", anomaly types determined via spatial correlation, an alternative method free of these limitations, are more representative of observed climatic cariation and can be more readily interpreted in synoptic terms (BLASING, 1975).

Because of these advantages, spatial correlation is applied in this study to the purpose of describing modes of rainfall fluctuations in the semi-arid region south of the Sahara. The technique is used to determine rainfall anomaly types, i.e., like eigenvectors, patterns of preferred configurations of rainfall departures. The anomaly types further depict climatic teleconnections between this region and other parts of Africa and help to examine the frequently assumed simplicity of the climate of the Sahel-Soudan region.

II. Data

The data base consists of annual rainfall data for 419 African stations in the area 10° S to 37° N, for each year from the beginning of a station's record until 1973. Data provided by ORSTOM, 25 African Weather Services and the libraries of the Meteorological Office (England) and the Deutscher Wetterdienst (West Germany) complement those published in *World Weather Records* and *Monthly Climatic Data for the World*. The resulting station network (Fig. 1) represents an attempt to maximize both lengths of the series and areal coverage, and thus does not necessarily utilize the longest records available. 75 stations begin in 1901 or earlier, while a total of 300 or more begin before 1925. In the analysis described in Section III, correlation of annual rainfall reparture patterns, only 238 of the 419 stations are used. All stations lying in the regime of extra-tropical winter rainfall north of c. 22° N are excluded, and 70 of the stations within the tropical summer rainfall regime associated with the ITCZ are omitted in order to approach equality of station density in most of the analysis region. The results of a second analysis which adds the available winter-rainfall stations north of 22° N appear elsewhere (NICHOLSON, 1979b). Results presented in Section III, maps representing determined anomaly types, are based on all 419 stations.

III. Methodology

The spatial correlation technique described below, originally derived from LUND's (1963) map classification scheme and modified from BLASING's (1975, 1977) study, correlates two variables in a manner analogous to the usual (temporal) linear correlation of time series of observations of two variables (e.g., temperature and rainfall). Whereas the N observations of two variables temporally correlated represent points in time, the N elements comprising the observational series of two spatially correlated variables (in this case, years, or the annual rainfall departure patterns corresponding to them) are functions of space (in this case, a station's annual rainfall departure for the year in question). The procedure is described below stepwise, using the following symbols:

r_{ij} = annual rainfall for station i in the year j

n_i = number of record years for station i

$\bar{r}_i$ = mean annual rainfall for station i $= n_i^{-1} \sum_j r_{ij}$

σ^2_i = variance of annual rainfall totals for station i

N_{jk} = number of stations available in both years j and k

X_{ij}, X_{ik} = normalized annual rainfall departures for station i in the years j and k respectively (calculated in step I)

C_{jk} = coefficient of linear correlation between years j and k, i.e., between normalized annual rainfall departure patterns for these years (calculated in step II)

Step I. Normalization of Annual Rainfall Totals

Annual rainfall at individual stations ranges from 50 to 3000 mm and variabilities of annual totals differ by factors of two or three. Therefore, some normalization procedure is required in order to correlate annual rainfall patterns. For each station i, annual rainfall r_i is normalized as follows to produce a series of annual departures:

$$X_{ij} = (r_{ij} - \bar{r}_i)/\sigma_i \quad (1)$$

where σ_i, square root of the variance of annual totals, is derived as:

$$\sigma_i = (n_i^{-1} \sum_j r_{ij}^2 - (\bar{r}_i)^2)^{1/2} \quad (2)$$

For each value of j (or k) from 1901 to 1973 the series X_{ij} (or X_{ik}) represents a normalized annual rainfall departure pattern for the area between 10° S and 37° N as depicted in Fig. 1. Use of σ_i in this procedure, rather than annual mean, gives less weight to more arid stations, where variability is large compared with the mean and thus where even large percent-of-mean departures do not necessarily reflect a climatic anomaly.

Step II. Linear Correlation of Annual Rainfall Depature Patterns

Calculation of the linear correlation coefficient C_{jk} between annual departure patterns for the years j and k derives from PANOFSKY and BRIER's (1968) formula for correlating two variables y_i and y_2:

$$C_{12} = (\overline{y_1 y_2} - \bar{y}_1 \bar{y}_2)/((\overline{y_1^2} - \bar{y}_1^2)^{1/2} (\overline{y_2^2} - \bar{y}_2^2)^{1/2}) \quad (3)$$

Substituting the variables X_{ij} and X_{ik}, as defined above, for y_1 and y_2, and expanding the averages in Eq. 3, the coefficient of linear correlation between the years j and k is expressed as:

$$C_{jk} = \frac{N_{jk}^{-1} (\sum_{i'} X_{ij} X_{ik}) - (N_{jk}^{-1} \sum_{i'} X_{ij}) (N_{jk}^{-1} \sum_{i'} X_{ik})}{(N_{kj}^{-1} \sum_{i'} X_{ij}^2 - (N_{jk}^{-1} \sum_{i'} X_{ij})^2)^{1/2} (N_{jk}^{-1} \sum_{i'} X_{ik}^2 - (N_{jk}^{-1} \sum_{i'} X_{ik})^2)^{1/2}} \quad (4)$$

where $\sum_{i'}$ denotes summation over all N_{jk} stations of the network i which are mutually available in the years j and k. In this step, only a subset of the available stations (as indicated in Fig. 1) is used to form the departure patterns to be correlated.

