Geof. Int. Vol. 18: 4, 1979. pp. 395-409

CONTRIBUTION TO THE CLIMATOLOGY OF THE TEMPERATURE CONDITIONS IN MEXICO

D. KLAUS*

(Received April 1st, 1980)

RESUMEN

Usando análisis de correlación se determina la relación entre la latitud geográfica, la altitud orográfica y las temperaturas medias mensuales. El efecto de fuente de calor elevado de la Meseta Mexicana se estima en 0.2° C por 1000 m. de altitud. La temperatura como una función de la altitud es menos pronunciada en invierno que en el otoño y el verano.

Las fluctuaciones de largo período de la temperatura en el norte de México muestran valores máximos en un cinturón orientado NO-SE. La variabilidad de la temperatura muestra una dependencia sobre la altitud significativa y positiva.

Mediante análisis de la tendencia de las temperaturas estacionales (1949-1977) es posible mostrar para el norte de México un decrecimiento significativo. Usando análisis de potencia, se observa la oscilación casi bienal en las fluctuaciones de las temperaturas invernales del norte y el centro de la Meseta Mexicana.

* *Rhein. Friedrich-Wilhelms-Universität, Geographische Institute, Franziskanerstr. 2 (am Stockentor) 5300, BONN 1.*

ABSTRACT

The relationship between geographical latitude as well as between orographic altitude and the mean monthly temperatures are being determined by correlation analyses. The elevated-heat-source-effect of the Mexican Meseta may be estimated at 0.2° C per 1000 m of altitude. The temperature as a function of the altitude is less pronounced in winter than in the fall and summer.

Long-term temperature fluctuations show maximum values for a NW-SE oriented belt in northern Mexico. The temperature variability shows a significant positive dependence on altitude. In northern Mexico it is possible to prove a significant temperature decrease for large areas by trend analyses of the seasonal temperatures (1949-1977). The quasi biannual oscillation is reflected by the fluctuations of the winter temperatures in the northern and central Mexican Meseta as will be shown by power spectrum analyses.

1. INTRODUCTION

An attempt is made to describe the seasonal and long-term spatial and temporal temperature fluctuations in Mexico and to interprete their relationship with parameters such as geographic latitude and orographic altitude. For this purpose, 131 stations were selected for which homogenic time series of the monthly temperatures for 1949-1977 are available. The data were put to our disposal on magnetic tape through the courtesy of the "Servicio Meteorológico Nacional de México".

2. CHARACTERISTIC FEATURES OF THE SEASONAL TEMPERATURE REGIME

Maps with the mean monthly temperature distribution for Mexico are already available (Mosiño and García, 1974). Fig. 1 shows the months in which, averaged over the period of observation, the maximum monthly temperatures occur. The primary temperature maximum is reached one to two months earlier in the Meseta than in the coastal plains as a result of the poor maritimity of the elevated locations. South of the Tropic of Cancer the temperature maximum precedes the solstices by approximately 3-4 weeks as a result of the rainy period beginning shortly after the summer solstices and the temperature damping effect connected therewith. In almost the entire Mexican area the secondary maximum is reached one month earlier than the primary temperature maximum.

Fig. 2 shows that the annual temperature amplitude increases steadily in a south-north direction. It becomes evident that extremely low amplitudes occur in southwest Mexico while in the NE part of the country the area of high temperature amplitudes is shifted southward and the area of low temperature amplitudes is shifted far to the north in the NW of Mexico. Thus, an annual temperature fluctuation of 10^{o} C can be observed in NW Mexico at 32^{o} N and in the NE of the country at 20^{o} N. In the NW of Mexico the amplitude remains small due to the upwelling of cold water which reduces the summer temperatures. In the NE of Mexico the winterly Northers strongly reduce the winter temperatures in the coastal plains, causing a high annual temperature amplitude as a result of the extremely high summer temperatures in these areas.

These basic features of the spatial structure of the seasonal temperature fluctuations are of great importance for the interpretation of the relationship between geographic latitude and/or orographic altitude and the monthly temperatures.

3. RELATIONSHIP BETWEEN THE GEOGRAPHIC LATITUDE AND THE REDUCED TEMPERATURES

An attempt is made to determine analytically the complex structures of relations between the geographic latitudes, orographic altitudes and the temperatures by means of linear regression analyses between the geographic latitudes and the seasonal temperatures reduced to sea level. In Fig. 3 the results for the different seasons and altitudes are compiled.

