v. 3, n. 32, 2023

Journal of
Engineering
Research

# ANALYSIS OF THE CONCENTRATION AND SOME PRECIPITATION INDICES IN THE STATE OF JALISCO, MEXICO

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**Abstract:** This work presents an analysis of the behavior of precipitation concentration in the state of Jalisco. The study of precipitation concentration has recently been used as a tool to analyze the statistical structure of precipitation. In particular, the precipitation concentration indices analyze the contribution of the days with the highest precipitation to the total precipitation. The objective of this work consisted of the analysis of the behavior of precipitation using the precipitation concentration index, in addition to five precipitation indices developed by the Team of Experts in the Monitoring and Detection of Climate Change and Indices (ETCCDMI), in both cases taking as reference the rainfall data of the state of Jalisco, Mexico. With the results of each station, a spatial interpolation was carried out to know the variations of the index throughout the territory of the state of Jalisco. The results obtained for the concentration index range between 0.487 and 0.687, these values are considered in the literature as values for medium and high concentrations. The highest values of the concentration index are more frequent along the coastal zone of the state, which could suggest that cyclonic activity in this zone plays an important role in the behavior of precipitation, although some important values are also observed in the central and northern regions of the state. Regarding the ETCCDMI indices, a decreasing trend was mainly observed in the case of total annual precipitation (PRCPTOT) and on the other hand an increase in the index of consecutive dry days (CDD), the latter being able to influence the way in which Precipitation is concentrated throughout the year.

**Keywords:** precipitation; precipitation concentration; concentration index

## INTRODUCTION

The study of precipitation is of primary interest for both climatology and hydrology due to the high spatial and temporal variability that this variable presents. In particular, regarding its temporal behavior Cortesi et al. (2012) point out that precipitation shows the behavior of a process compressed in time, that is, that a few days concentrate most of the total precipitation that occurs in some place. This, according to Ferrari et al. (2013) could have problematic consequences in activities related to agriculture, energy production and the supply of drinking water, etc. For their part, Liu and Xu (2016) and Zamani et al. (2018) mention that the high concentration of precipitation could generate problems related to droughts, floods, as well as soil erosion. On the other hand, Trenberth et al. (2007) mention based on the update of the fourth evaluation report of the Intergovernmental Panel on Climate Change that extreme precipitation events have been increasing in recent years, that is, precipitation is becoming higher than the historical average. However, according to Li et al. (2011) few studies have analyzed the concentration of precipitation compared with the studies carried out to know the frequency and intensity of this climatological variable.

The concentration of precipitation has been analyzed mainly, at a monthly level, with the precipitation concentration index proposed by Oliver (1980) and at a daily level with the concentration index of Martin-Vide (2004). The Martin-Vide (2004) proposal states that precipitation can be a discrete process that can be modeled by negative exponential distributions where a few days of rain concentrate the greatest amount of total precipitation. Thus, the concentration index proposed by Martin-Vide (2004) allows exploring the contribution of the days with the highest rainfall to the amount of total precipitation. The aforementioned index is based on the Lorenz curve, which was initially proposed by economists to evaluate the distributions of income and well-being. To date, the precipitation concentration index has been widely used to analyze the statistical characteristics of daily precipitation worldwide. An example of this is the work carried out by Martin-Vide (2004) in Spain, Alijani et al. (2008) in Iran, Zhang et al. (2009) in the Pearl River basin in China, Benhamrouche and Martín-Vide (2012) in Spain, Cortesi et al. (2012) in Europe, Suhaila and Jemain (2012) in Malaysia, Shi et al. (2013) in the Lancang River basin in China, Shi et al. (2014) in the upper Huai River in China, Benhamrouche et al. (2015) in Algeria, Patel and Shete (2015) in India, Yesilirmak and Atatanir (2016) in Turkey, Mayer et al. (2017) in the Canary Islands of Spain, Serrano-Notivoli et al. (2017) in Spain, Zubieta et al. (2017) in Peru, Llano (2018) in Argentina, and Vyshkvarkova et al. (2018) in southern Russia, to name just a few.

