INFLUENCE OF THE PACIFIC AND ATLANTIC OCEANS ON THE BEHAVIOR OF RAINFALL IN VENEZUELA

María Isabel Rojas Polanco

The Ocean Statistical Modeling System (SIMOC), based on the Canonic Correlation Analysis, was applied in this research in order to study the relationship between the Atlantic and Pacific Oceans and the anomalies of rainfall registered in Venezuela. This would aid in determining the area and month of greater impact for forecasting rainfall during the rainy season. To be able to study the oceans as incidence factors in rainfall behavior during the rainy season in Venezuela the Sea Surface Temperature (SST) was selected as a macroclimatic variable. This information was obtained from the series of data reconstructed by the National Center for Environmental Prediction (NCEP), starting with COADS (Comprehensive Oceanic and Atmospheric Data Set) with a two-degree latitude by longitude resolution, in the 1950-1992 period, and the Climate Prediction Center (CPC) data from the 1993-1997 period. The rainfall data from the period between 1951 and 1995 was used as a dependent field. In the selection of the predictor field with greater impact on rainfall anomalies in the rainy season, the assay that explains the 80% variability with the least number of modes and the first component in the predictor field to retain the largest variability percentage, were examined. To determine the most representative month and the region of greater influence on the rainfall pattern, an examination was made of the percentage of pluviometric stations that presented a significant correlation equal to or greater than the absolute value of 0.4 with the predictor field in the selected month. Validation of the model was carried out by applying a multiple regression during the 1981-1995 period. In this manner it was determined that the greatest consideration (variability in the number of modes) occurred in the area of the Atlantic Ocean during the month of March, at which time 62% of the stations with the most correlation, exist, with average rainfall anomalies registered during the months of April, May, June, July (A_J). This period is the first quarter of the rainy season in most of the Venezuelan territory. It has a unimodal rainfall rate (maximum in June), and is directly affected by the Tropical Convergence activity. The second highest value considered was in the Pacific Ocean during the month of January. It had the greatest influence on rainfall in the month of February, with an incidence rate of 32% in stations that coincide with areas where there is a semiannual pattern and which complete two oscillations a year between the rainy and dry seasons.

1. INTRODUCTION

Venezuela is located between 0° 39' to 12° 12' latitude north and 59° 47' to 73° 23' longitude west. Thus in large measure, its weather is affected by the constant influence of northeastern and eastern winds from the lower troposphere. In relation to the variability of atmospheric circulation in the extreme summer or winter periods (northern hemisphere) we found that in July the winds from the east extend from the surface to the high troposphere. During the summer months (May to September) convergence predominates above the Caribbean Sea, from the surface level to 300 mb (Hastenrath, 1976). Hastenrath also emphasizes the presence of separate high pressure cells in the Caribbean-Atlantic and the supremacy of a northern component of strong winds in the high troposphere which appears to be associated with the occurrence of a dry period in the rainy season.

In September and October convergence and the rising movement of air through the troposphere increases again and in this manner favors rainfall generating mechanisms. A more or less abrupt change towards the type of circulation that occurs in winter is observed towards the end of October when the Caribbean starts to increase the divergence in the lower levels and towards 400 mb, from November to February.

Another planetary element that controls the climatic conditions of the country is the Inter-Tropical Convergence Zone (ZCIT), which has a profound influence on atmospheric conditions. Enfield and Alfaro (1997) point out that this situation will be dominant when a dipolar meridional configuration takes place between the SST of the Atlantic and Pacific Oceans (nonsymmetrical with the ZCIT), depending on atmospheric stability, wind fields and the tropical thalweg.

Starting with the systems mentioned above and because of the topography above the national territory, up to 18 prototypes of annual rainfall distribution have been determined in the different regions of the country. If we generalize, two generic patterns emerge from this complex variability of pluviometric systems: the unimodal pattern with a maximum that occurs during the summer (astronomic – H.N.), which is predominant in almost all the Venezuelan territory, and the bimodal that is characteristic of all the region north and west of the Andean mountain range, as well as the coastal areas, with a main maximum in the month of October and a secondary one in the month of April.