In winter (Dec., Jan., Feb.), the relationship between the geographic latitude and the seasonal temperature is generally negative. The regression coefficients reach values between 0.8 and 0.5 which means that in altitudes above 2000 m the temperatures decrease approximately 0.5° C per degree of latitude, poleward by below 1000 m, the decrease is about 0.8° C (Fig. 3). The different number of stations in the altitude belts separated for analysis located at the different geographical latitudes was not weighed in particular for the regressions. However, when selecting the stations an attempt was made to achieve a spatial random distribution of the station locations.

All correlation coefficients are significant at the 1 % level in winter. Particularly high are the correlation coefficients below 1000 m. Fig. 4 constitutes a good example of the relationship between the geographic latitudes and the dry season temperatures.

Also in the spring (March, April, May) and in the fall (Sep., Oct., Nov.) the poleward temperature changes remain negative or zero. However, they are reduced considerably in comparison to the winter values. In the summer, all stations except those in the coastal plains (not significant), show a temperature increase polewards. This temperature increase is highly significant for the elevated stations and amounts to values between 0.6° C (above 2000 m) and 0.47° C (above 1000 m) per degree of latitude. While in the winter the poleward temperature decrease for the elevated stations is lower than that for stations below 1000 m, the poleward temperature increase in the summer is much greater for elevated stations than for those at lower levels. In winter, this effect is due to the fact that the polar outbreaks of cold air into the tropics mainly influence the temperatures only up to an altitude of 1000-1500 m (Hill, 1969), whereas in the summer, the cloud and precipitation regime is likely to be responsible for this phenomenon. Apart from these effects, however, the elevated Mexican Meseta also reacts as a heating source (Klaus, 1975; Lauer and Klaus, 1975). This heating effect which is noticeable during all seasons reduces (or increases in summer) the normal temperature decrease towards the pole by 0.2° C per 1000 m of increased altitude. As Hastenrath (1968) was able to show, the arrangement of the vegetation belts reflects these heat source effects. For example, the upper forest line in western Guatemala is located at 3800-3900 m and moves upward to more than 4000 m in the central Mexican Volcanoes as a result of the increased altitude and expanse of the central American mountain areas..

4. RELATIONSHIP BETWEEN ALTITUDE AND TEMPERATURE

There is a highly significant relationship between the elevation above sea level and the seasonal temperatures, when considering all Mexican stations. For the fall temperatures, the regression is presented in Fig. 5. Only in spring the temperature decrease drops to about 0.3° C/100 m with altitude, in all the other seasons of the year the gradient is 0.4° C/100 m. In the winter, the coefficients of correlation are at -0.69 and decrease steadily to -0.92 in the fall. The fact that the relationship between altitude and temperature is less strong in winter than in the remaining seasons, probably is attributable to the outbreaks of cold air afflicting the lowlands more frequently than the Meseta. The reduction of the gradient in the spring is due to the heating taking place more rapidly at high elevations when the sun moves northward.

There is no significant relationship between the annual temperature amplitude (Fig. 2) and the altitude.

5. LONG-TERM TEMPERATURE FLUCTUATIONS

a) Spatial pattern of the standard deviation

For the study of the long-term temperature fluctuations the monthly temperature values of the 131 selected Mexican stations were analyzed for the period 1949-1977. Fig. 6 shows the standard deviations of the annual temperatures. For the months January and July very similar spatial distributions of the standard deviations occur.

The area of high standard deviations extends from NW-SE of Mexico and includes large areas of the Gulf coast. Values of 3-4° C are observable at isolated stations. The spatial pattern of the standard deviation gives rise to the assumption that disturbances originating in the extra tropical west wind drift are mainly causing the temperature fluctuations in Mexico. It is very likely that the Northers (Externbrink, 1937) penetrating from the NW and north into the Mexican region as well as the northward extension of the tropical precipitation belt are of great importance here.

Statistically, there is no relationship between the altitude and the standard deviation. This applies to seasonal as well as annual temperature standard deviations. When comparing the standard deviation with the mean of the respective station, the spatial pattern of this parameter (variability) changes. Extreme values now occur in a NW-SE directed area which, however, only extend to the Gulf coast in limited areas. Between the quotient of the standard deviation and the mean values and the orographic altitude there is a significant correlative relationship which in winter shows a variability increase by approximately 0.2° C/100 m and in the summer by only about 0.1° C/100 m.

b) Trend analysis

On the basis of very few homogeneous temperature time series Sánchez and Kutzbach (1974) have proved a cooling trend for large areas of central and northern Mexico for the Sixties compared with the "normal period" (1931-1961). The 131 temperature time series used in this paper date back only to the Forties. In other words, a comparison with the "normal period" is impossible.

