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Climatic variability in the hydrographic basin of the Chalpi Grande river in Napo-Ecuador

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Abstract: The watershed basin of the Chalpi Grande River is located in the Ecuadorian Amazon. This basin has an elevation of over 3200 meters and features the Andean and Amazon ecosystems. Its protection is crucial as the raw water supply of 2.2 m/s in the Quito metropolitan area relies on this river. The purpose of this study is to describe the 31-year (1985-2015) climate variability of temperature, precipitation and flow records of the Chalpi grande River based on the historical records of INAMHI, EPMAPS and FONAG. These records are systematized and filled out based on statistical methods and remote sensors to verify the data. Climate variability has increased in both winter and summer behavior and trends. And climate parameter trends may be affected by atmospheric phenomena, such as potential climate change issues.
Key words: hydrology; El Niño-southern oscillation; climate change; temperature; precipitation; flow; remote sensing

1 Introduction

Today, the connection between climate change and water resources has attracted greater interest from the scientific community around the world, because water supply is an important issue and a fundamental right for the development and protection of every species on the Earth (Bates et al., 2008; Torres-Bagur and Pavón Gamero, 2021; Vuille, 2013).

Historical hydrological and meteorological records, combined with predictions from climate experts, provide some information which warns us that over time, if this issue is not taken with necessary seriousness, its impact on society, environment, and economy will be catastrophic in the near future (Bates et al., 2008; Torres-Bagur and Pavón Gamero, 2021; Vuille, 2013).

Measures to adapt to climate change are strong support for efforts to reduce the impact on populations and different ecosystems on the Earth. Water resources are considered fragile environments. The interaction between different variables guarantees public health, economic development and harbor biodiversity of both flora and fauna (Bates et al., 2008).

If different measures are not taken, disastrous scarcities such as those observed around the world may occur, resulting in increasingly frequent floods and droughts. This has had some impacts, such as water scarcity, increased basin erosion and sedimentation, glacier retreat, sea level rise, and water quality deterioration (Bates et al., 2008; Pachauri et al., 2015).

The potential impact of climate change often affects freshwater systems, which will lead to a weakening of the benefits of this system worldwide. By 2050, the scientific community estimates that the Earth's surface will be affected by the intensification of water pressure factors. Countries in the global South will be more affected as they are vulnerable to the adverse effects of climate change (Bates et al., 2008; Pachauri et al., 2015).

In Ecuador, the situation of this problem can be proven in river basins, which may have high economic and social costs, as demonstrated in the Azuai province. River bed overflows in river basins, and water supply in coastal areas is insufficient, with the respective loss for small farmers. Today, several proposals are being developed to mitigate climate change issues, such as amending legislation, global agreements, developing adaptation projects. Adapting to these suggestions and changing attitudes towards protecting the Earth are necessary so that each level of development can survive in the contemporary world (Bates et al., 2008; Pachauri et al., 2015).

Amazon plays an important role in the world because it is one of the most effective carbon sinks on the Earth. Its care and maintenance is crucial, especially because it can reduce the new issues of climate change. The development proposal aimed at protecting the Amazon region suggests that as long as the climate goals proposed by international cooperation are achieved, a healthy and balanced environment can be ensured in the future. (Armenta et al., 2016; Lavado Esteban and Marcelle São Pedro, 2021).

The Fifth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) shows different concentration pathways that may have large-scale impacts in the near future. Compared to northern countries with greater resilience, the situation in the global southern countries will be more severe (IPCC, 2013; Lavado Esteban and Marcelle São Pedro, 2021).

The most obvious impacts are heatwaves, extremely cold winters, natural disasters, etc. These activities are becoming increasingly common, especially in northern countries around the world. However, when it comes to Ecuador, the main problems are low food quality, unstable drinking water supply, and low economic activity. The poorest social classes are most severely affected as they do not have the conditions or means of production to obtain income that can be converted into population development (Armata et al., 2016; Calderon, 2016; Hermosa et al., 2010).