The derived correlation coefficients measure the similarity of two annual departure patterns, with a high positive correlation implying that the sign of departures at most stations was the same in both years. The pattern for each year 1901 to 1973 is correlated with that of every other year; the results are best visualized as a 73 x 73 matrix of correlation coefficients with both rows and columns corresponding to years. The program utilized throughout this analysis, DSTAT2 in the University of Wisconsin STATJOB series, produces such a matrix and is capable of omitting missing data as required.

Step III. Determination of Anomaly Types

The correlation matrix is scanned to determine which of the 73 years is "well correlated" (positively) with the greatest number of other years and hence typifies frequently occuring rainfall departure patterns. "Well correlated" signifies that the correlation reaches some arbitrarily chosen level of confidence c_i for anomaly type i. This criteria, rather than a critical minimum value of C_{jk}, is used because missing data and variable lengths of rainfall records at individual stations cause N_{jk} (the number of stations involved in each correlation) to vary greatly.

The DSTAT2 program computes the confidence level on the basis of N_{jk}-1 degrees of freedom and thereby overestimates it by assuming that stations vary independently. However, choice of very high confidence levels (.001 for anomaly type 1, decreasing to .03 for higher order types) insures that the confidence level based on a more realistic reduced number of degrees of freedom is generally .05 or better. A reasonable reduction of the number of degrees of freedom is probably between (N_{jk}-1)/2 and (N_{jk}-1)/3, considering (1) the number of stations in year j which differ from the mean departure pattern corresponding to the anomaly type representing year j, and (2) a brief comparison of time series of nearby station pairs, which indicates stations vary independently in about 1 in 2 or 1 in 3 years.

In order to form the annual departure pattern corresponding to "Anomaly Type 1", a composite of five individual years is derived. That is, the departure pattern for year j, the year selected from the matrix as correlating at the c_1 level (.001) with the greatest number of other years, is averaged together with the departure patterns for the four years best correlated with year j. This averaging technique eliminates some of the "noise" of the individual annual patterns, while preserving features common to years comprising the anomaly types. Continuing, all 73 years (i. e., annual departure patterns) are then spatially correlated, in the manner described in Step II, with Anomaly Type 1. Those years correlated with it to the same c_1 confidence level are classified as Type 1 and removed from the data set, i.e., from the correlation matrix. To determine higher order anomaly types the procedure described in Step III (scanning the matrix, determination of the next anomaly type i, correlation of the data set with anomaly type i, etc.) is repeated, using for each iteration only the years remaining in the correlation matrix after the years classified as anomaly type i in the previous iteration are removed. Thus, when Anomaly Type 2 is calculated, each year remaining in the matrix is correlated with it and so classified if the correlation exceeds the c_2 confidence level, and so forth. The level c_i defining "well correlated" changes with successive iterations: when no year in the remaining data correlates to the .001 level with at least four other years, c_i is first lowered to .005 then to .010, .020, .025 and .030 in later iterations. For each iteration i the confidence level c_i is the same when judging the inter-annual correlation to form an anomaly type and when correlating individual annual departure patterns with anomaly type i determined during the iteration.

IV. Results

The results of the anomaly typing scheme appear in Tab. 1 and in map form in Figs. 2 through 7. The resulting seven rainfall anomaly types classify 54 of the 73 years (Tab. 1) or 74%. The first three types together classify 30 years (41%), but each of the higher order types classifies only one year in addition to the five years comprising it, and does not represent a particularly frequent pattern of variability. This is comparable to KLAUS' (1978) results obtained with eigenvectors: the first three account for 40% of the rainfall variance in the analysis area south of the Sahara and six eigenvectors account for 52% of the variance. Commonly, more departure types or eigenvectors are required to explain precipitation variance than to explain temperature or pressure variance (NAMIAS, 1968, KUTZBACH, 1967, KIDSON, 1975) because of the larger temporal and spatial variability of rainfall and greater magnitude of local effects. The number of years classified by these anomaly types is considered good in view of this and further difficulties imposed by the nature of rainfall in the analysis area: extreme tem-