An overview of the temperature development in Mexico can be given by a trend analysis of the temperature time series. Fig. 7 presents the correlation coefficients of a linear trend analysis for the temperature time series of the dry season (1949-1977). Correlation coefficients greater than 0.5 may be considered as highly significant (1 %). A general temperature decrease for large areas is not recognizable. However, a NW-SE oriented area in which high values of standard deviation were already confirmed, shows frequent temperature decreases. The highest temperature decreases (1° C per 10 years) are marked by circles. On the other hand, temperature increases are observable in parts of central and southern Mexico.

While the map of temperature deviations prepared by Sánchez and Kutzbach (1974) implies a strong increase of cold air outbreaks in the lee of the Rocky Mountains, the significant negative correlation coefficients in Fig. 7 point to a frequency increase of the Northers of the Pacific type.

Temperature decreases in northern Mexico are characteristic also for the rainy season (Fig. 8). Significant cooling effects are observable in large areas. The question whether the reason of this negative temperature trend also observable in SW Mexico is attributable to an equatorward shift of the circulation belts as must be concluded from the studies by Namias (1970), Rowntree (1972), Berryman (1973) as well as by Jauregui and Klaus (1975), cannot be answered here.

c) The quasi biennial fluctuation of the seasonal temperatures

From all parts of the world an almost two-year periodicity of important climatic elements has repeatedly been confirmed. Power spectrum analyses have been carried out separately for the seasons for all 131 stations. Fig. 9 presents the variance distribution for the winter month for the 2.2 year interval. For this interval it was possible to explain maximum portions of variance during all seasons for the majority of stations.

When comparing the variance portions with the white noise continuum it becomes evident that explained variance portions greater than 12.5 % can only be obtained at random in not more than 5 % of all cases.

The spatial pattern of significant variance values is oriented in a NW-SE direction and shows maximum values in the Mexican Meseta. At isolated stations in Yucatan and SW Mexico quasi biennial oscillations of the temperature are recognizable.

The cause of the almost two-year oscillation is controversial. Certain connections with the sunspots are being discussed. It is more or less certain that the intensity fluctuations of the polar west winds temporarily reflect the quasi biennial oscillation (Lamb, 1972). As the frequency of cold air outbreaks in the tropics correlate with the intensity of the polar west winds, certain connections may be assumed here.

ACKNOWLEDGMENTS

I would like to thank Dr. E. Jáuregui for helpful discussions and his assistance in procuring the data. Mr Thiel assisted me in translating this paper and Miss D. Klöckner carried out the final drawings.