The main objective of this paper was to apply the SIMOC model in order to study the relationship of the Atlantic and Pacific Oceans with respect to rainfall anomalies registered in Venezuela and to determine the area of greater incidence and the month for the purpose of forecasting rainfall in the rainy season.

2. DATA BASE

To study the thermodynamic behavior registered in the oceans as incidence factors in rainfall behavior during the rainy season in Venezuela the Sea Surface Temperature (SST) was selected as a macroclimatic variable. This information was obtained from the series of data reconstructed by the National Center for Environmental Prediction (NCEP), starting with COADS (Comprehensive Oceanic and Atmospheric Data Set) with a two-degree latitude by longitude resolution, in the 1950-1992 period, and the Climate Prediction Center (CPC) data from the 1993-1997 period.

The series of monthly rainfall data was obtained from the Red Pluviometrica Nacional de Venezuela (Venezuelan National Pluviometric Network) attached to the Hydrology and Meteorology Office of the Ministry of the Environment and of Renewable Natural Resources. 129 stations were selected from a period between 1951 and 1995, which were submitted to a quality control beforehand and to an estimation of 6% of missing data. Temporary linear interpolation was applied based on the total rainfall of the former and subsequent months.

3. METHODOLOGY

The Ocean Statistical Modeling System, SIMOC, developed by C. Repelli in 1996 was applied in this paper. This model was created in order to make more operative all calculating procedures required for the application and validation of the Canonic Correlation Analysis, CCA. It also permits access to the macroclimatic data base and geographic visualization of results, thus representing a valuable tool to carry out studies in diagnosis and for forecasting in the fields of climatological variables.

The CCA is considered the hierarchic summit in regression models. It is a multi-variable statistical procedure by means of which linear combinations of variables from a predictor field can be made as effective as possible, which explains the greater variability in another set of dependent variables. In this sense the method has been used extensively in climatology (Barnett and Preisendorfer, 1987; Barnston and Ropelewski, 1991; Repelli, 1996) and also as an effective statistical technique for forecasting purposes.

In order to determine the relationship existing between rainfall anomalies during the rainy season in Venezuela and temperature anomalies above sea level registered in the Atlantic and Pacific Oceans the predictor field was defined as the one resulting from measurements of SST, and the dependent field, as the one made from rainfall data in the period between 1951 and 1995. In this manner we proceeded to design three large experiments: a) Atlantic Ocean (30° N – 30° S; 80° W – 0° W); b) Pacific Ocean (30° N – 30° S; 80° - 160° W) and c) Oceans: Atlantic – Pacific (30° N – 30° S; 160° W – 0° W), in several months of rainfall lag from February to August, in order to determine the month in which the predictor field registered greater influence in the months of January, February, March, April and May in the dependent field, as can be seen in Table 1.

PREDICTOR	JANUARY	FEBRUARY	MARCH	APRIL	MAY
PREDICTANT					
FEB	X				
MAR	X	X			
APR	X	X	X		
MAY	X	X	X	X	
JUN	X	X	X	X	X
JUL	X	X	X	X	X
AUGUST	X	X	X	X	X
APR/MAY	X	X	X	X	X
APR/MAY/JUN	X	X	X	X	X
MAY/JUN/JUL	X	X	X	X	X
JUN/JUL/AUG	X	X	X	X	X
APR/MAY/JUN/JUL	X	X	X	X	X

Table 1. Test Lags

Afterward each set of data was analyzed for Empirical Orthogonal Functions (EOF) in order to eliminate instabilities and noises existing in the predictor field, as well as in the dependent field, thus making as effective as possible the maximizing solution given in CCA. Upon applying the EOF, an indication was made in each experiment that the number of components (modes) retained should explain the 80% variability contained in the defined fields, to subsequently solve the problem of canonical correlations. During this exploratory stage we worked within the period from 1951 – 1980.

To select the predictor field with greater impact on rainfall anomalies in the rainy season the experiment was considered among all the tests performed in which the 80% variability was explained with the least number of modes and in which the larger percentage of variability in the first component of the predictor field, would be explained. Besides this, the value of the cumulative squared covariant fraction (CSCF) was compared, which indicates how good the method is for explaining the covariant matrix observed among the fields using the selected n modes (Bretherton, Smith; 1992).