In Mexico, studies related to precipitation have focused mainly on the analysis of the behavior and trend of this variable, as shown in the studies of García (2003) and Méndez et al. (2008), on the other hand, Giddings et al. (2005) have studied the precipitation series according to the standardized precipitation index (SPI) and have developed a zoning of the country according to the behavior of this index. The aforementioned studies conclude that in Mexico important fluctuations have been observed in the behavior of precipitation, which could generate important risks mainly in regions where significant increases in annual precipitation have been observed. In this sense, the study of precipitation concentration could represent a complementary tool to the previous analyses. However, in Mexico the study of precipitation concentration has only been addressed in the works of Roblero-Hidalgo et al. (2018) for the Río Grande de Morelia basin, in the state of Michoacán, and at the national level by Núñez-González (2020). Thus, the objective of this work is to analyze the behavior of precipitation using the precipitation concentration index in combination with some of the indices developed by the Team of Experts in the Monitoring and Detection of Climate Change and Indices (ETCCDMI). taking as a case study the rainfall information of the state of Jalisco. The above will allow us to know the areas most susceptible to high concentrations of this climatological variable.

## MATERIALS AND METHODS

To carry out this work, daily precipitation data were obtained from 37 weather stations located in the state of Jalisco through the website of the National Meteorological Service (SMN, 2018). The precipitation series used cover the period 1970 – 2010, coinciding with the period reported in several publications on the concentration of precipitation in other countries. The spatial distribution of the climatological stations as well as the behavior of the average annual precipitation in the study area are presented in Figure 1. The homogeneity of the precipitation data series was tested using the methodology proposed by Wang et al. (2010).

The analysis of the concentration of precipitation in the state of Jalisco was based on the behavior of the concentration index proposed by Martin-Vide (2004). To calculate this index, daily precipitation data are classified into 1 mm categories in ascending order. Afterwards, the accumulated sum of rainy days and precipitation amounts are calculated, which are subsequently converted into accumulated frequencies of rainy days (variable x) and their corresponding accumulated frequencies of precipitation (variable y). With these data, a function of the form presented in equation 1 is fitted with the least squares method:

$$y = axe^{bx} \qquad (1)$$

where a and b are the regression constants.

The Martin-Vide (2004) concentration index is defined as

$$CI = \frac{A}{5000} \qquad (2)$$

where $A$ represents the area between the equidistribution line

$$y = x \qquad (3)$$

and the curve fitted with equation 1, and can be calculated as

$$A = 5000 - \int_0^{100} axe^{bx}dx \qquad (4)$$

where the value of 5000 corresponds to the area of the lower triangle that is formed in the plane from the equidistribution line represented by equation 3.

On the other hand, with the purpose of contrasting the results obtained from the analysis of precipitation concentration, the indices presented in Table 1 were calculated, which were developed by the Team of Experts in the Monitoring and Detection of Climate Change and Indices (ETCCDMI). These indices have the characteristic that they are easy to calculate and update, of interest and validity on a global, regional and local scale; They are easy to understand and compare, while at the same time they have a clear physical meaning (Brunet, 2010). The complete description of these indices is presented in the work of Peterson et al. (2001). The linear trend was calculated for the series produced for each of the indices based on the slope estimator proposed by Sen (1968), which is based on the Kendall range test.

| ID | Index | Definition |
|---|---|---|
| PRCPTOT | Total annual precipitation | Total annual precipitation (RR>=1mm) |
| SDII | Simple daily intensity index | Total annual precipitation divided by the number of days with rain |
| RX1day | Maximum rainfall in a day | Maximum precipitation in a day |
| CDD | Consecutive dry days | Maximum number of consecutive days with RR<1mm |
| CWD | Consecutive days with rain | Maximum number of consecutive days with RR>=1mm |

Table 1 ETCCDMI precipitation indices used

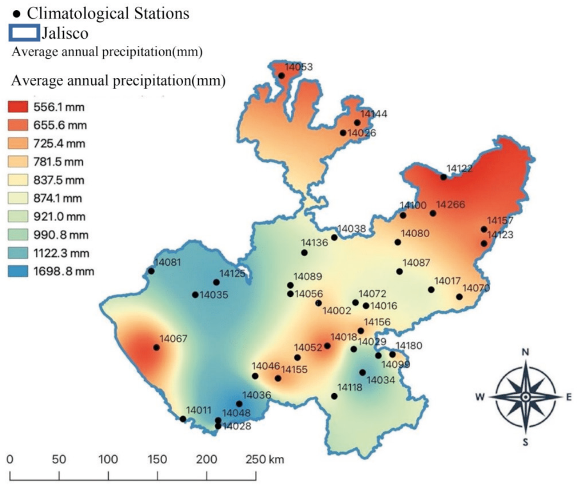


Figure 1. Location of the climatological stations. Source: self made.