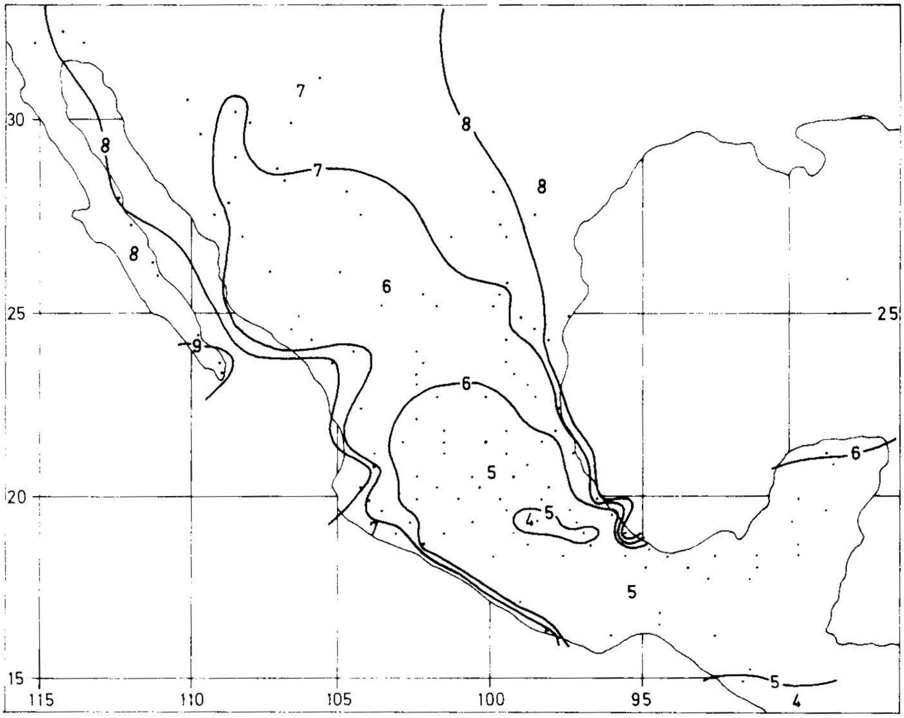

Fig. 1: Month of occurrence of the maximum annual temperatures. The points mark the location of the selected stations.

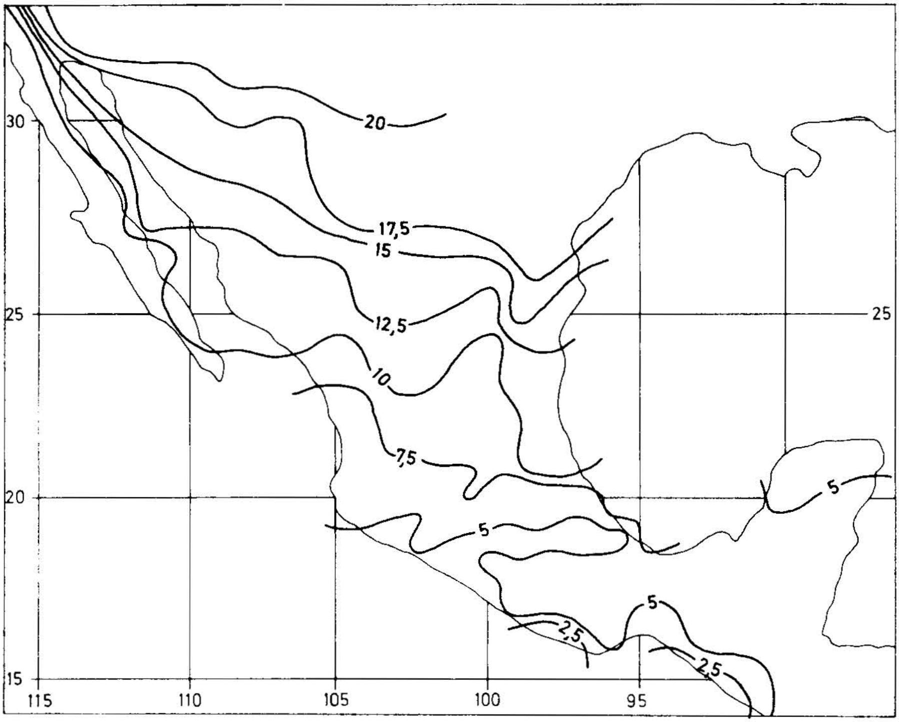

Fig. 2: Mean annual temperature amplitude for 1949-1977.

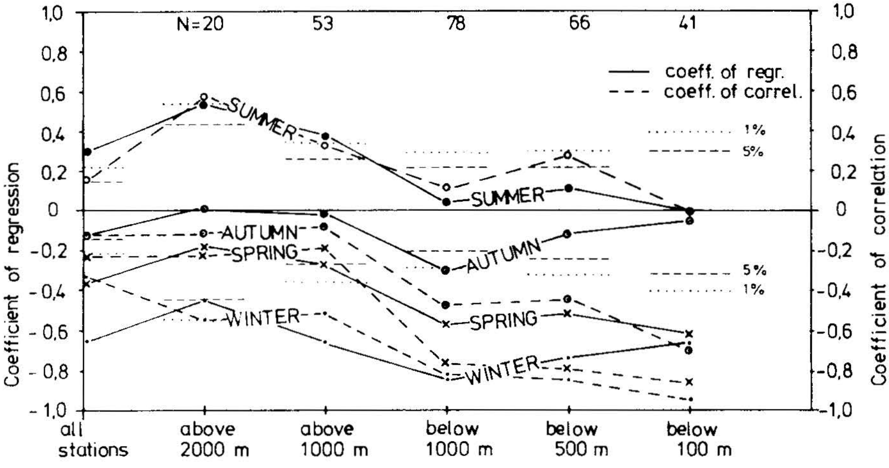

Fig. 3: Correlative relationship between geographic latitude and reduced seasonal temperature as a function of the orographic altitude of the stations.