The next step was to determine the most representative lag and the region of greater influence in the rainfall pattern, for which the percentage of pluviometric stations were analyzed in the different lags, which presented a significant correlation greater or equal to the absolute value of 0.4 with the predictor field in the chosen month.

Lastly, the forecasting model was validated for the period from 1981 to 1995, with a multiple regression model, the parameters of which were defined by the coefficients of the canonical components calculated.

4. RESULTS

When the basic statistics (average and standard deviation) had been calculated, the anomalies had been normalized and the noise eliminated from the data, in each of the experiments we obtained the number of modes retained to explain the 80% variability in the predictor field, as well as in the dependent field.

The first canonical component in the predictor field of each of the experiments was considered as the incidence factor of the area in the selected forecast month.

In this manner and according to the methodology presented above for selecting the predictor month and field, we observed (Table 2) the balance (variability in number of modes) that represented the area of the Atlantic Ocean in the month of March, and the Pacific Ocean in the month of January, in relation to other tests performed.

TABLE 1.

Predictor	JANUARY		FEBRUARY		MARCH		APRIL		MAY	
	MOD	VAR	MOD	VAR	MOD	VAR	MOD	VAR	MOD	VAR
PACIFIC	**9**	**35.5**	11	30.9	11	28.7	11	29.7	11	29.3
ATLANTIC	9	22.61	9	23.1	**8**	**30.5**	8	28.6	9	26.5
ATLANTIC- PACIFIC	12	25.81	12	23.8	12	24.1	12	24.3	13	22.7

Based on these results we observed that for the month of March and with a month's lag (Figure 1) 62% of stations exist with average rainfall anomalies registered during the months of April, May, June and July (a_j). They are more correlated with the situation that takes place in the Atlantic Ocean. A similar situation occurred in the period between April and June (amj), the first quarter of the rainy season in most of the Venezuelan territory with a unimodal rainfall system (with a maximum in June), affected directly by the Tropical Convergence activity. Besides, emphasis should be made on the slight incidence that the Pacific has (25% less), or the combined effect of both oceans during these months.

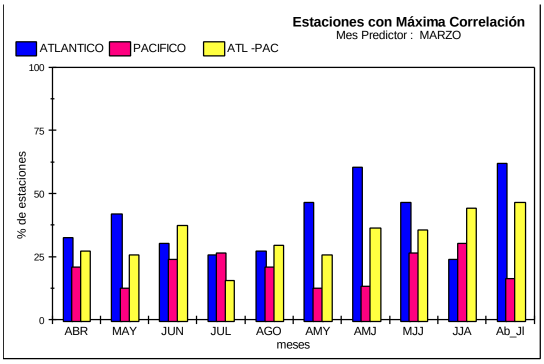

Fig. 1. Percentage of stations with greater Correlation. Month: March

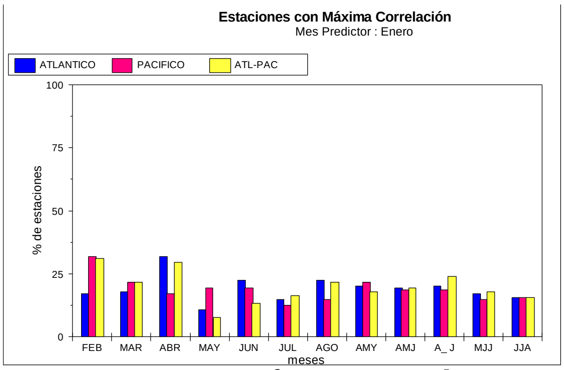

Fig.2. Percentage of stations with greater Correlation. Month: January

In considering the month of January as a possible predictor (Fig.2), we observed that less than 35% of the pluviometric stations were significantly correlated with the STT registered in each of the defined predictor fields. The greater incidence of 32% took place in the month of February, which indicates the possible influence of temperature anomalies of the Pacific on the Venezuelan territory in areas with a a semiannual pattern and which complete two oscillations a year between the rainy and dry seasons.

In Figure 3 the areas of greater influence of the Atlantic in the month of March are shown in relation to the rainy season, which is between April and July. There is a greater correlation with the north-central and eastern regions of the country (Fig. 4). In Fig. 5 the SST pattern of the Pacific Ocean in January can be seen. It has a greater influence on the rainfall field in February, and spatially (Fig. 6) a greater correlation is present in the western region of Venezuela.