All of these divide the actions taken to address climate change into two parts:

The focus of mitigation actions is on countries in the northern part of the world, as their high concentrations of GHGs, CO, among others, have caused the sudden increase in temperature at the Earth's surface level. For example, we have China, India, the United States, etc (IPCC, 2007, 2008, 2008).

The action to adapt to climate change aims to build resilience for the environment and people to cope with the impact of this issue. There are some examples of such measures in the country, such as integrated water resource management and reducing emissions from deforestation. These actions revolve around protecting the ecosystems of southern countries around the world (Benítez Carranco, 2018; Gómez Martín et al., 2017; Nicholls y Altieri, 2019).

The purpose of this study is to characterize the climate variability of the Chalpi Grande River basin based on environmental variables such as precipitation, temperature, and flow. The specific goal is to collect and systematize climate variable data for 31 years. In addition, it is verified through specialized weather and climate remote sensors.

2 Methodology

2.1 Study area

The Chalpi Grande River basin is located in the Quijos Oblast of Napo Province, Ecuador, between the Papallacta and Cuyuja dioceses, as shown in Fig. 1. The Chalpi Grande River basin covers an area of approximately 102.6 square kilometers. The basin consists of the following micro basins: Chalpi A- Chalpi B- Chalpi C- Rio Antado. These slopes are located at a height of 3830 meters S.N.M. and contribute to the water system of the Chalpi Grande River.

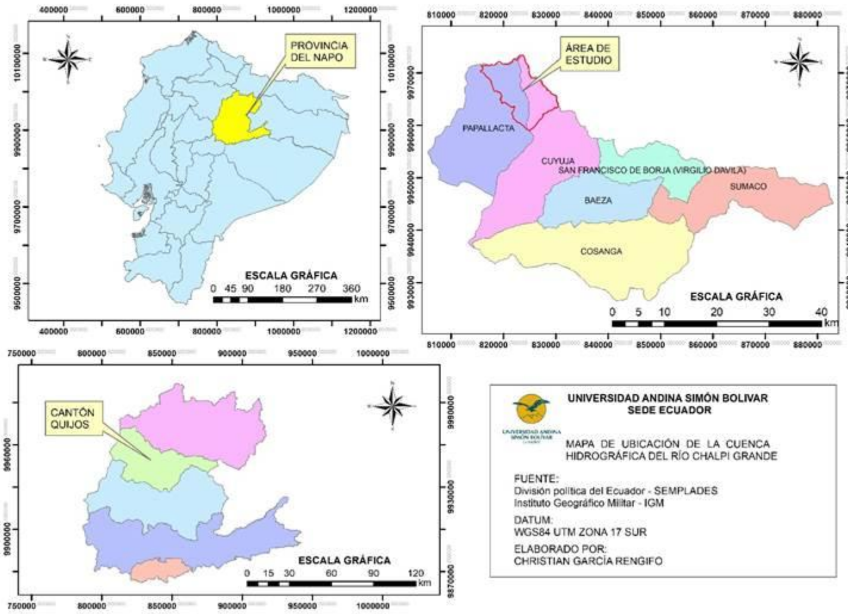

Fig. 1. The location of the Chalpi Grande River basin from the mainland equator to the political division of Quijos state (Military Geography Institutions and Signals Self Made)

2.2 Climate information

The historical records from 1985 to 2015 were obtained from 13 meteorological and hydrological stations near the Chalpi Grande River basin. The environmental variables considered in this article are temperature, precipitation, and flow. All of these are the main basis for determining the correlation between measured flow and historical precipitation and temperature records.

The records of the above environmental variables belong to the stations of the National Institute of Meteorology and Hydrology (INAMHI), the Quito Metropolitan Public Drinking Water and Sanitation Company (EPMAPS), and the Water Conservation Fund (FONAG). These stations are selected based on a maximum distance of 30 kilometers from the Chalpi Grande River basin. M0188 station is used as a reference station for data filling development.