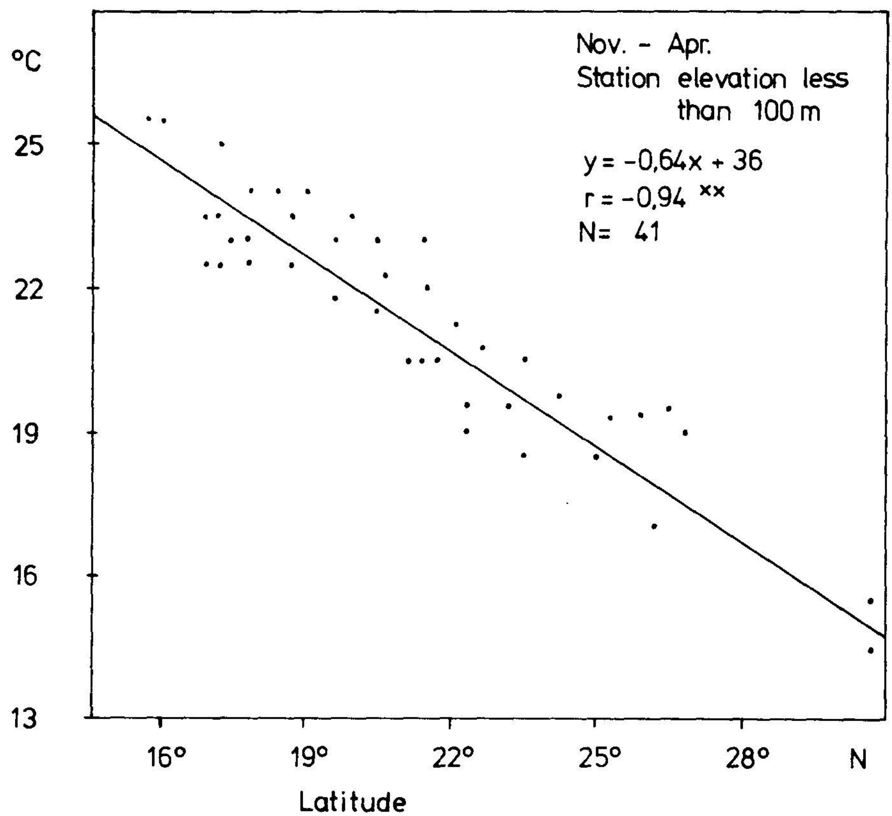

Fig. 4: Linear regression between geographic latitude and the reduced dry season temperatures of the stations below 100 m.

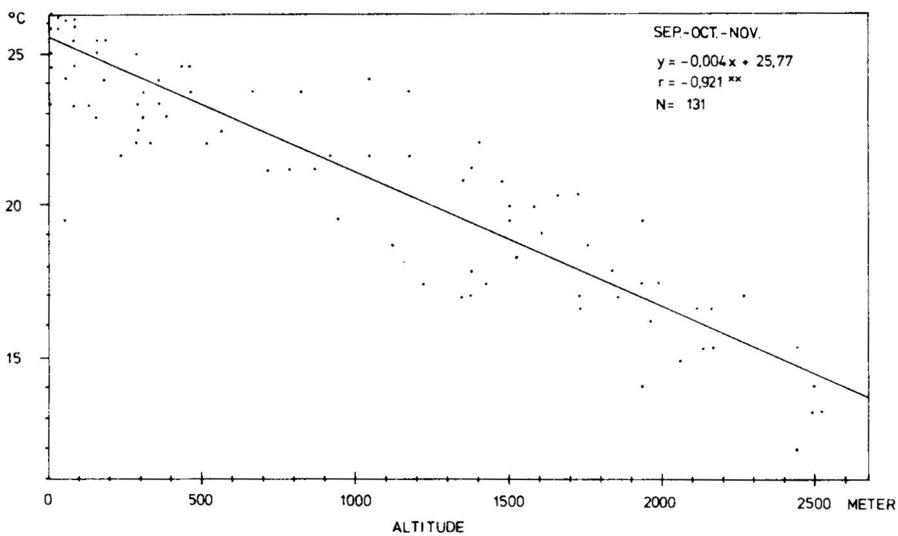

Fig. 5: Linear regression between the orographic altitude and the fall temperatures for all stations selected.