Table 1: Results of Rainfall Anomaly Typing by way of Spatial Correlation

ANOMALY TYPE	A	B	C
1	1936, 1950, 1952, 1956, 1958	1943, 1945, 1946, 1953, 1954, 1964	1915, 1925, 1931, 1934
2	1913, 1963, 1968, 1972, 1973	1941, 1949, 1960, 1962, 1971	1920, 1938
3	1924, 1927, 1928, 1930, 1955	1918, 1922, 1929, 1939	1923, 1940, 1942, 1961, 1971
4	1916, 1917, 1944, 1947, 1949	1915	
5	1935, 1957, 1966, 1967, 1969	1965	1921, 1933
6	1912, 1919, 1926, 1937, 1951	1914	
7	1903, 1904, 1905, 1906, 1908	1907	

A Five years composited to form anomaly type

B Additional years classified as this type

C Years negatively correlated with this type

poral variability in semi-arid and arid regions; the "hit-and-miss" nature of tropical rainfall, which sharply decreases inter-station correlation and creates "noise" in the rainfall patterns; and the diversity of rainfall regimes in the analysis area.

As explained, the anomaly types are determined on the basis of correlations between departure patterns derived from a network of 238 stations, as indicated in Fig. 1. However, the maps (Figs. 2 through 7) depicting these anomaly types extend the corresponding patterns to North Africa and add detail in the sub-Saharan region by stratifying the data for all 419 stations according to anomaly type, i.e., calculating for each of these stations a "normalized annual departure" averaged for the five years comprising each anomaly type. While the larger maps portray the precipitation departure patterns corresponding to Types 1 through 6*) with greater spatial resolution, the broad features of the generalized patterns depicted in the inset maps better describe variability patterns typical of numerous individual years. These anomaly types primarily represent preferred configurations of rainfall departures during periods of anomolous rainfall in the semi-arid Sahel and Soudan zones. Anomalies in these zones dominate the results because of (1) large annual rainfall variability there, (2) a high degree of coherence of variability within this region, and (3) a large number of stations within this region.

Several basic modes of climatic fluctuation emerge from both sets of maps. The first involves periods of decreased rainfall throughout the entire Sahel-Soudan zone; a second involves increased precipitation throughout this region; and a third consists of a mixed configuration with zonal variations occurring across the region's east-west extent. Sahel-Soudan drought is frequently accompanied by negative departures in much of the Sahara and North Africa, but either increased (Types 2 and 4) or decreased (Type 6) rainfall in the Guinea Coast area (Ghana, Ivory Coast, etc., south of c. 10° N). Increased Sahel-Soudan rainfall is generally accompanied by positive departures in most of the Sahara and much of North Africa, but decreased rainfall in the equatorial regions and East Africa. These periods are most commonly characterized by negative departures in the Guinea Coast region (Type 1), but increased rainfall may occur synchronously in both the Guinea Coast and the Sahel-Soudan zone (Type 3). A third basic mode, a mixed configuration with east-west differential behavior in the Sahel-Soudan zone (drought between certain longitudes, above-average rainfall in other longitudinal zones) is represented clearly by Types 3 and 5 and, to a lesser extent, by Type 6. Such mixed configurations are more common in individual years and they also typify the "Sahel" droughts of the 1770's and possibly 1680's (Nicholson, 1978); such patterns may have occurred more frequently in early centuries.

V. Conclusions

The six rainfall anomaly types depicted in Figs. 2 through 7 illustrate that while rainfall fluctuations tend to be coherent throughout semi-arid zones south of the Sahara, a mixed configuration of drought within parts of this zone is not uncommon. The coherence shown for the Saharan margin, the Sahel and the Soudan frequently breaks down within the Soudano-Guinean zone toward 10° N: although anomalies of the same sign may affect both the regions south of 10° N and the sub-Saharan semi-arid zones, there exists a marked tendency for opposing departures north and south of this latitude.

Both of these features, a discontinuity toward 10° N and east-west differential behavior, are apparent from comparisons of rainfall departures series for each of these zones and for smaller regions within them

*) No map is presented for Anomaly Type 7, years of summer drought in the western Sahel and Soudan, because the sparse available data masks this drought: a few extraordinary winter rainfalls in this area in two years cancel out the weaker drought anomalies. Drought prevailed throughout the Sahel and Soudan zones.