## RESULTS

The spatial distribution of the concentration index (CI) of daily precipitation is presented in Figure 2. In this figure it can be seen that the range of values between which the CI oscillates goes from 0.487 to 0.687. This range of values coincides with what was found in the works of Martín-Vide (2004) in Spain, Suhaila and Jemain in Malaysia, Shi et al. (2013) in China, Mayer et al. (2017) in Spain, Zubieta et al. (2017) in Peru, and Vyshkvarkova et al. (2018) in Russia, among others. The lowest CI values are associated with places where the 25% of the wettest days concentrate about 59% of the total precipitation while the highest CI values are associated with places where the 25% of the rainiest days can concentrating up to 77% of the precipitation. The extreme CI values were observed at stations 14125 San Gregorio (minimum) and 14028 Cihuatlán (maximum).

The low values of the CI indicate a more uniform distribution of precipitation than the high values, which agrees with these stations, since while station 14125 is located in a mountain area, station 14028 is located on the coast of Jalisco where the presence of cyclonic precipitation is common (García, 2003), which can contribute to the high concentration of precipitation on a few days of the year. The range of values observed in the IQ in the state of Jalisco also agrees with the work carried out by Roblero-Hidalgo et al. (2018) in the Río Grande de Morelia basin, in the state of Michoacán, although in their case the range of CI values was a little lower, namely 0.476 - 0.607. Furthermore, it can be seen that the most important difference with respect to what was observed in the Río Grande de Morelia basin occurs in the case of the highest concentration values, which suggests that in the state of Jalisco there are areas where precipitation is concentrated in a number of days less than that observed in said basin.

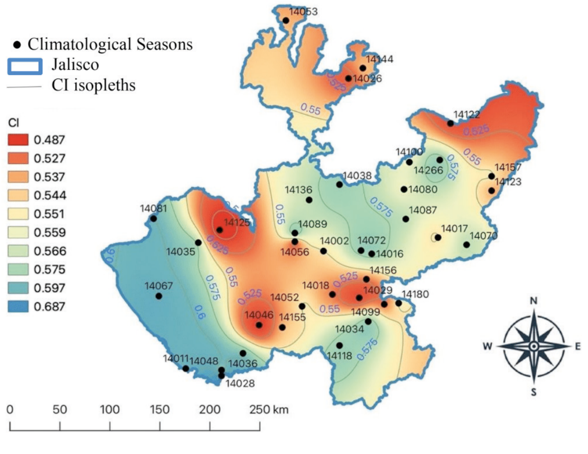


Figure 2. Spatial distribution of the precipitation concentration index. Source: self made.

According to the spatial behavior of the IQ, a classification of said index was made into three categories: low, medium and high concentration. The definition of the classes is based on the values obtained for the 1st, 2nd and 3rd quartiles of the concentration index. Based on the previous criterion, a low concentration was considered those stations where the CI value is less than 0.54, the average concentration for values between 0.54 and 0.58 and the high concentration in the case of stations with a CI equal to or greater than 0.58. In accordance with this classification, the results found that 24% of the stations analyzed showed a low concentration, 41% a medium concentration and the remaining 35% a high concentration.

In Figure number 2 it can be seen in general that the areas of the state of Jalisco that present IC values considered as high concentration are located in a strip parallel to the Pacific Ocean and limited by the Sierra Madre del Sur, known as the coastal zone. from Jalisco. The above suggests that the high concentration of precipitation in this area may be associated with Pacific cyclonic activity. On the other hand, a large part of the values considered as low concentrations are located in the northeastern area of the mountain ranges that are part of the Sierra Madre del Sur, an area characterized by elevations greater than 1000 meters above sea level, which even reach 2400 meters above sea level, thus functioning as a barrier to the path of cyclonic precipitation (García, 2003). Another area with high IQ values is found in the regions of the state called Valles, Centro and Altos Sur, where there are important population centers such as the city of Guadalajara, which due to the extension of its urban area has presented problems of floods recently, which highlights the need to continue deepening studies on the behavior of precipitation at finer time scales.