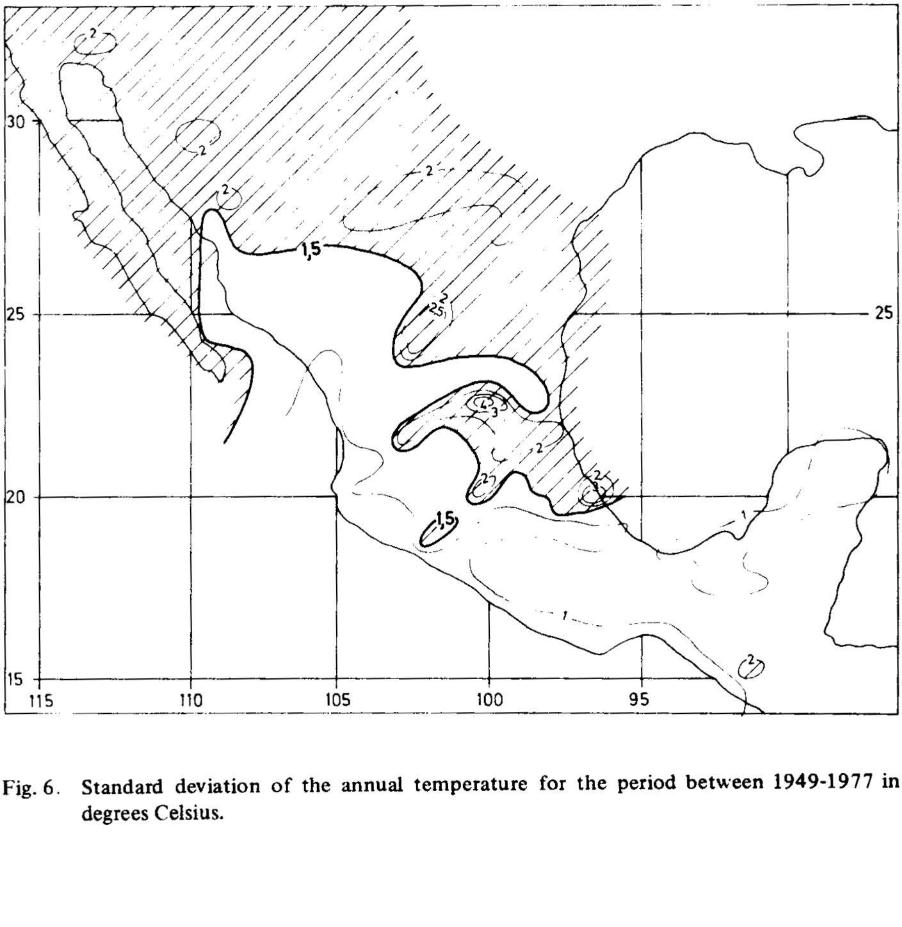

Fig. 6. Standard deviation of the annual temperature for the period between 1949-1977 in degrees Celsius.