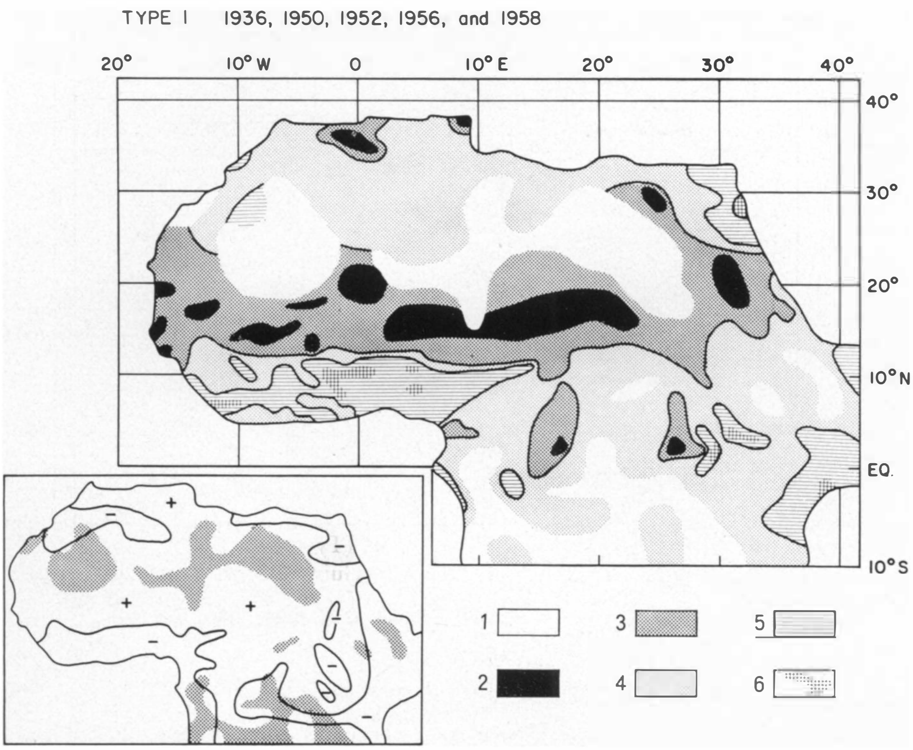


Fig. 2: Anomaly Type 1: mean rainfall departure pattern for a composite of years 1936, 1950, 1952, 1956 and 1958
1 areas with no data available; 2 well above normal precipitation; 3 above normal precipitation; 4 normal precipitation; 5 below normal precipitation; 6 well below normal precipitation

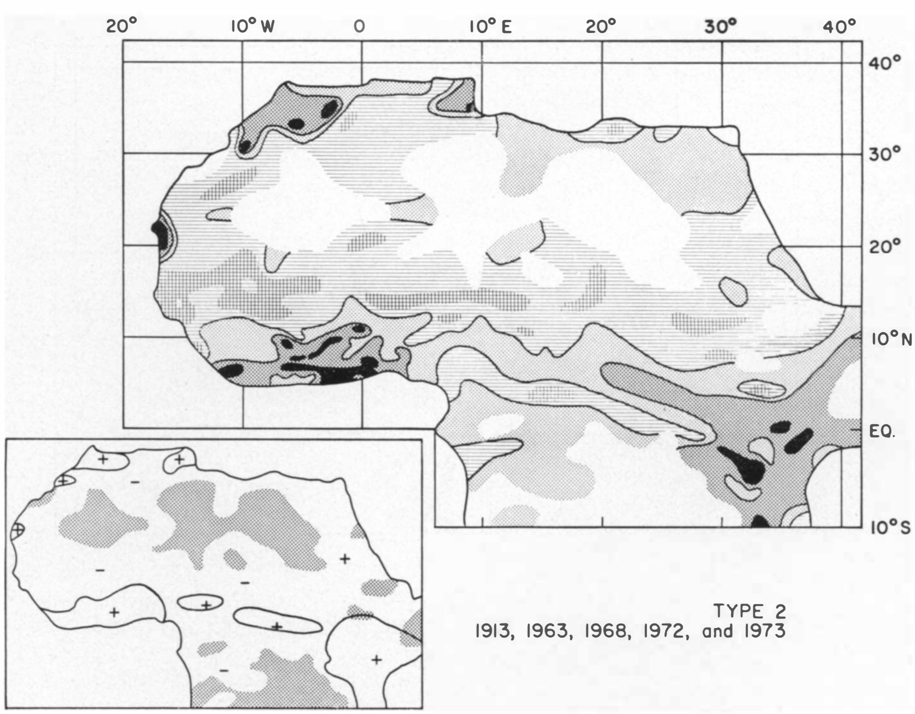


Fig. 3: Anomaly Type 2: mean rainfall departure pattern for a composite of years 1913, 1963, 1968, 1972 and 1973 (legend, Fig. 2)