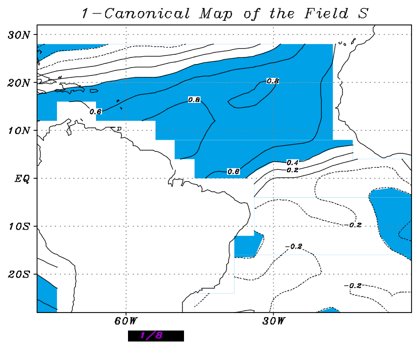

Fig.3 Area of Influence of the Atlantic Ocean (Map G)

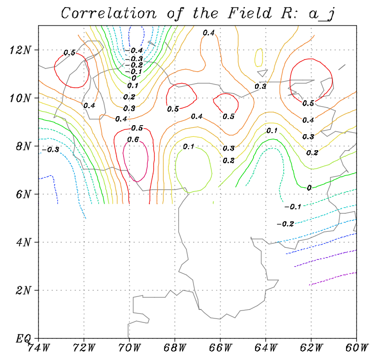

Fig.4 Area of Incidence in Venezuela

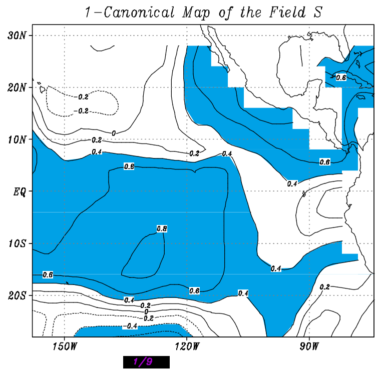

Fig.5 Area of Influence of the Pacífic Ocean (Map G)

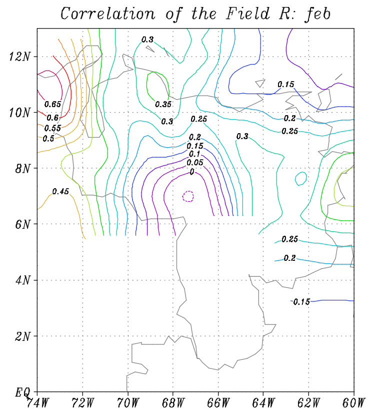

Fig.6 Area of Incidence in Venezuela

In verifying the model for the Area of the Atlantic Ocean in March with the values observed in the April/May/June/July period, a correlation of 0.97 was obtained for the first temporal canonical **u**(**t**) and a 0.87 for the second component **v**(**t**), with CSCF equal to 0.92. These results show that the model presented a good adjustment upon estimating the values during the rainy season in the north-central and eastern regions of the country, mostly affected by the Atlantic Ocean.

With respect to the Pacific Ocean, in January and in relation to the rainfall anomalies observed for the month of February, the temporal canonical components (**u** and **v**) associated with the experiment showed a correlation of 0.92 and 0.89, respectively, and the CFSC presented a value equal to 0.85. Thus we can affirm that the model can be used to estimate the values of the first rainy season to take place in the western region of the Venezuelan territory.

6.-CONCLUSIONS

- The results showed a difference between the possible effect that SST patterns in the Atlantic and Pacific Oceans have on the more frequent rainfall systems registered in Venezuela.
- The Tropical North Atlantic area can be considered the main factor of influence of rainfall anomalies registered in the period between April and July.
- The region of Venezuela most affected by the pattern of temperature anomalies observed in the Pacific Ocean is situated in the area adjacent to the western slope of the Andean mountain range, between 71 and 74 degrees longitude west.
- The model proved to have a good adjustment both in the Atlantic, as well as the Pacific Oceans. Therefore, in both cases it could be used as an efficient forecasting tool for the different regions of the country.

ACKNOWLEDGEMENT

The author is grateful to the Centro de Prevision del Tiempo y Estudios Climaticos – cptec, for the cooperation it rendered in the accomplishment of this paper. This paper was financed by the Instituto Inter Americano de Cambios Globales, IAI, through the Regional Cooperation Program for Activities which supports research for global change in IAI countries. Project: IAI-WMO-GEF-RLA/92/G34 .

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