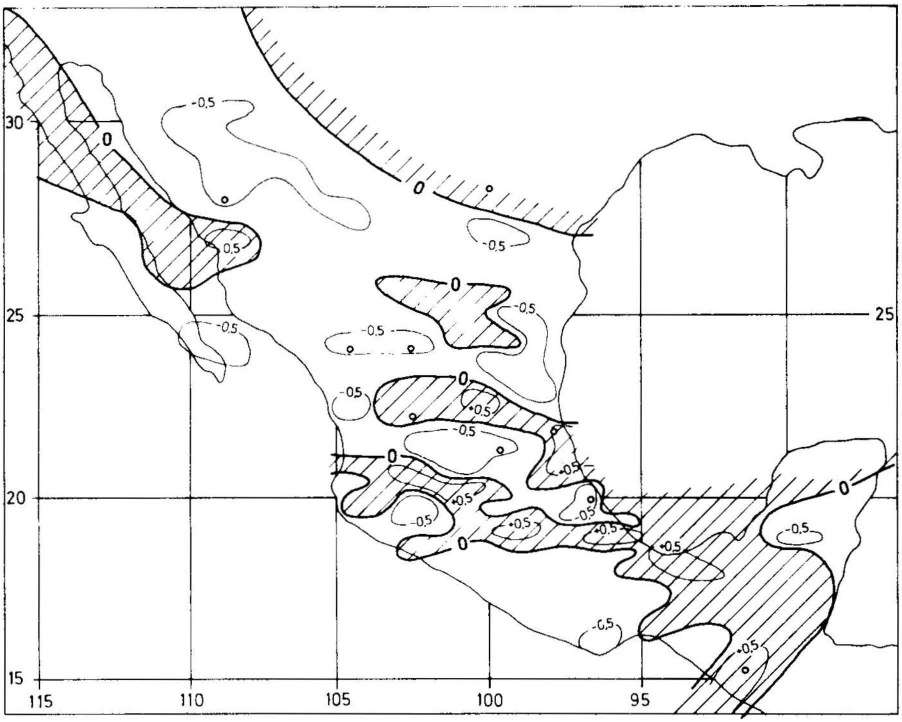

Fig. 7: Correlation coefficients of a linear trend analysis of the dry season temperatures for 1949-1977.
Areas with positive correlation coefficients are marked by stripes; the circles mark those stations at which the increase and/or decrease of the temperature amounts to more than 1^{o} C per 10 years.

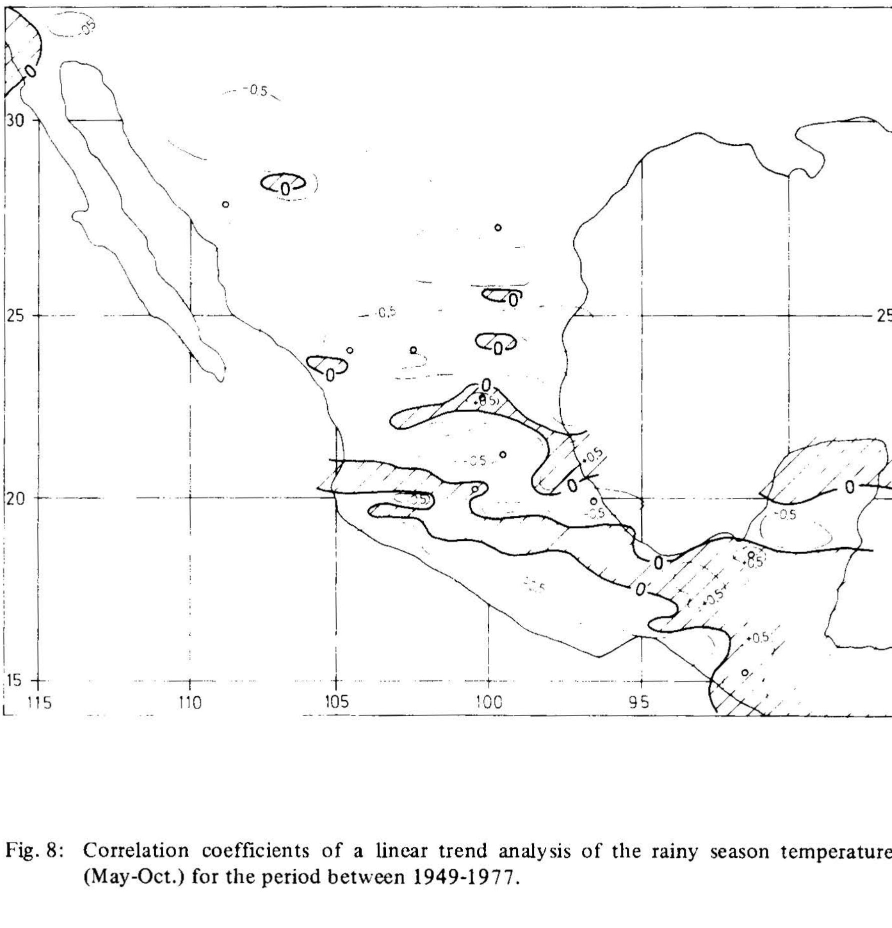

Fig. 8: Correlation coefficients of a linear trend analysis of the rainy season temperatures (May-Oct.) for the period between 1949-1977.