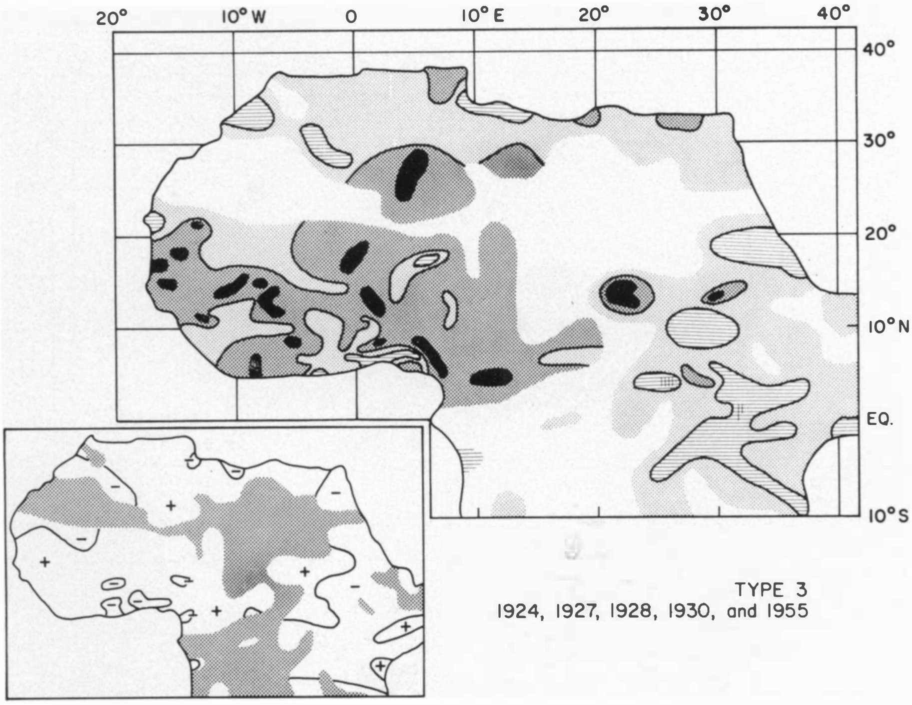


Fig. 4: Anomaly Type 3: mean rainfall departure pattern for a composite of years 1924, 1927, 1928, 1930 and 1955 (legend, Fig. 2)

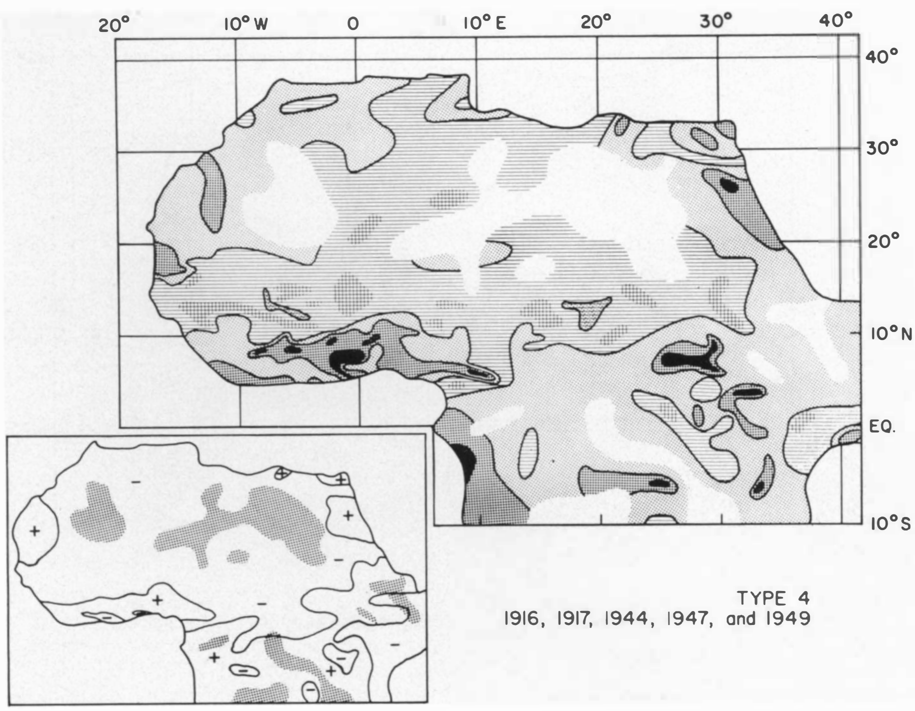


Fig. 5: Anomaly Type 4: mean rainfall departure pattern for a composite of years 1916, 1917, 1944, 1947 and 1949 (legend, Fig. 2)