Table 2 presents the descriptive statistics of the trend calculated for each of the series of the ETCCDMI indices. According to the results shown in this table, it can be observed, in the case of the annual total precipitation index (PRCPTOT), a tendency towards a decrease in accumulated precipitation since a little more than half of the series show negative trends, although in some stations important growth trends are observed.

On the other hand, regarding the simple daily intensity index (SDII), an increasing trend is observed. However, the average magnitude observed in the trend of this index can be considered small. On the other hand, the maximum precipitation index in one day (RX1DAY) shows mostly positive trends in most of the series analyzed.

In the same sense, for the index of consecutive dry days (CDD) it was found that in 85% of the results the trend was positive, observing on average an increase in consecutive dry days of 6 days for every 10 years; while, in the case of the station with the most extreme condition, the number of consecutive dry days could increase according to the trend found up to 20 days.

Finally, in the case of the index of consecutive days with rain (CWD), the trend is opposite to the index of consecutive dry days, since in this case a decrease in the number of consecutive days with rain can be seen in 77% of the seasons although the level of decrease is not very large compared to the magnitude observed in the CDD.

The trend of precipitation indices seems to confirm what was stated by Greenpeace (2010) and INECC (2016) in the sense that in the state of Jalisco a decrease in precipitation can be expected in the medium and long term. The main indices that support this hypothesis are the annual total precipitation index (PRCPTOT) and the consecutive dry days index (CDD). The tendency to decrease precipitation coincides with what was found by Méndez et al. (2008) in a study carried out on the precipitation trend at the national level, where they point out that the most notable decrease in rainfall is recorded in the region called the central coasts of the Mexican Pacific, where the state of Jalisco is located. Although the increase in consecutive dry days (CDD) can also affect the concentration of precipitation.

## CONCLUSIONS

The analysis of the concentration index (CI) of precipitation allows us to know the statistical structure of daily precipitation in different places, with which we can have an idea of the possibility of occurrence of extreme precipitation events.

The concentration of precipitation was evaluated from the relationship between the accumulated frequency of precipitation and the accumulated frequency of rain events.

According to the spatial distribution of the concentration index, it was found that the areas most susceptible to the occurrence of large amounts of rain in a few days are in the coastal area adjacent to the Pacific Ocean as well as in the Valleys, Center and Altos Sur regions. where important population centers such as the city of Guadalajara are located. The high concentrations observed in the coastal area may be related to the cyclonic activity of the Pacific Ocean.

In areas with the presence of mountain chains, a significant decrease in the precipitation concentration index is observed, suggesting a more uniform distribution of precipitation compared to the coastal zone of the state.

The values observed in the concentration index are within the ranges reported in the literature for other countries as well as for other areas of Mexico. While the indices calculated for total precipitation show a tendency to decrease the amount of precipitation in the state of Jalisco but with a tendency to increase the number of consecutive dry days, which can influence the way precipitation is concentrated in Jalisco state.

| Statistical | PRCPTOT (mm/year) | SDII (mm/d) | RX1day (mm/d) | CDD (days/year) | CWD (days/year) |
|---|---|---|---|---|---|
| Minimum | -5.61 | -0.067 | -0.35 | -0.97 | -0.16 |
| Maximum | 9.01 | 0.14 | 1.59 | 2.01 | 0.07 |
| Half | -0.65 | 0.02 | 0.17 | 0.62 | -0.03 |
| Typical deviation | 2.96 | 0.04 | 0.37 | 0.62 | 0.04 |
| Statistically significant trends (a = 0.05) | 6 | 8 | 6 | 13 | 4 |
| Statistically significant trends (a = 0.05) | 4 | 6 | 1 | 0 | 5 |

Table 2 Descriptive statistics of the trend of precipitation indices

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