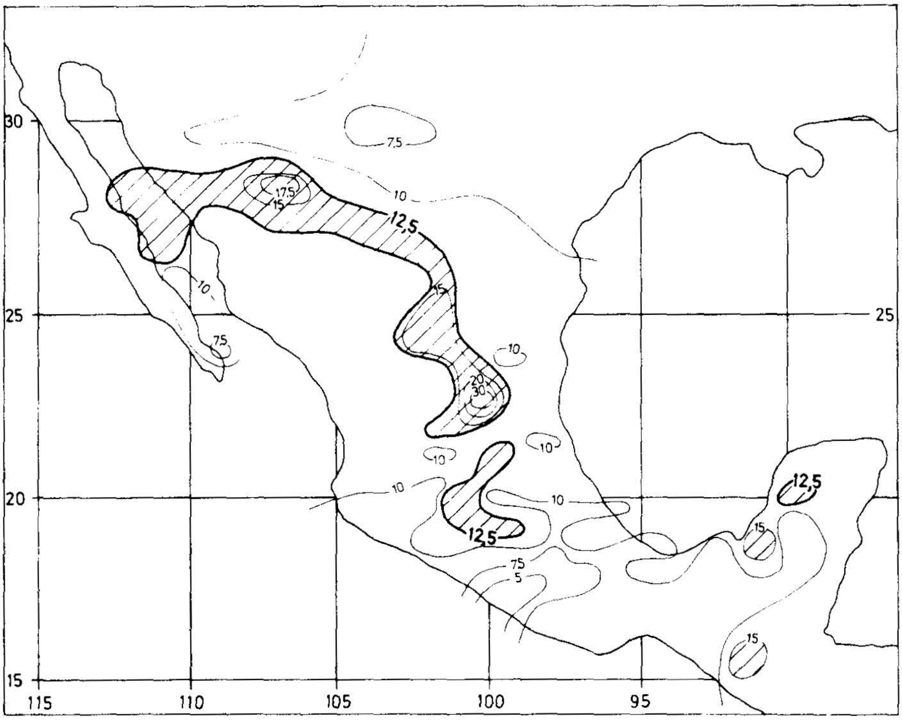

Fig. 9: Explained variance for the quasi biennial period (2.2 years) for the winter temperature time series of the interval from 1949-1977, determined by a power spectrum analysis. Variance portions exceeding 12.5 % are significant at the 5 % level.

BIBLIOGRAPHY

BERRYMAN, B. F., 1973. Large scale lower-tropospheric circulation change, 1951-1970. Dept. Meteorol., Univ. of Wisconsin, Wisconsin.

EXTERNBRINK, H., 1937. Kaltlufteinbrüche in die Tropen. Arch. d. Dtsch. Seewarte u.d. Marineobservatoriums, Vol. 57/7, Hambg.

HASTENRATH, S., 1968. Certain aspects of the three-dimensional distribution of climate and vegetation belts in the mountains of central America and southern Mexico. *Colloqu. Geographicum,* Vol. 9, p. 122-129.

HILL, J. B., 1969. Temperature variability and synoptic cold fronts in the winter climate of Mexico. Mc Gill University, Montreal.

JAUREGUI, E. and D. KLAUS, 1975. Some aspects of climate fluctuations and their relationship to rainfall in Mexico, XVI Assembly of Intern. Union Geodesy and Geophys., Grenoble, p.118.

KLAUS, D., 1975. Niederschlagsgenese und Niederschlagsverteilung im Hochbecken von Puebla-Tlaxcala, Bonner Geograph. Abhdlg. Heft 53, Bonn.

LAMB, H. H., 1972. Climate: Present, Past and Future. Vol. 1, Methuen, London.

LAUER, W., D. KLAUS, 1975. The thermal circulation of the central Mexican Meseta within influence of the trade winds. *Arch. Meteorol. Geophys. Biokl.,* Vol. 23, p. 343-366.

MOSIÑO, P.A., E. GARCIA, 1974. The Climate of Mexico. In: Ed. Bryson, R.A. and Hare, F. K. (Ed.): Climates of North America. World Survey of Climatology, Vol. 11, p. 345-391.

NAMIAS, J., 1970. Climatic anomaly over the United States during the 1960's. *Science,* Vol. 170, p. 741-743.

ROWNTREE, P. R., 1972. The influence of tropical east Pacific Ocean temperatures on the atmosphere. *Quart. J. Roy. Met. Soc.* Vol. 28, p. 290-321.

SANCHEZ, W. A., J. E. KUTZBACH, 1974. Climate of the American Tropics and Subtropics in the 1960's and possible comparisons with climatic variations of the last Millenium. *Quart. Research,* Vol. 4, p. 128-135.