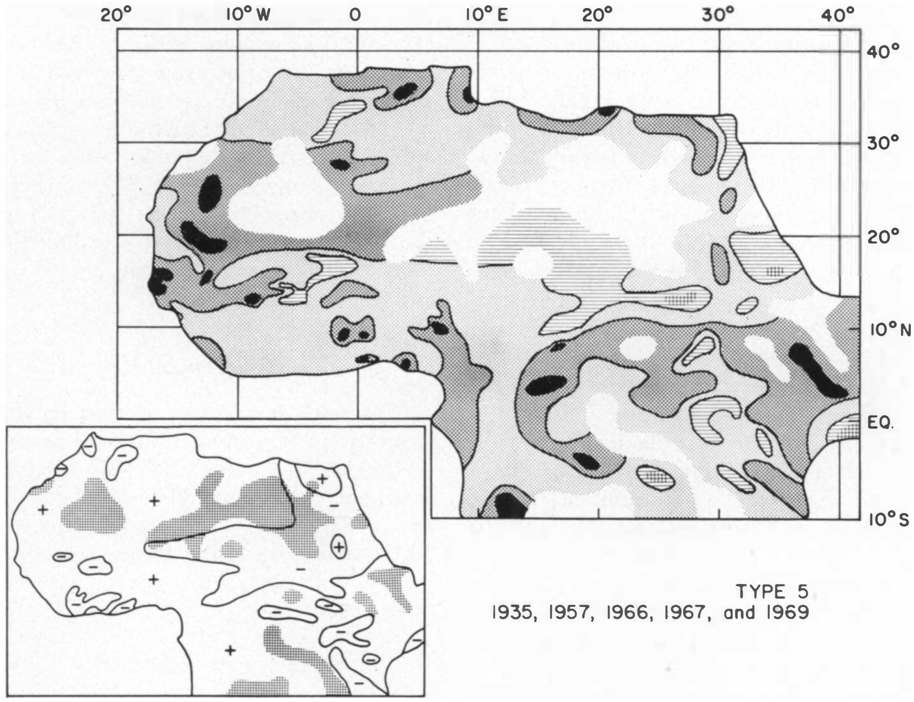


Fig. 6: Anomaly Type 5: mean rainfall departure pattern for a composite of years 1935, 1957, 1966, 1967 and 1969 (legend, Fig. 2)

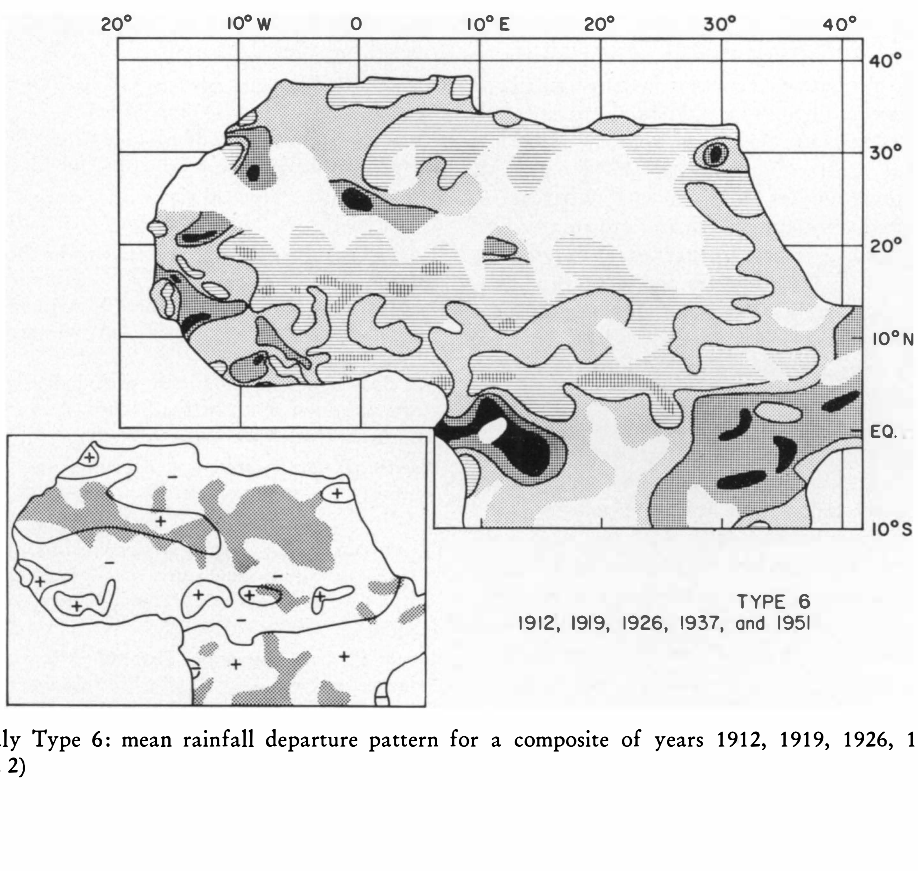


Fig. 7: Anomaly Type 6: mean rainfall departure pattern for a composite of years 1912, 1919, 1926, 1937 and 1951 (legend, Fig. 2)

(Nicholson, 1979b). Klaus' (1975, 1978) analyses produce similar characteristics: regionalization (via eigenvectors) indicates several discontinuities across the east-west extent of the Sahel-Soudan zone and a major latitudinal discontinuity c. 10° N, and a statistical analysis of the frequency distribution of annual totals shows a reversal of the mode of distribution east and west of 0° and a change in distribution at about 10° N and again at about 16° N.

The anomaly types determined in this study further indicate that the teleconnections between the Sahel-Soudan region and other parts of Africa are not straightforward. Anomalies in this zone and, for example, in East Africa are neither consistently of the same sign (e.g., Type 4) nor consistently opposite (e.g., Type 2); nevertheless, synchronous fluctuations in the two areas may relate to the same large-scale atmospheric circulation changes. This holds true for the relationship between the Sahel-Soudan region and the Guinea Coast or North Africa (Nicholson, 1979b); hence simplified Sahel drought explanations based on displacement of the ITCZ or of the Subtropical Highs neglect the intricacies of the Sahel-Soudan climate. Rather, several mechanisms may produce such droughts and case studies based on particular types of drought (i.e., anomaly) patterns may isolate these mechanisms better than studies (e.g., Lamb, 1978, Schupelius, 1976) comparing simply wet or dry years in the Sahel.

Another characteristic emerges from the rainfall anomaly types in Figs. 2 through 7: climatic variation in the African subtropics is insufficiently represented by the frequently assumed displacement of rainfall zones (represented by Type 2) and other climatic or general circulation features. Instead, expansions (Type 4) or contractions (Types 1 and 3) of the desert belt are common. Anomalous periods of both the historical and geological past (Nicholson, 1978) provide examples of these modes of variation. Whereas an equatorward displacement of African (and to a certain extent, hemispheric) climatic features characterized the late Würm glacial c. 18,000 years ago, a marked contraction of the desert belt occurred during the Neolithic 6,000 years ago. More recently, the late nineteenth century saw a contraction of the desert, with increased rainfall along both the southern margin in the summer tropical rainfall regime and the northern margin with winter extra-tropical rains. By contrast, the recent drought c. 1968–73 represented an expansion of the desert belt along both the southern and northern margin.

The characteristics of Sahel-Soudan rainfall variation described here contradict the frequently assumed climatic simplicity of the region. A more thorough analysis of this climate must consider the region's intermediate position between southern and northern hemispheres, hence the critical role of both; and it must depart from the scenario of a simple dependence of rainfall on the position or intensity of the ITCZ. More emphasis must be placed on secondary systems affecting the region, such as the Soudano-Saharan depressions or Atlas cyclones which act in the transition seasons. There is evidence that these systems played a greater role in the historical past (Nicholson, 1979a) and they may have been a factor in Holocene climate (Flohn, 1979). These systems may not only partially account for increased rainfall in the African subtropics, but also link the tropical and extra-tropical rainfall regimes prevailing to the north and south of the desert.

Acknowledgments

This work was funded in part by the Atmospheric Research Section of the National Science Foundation under their Grants ATM77–21547 given to the University of Virginia and GA–10651 given to the University of Wisconsin. Discussions of the study with J. E. Kutzbach are gratefully acknowledged.

References

Blasing, T. J.: Methods for analyzing climatic variations in the North Pacific Sector and Western North America for the last few centuries. Ph. D. Thesis, Univ. of Wisconsin, Madison (University Microfilms, No. 75–16, 297), 1975, 177 pp.

Blasing, T. J. and H. C. Fritts: Reconstruction of past climatic anomalies in the North Pacific and Western North America from tree-ring data. Quaternary Res. 6, 1976, 563–580.

Bryson, R. A.: Drought in Sahelia: Who or what is to blame? Ecologist 3, 1974, p. 366–371.

Flohn, H.: A scenario of possible future climates – natural and man-made. World Climate Conference, in press.

Kidson, J. W.: Tropical eigenvector analysis and the southern oscillation. Mon. Wea. Rev. 103, 1975, p. 187–196.

Klaus, D.: Periodische und statistische Beziehungen zwischen den jährlichen Häufigkeiten der Großwetterlagen Europas und der räumlichen Verteilung der jährlichen Niederschlagssummen in Teilen Westafrikas. Erdkunde 29, 1975, p. 248–267.

– : Spatial distribution and periodicity of mean annual precipitation south of the Sahara. Arch. f. Met., Geoph., u. Biokl., Ser. B 26, 1978, p. 17–26.

Kraus, E. B.: Subtropical droughts and cross-equatorial energy transports. Mon. Wea. Rev. 105, 1977, p. 1009–1018.

Kutzbach, J. E.: Empirical eigenvectors of sea level pressure, surface temperature and precipitation complexes over North America. J. Appl. Meteor. 6, 1967, p. 791–802.

Lamb, P. J.: Large-scale Tropical Atlantic surface circulation patterns associated with Subsaharan weather anomalies. Tellus 30, 1978, p. 240–251.

Lund, I. A.: Map-pattern classification by statistical methods. J. Appl. Meteor. 2, 1963, p. 56–65.

NAMIAS, J.: Long-range weather forecasting – history, current status and outlook. Bull. Am. Met. Soc. 49, 1968, p. 438–470.

NICHOLSON. S. E.: Climatic variations in the Sahel and other African regions during the past five centuries. J. Arid Envir. 1, 1978, p. 3–24.

– : Saharan climates in historic times: The Sahara and the Nile, M. A. J. WILLIAMS and H. FAURE, ed., A. A. BALKEMA, Rotterdam, in press, 1979a.

– : The nature of rainfall fluctuations in subtropical West Africa, forthcoming, 1979b.

PANOFSKY, H. and G. W. BRIER: Some applications of statistics to meteorolgy. Penn State University, University Park, 1968.

SCHUPELIUS, G. D.: Monsoon rains over West Africa. Tellus 28, 1976, p. 533–536.

WINSTANLEY, D.: Rainfall patterns and general atmospheric circulation. Nature 245, 1973, p. 190–194.

DAS ENTROPIEKONZEPT ZUR ERMITTLUNG RÄUMLICHER EIGENSCHAFTEN VON INNERSTÄDTISCHEN WANDERUNGSVERFLECHTUNGEN AM BEISPIEL LUDWIGSHAFEN/RHEIN

Mit 5 Abbildungen und 4 Tabellen

PAUL GANS

Summary: The concept of entropy for enquiry into spatial qualities of inner-city migratory inter-relations illustrated by the example of Ludwigshafen-on-Rhine

This paper examines migratory inter-weaving at the inner-city level between the urban districts of Ludwigshafen-on-Rhine during the years 1973, 1975 and 1977 by the application of entropy to the conditional probability of immigration and emigration, as well as of the comparison of migration figures actually available and those estimated on the basis of marginal totals. They show that the residential preferences of the population are limited to nearby parts of the town, and that there are hardly any connections between spatially isolated sub-areas of the town. These results are supported by the inclusion of continuity in time of the existence of residential preferences at the level of sub-areas, as well as districts, of the town, and an attempt is made to explain them taking a behavioural and decision-taking theoretical approach.

1. *Thematik*

Ludwigshafen hatte im Jahre 1970 rund 182 000 Einwohner. Seither geht die Bevölkerungszahl stetig zurück und beträgt im Jahre 1977 nur noch ca. 170 000. Die Einwohnerzahl Ludwigshafens zeigt somit die gleiche Entwicklung wie in allen Großstädten der BRD. Der Rückgang ist in erster Linie auf die Abwanderung der Bevölkerung in das Umland zurückzuführen (vgl. Informationen 75, Nr. 2, S. 8). Mit der Erschließung neuer Wohngebiete in den Außenbereichen der Stadt versucht man, dieser Entwicklung entgegenzuwirken.

Bei innerstädtischen Wanderungen liegen vor allem die Wohnung betreffende Wanderungsmotive vor. Für die Wahl der neuen Wohnung spielen auch Wohnpräferenzen eine entscheidende Rolle (vgl. Informationen 75, Nr. 2, S. 39). Es ist daher anzunehmen, daß Zuwanderer neuer Wohngebiete vorzugsweise aus bestimmten Teilbereichen der Stadt kommen. Ziel des Beitrages ist es, die räumlichen Eigenschaften der innerstädtischen Wanderungsverflechtungen zu erfassen und zu versuchen, diese mit Hilfe des verhaltens- und entscheidungstheoretischen Ansatzes zu erklären.

Für die Analyse der räumlichen Zusammenhänge, die Hinweise auf die Wohnpräferenzen der Ludwigshafener Einwohner geben, wird das Entropiekonzept verwendet.

2. *Der verhaltens- und entscheidungstheoretische Ansatz zur Erklärung innerstädtischer Wanderungsverflechtungen*

Der von WOLPERT (1965) in die Wanderungsforschung eingeführte verhaltens- und entscheidungstheoretische Ansatz bildet sowohl einen geeigneten Rahmen zur Erklärung der Frage nach dem „warum“, als auch nach dem „wohin“ bei Wanderungen, denn Wanderungsziel und -richtung werden mit einbezogen (vgl. SIMMONS, 1968, S. 623). Unter Wanderung wird nach ROSEMAN jeder Wohnungswechsel verstanden (ROSEMAN, 1971, S. 590). In diesem Beitrag werden nur solche Wanderungen berücksichtigt, bei denen Herkunfts- und Zielgebiet innerhalb des Stadtkreises Ludwigshafens liegen.

WOLPERT geht nun davon aus, daß ein Haushalt als Entscheidungsträger der Wanderung stets seinen Wohnstandort hinsichtlich verschiedener Komponenten wie Wohnungsgröße, Wohnumfeld, Wohnungsansprüche wertet. Diese Wertung fällt positiv oder negativ aus, je nachdem, ob ein gewisses Befriedigungsniveau am gegenwärtigen Standort erreicht ist oder nicht. WOLPERT führt dazu den Begriff „place utility“ ein, im folgenden mit Standortnutzen übersetzt (WOLPERT, 1965, S. 162). Der Standortnutzen drückt die individuelle Zufriedenheit oder Unzufriedenheit des Haushaltes in bezug auf den gegenwärtigen Wohnstandort aus. Das Befriedigungsniveau wird durch subjektive Vorstellungen des Haushaltes festgelegt. Es ist abhän-