The data series from 1985 to 2015 provide several gaps for the environmental variables to be analyzed. We proceeds with the filling of data for both temperature and precipitation. Records from stations near the study area are used. Correlation and linear regression models, region vector method (MVR), and cross average substitution are also used. The HEC-HMS software is used to fill in the flow data. In addition, satellite sensors (CFS Reasalysis Merra 2-Terra Climate Modis Terra Daily) have been chosen to obtain and correct values for precipitation and temperature records.

2.3 Temperature analysis

The temperature analysis is based on the highest, lowest, and average values of the study area over the past 31 years. We have analyzed the records of 13 stations near the area and validated the temperature data based on a linear correlation coefficient with R. equal to or greater than 0.75. These values are used to fill in data based on satellite sensors, not as reference stations for this work.

2.4 Precipitation and flow analysis

The reason for choosing to group the obtained records into 10 years is because ENSO has a quasi-biennial component with a repetition time of 2 to 2.5 years. Similarly, the frequency of occurrence is relatively low, ranging from 4 to 5 years (Aliaga et al., 2016; Rusticucci and Barrucand, 2002; Tisconia et al., 2016). Through this approach, the changes in rainfall and flow in the Chalpi Grande River basin are more pronounced on a scale that can be observed and compared.

In order to develop rainfall and flow characteristics, precipitation values for 10-year periods are chosen to be established. Due to global climate variability, it is strongly controlled by the occurrence of the El Niño phenomenon, also known as the Southern Oscillation (Fonag and EPMAPS-Q, 2020; INAMHI, 2021).

Finally, based on Pearson's correlation, the correlation between precipitation and flow has been performed every 10 years. This shows that there is a direct relationship between these two environmental variables due to the principle of hydrology.

3 Results

Meteorological and hydrological stations for INAMHI, EPMAPS, and FONAG are located in the Chalpi Grande River basin. However, due to the presence of more sites, environmental variables (precipitation and temperature) can be better described. In terms of flow, EPMAPS has a hydrological station within the river, so historical records mark the reality of the water system. From Fig. 2, we can see the distribution of stations around the Chalpi Grande River basin, as well as the use and land cover rate of the analyzed basin.

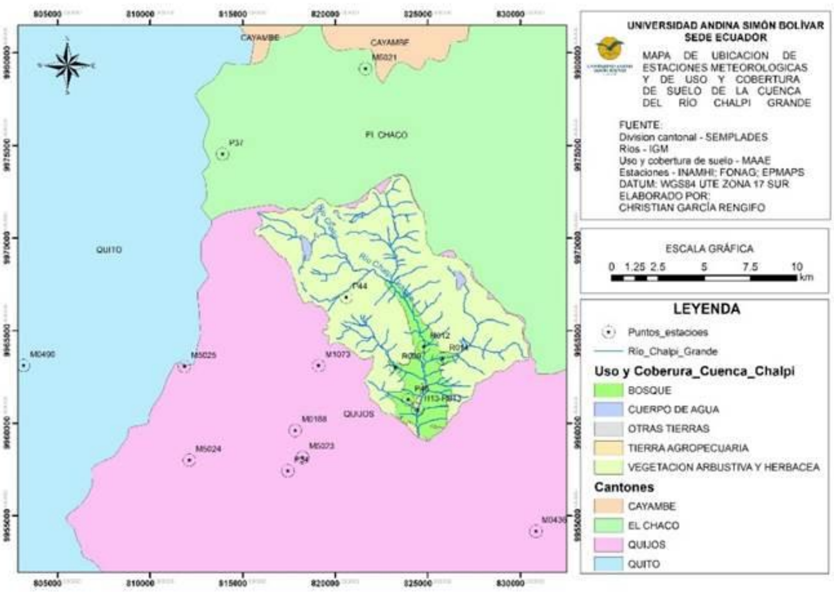

Fig. 2. Meteorological stations and land use and coverage in the Chalpi Grande River basin

(Developed by Military Geography Institute, Sempalades, MAAE, INAMHI, EPMAPS and FONAG)

3.1 Temperature

A 30-year study has been conducted in the Chalpi Grande River Basin (1985-2015), with a total of 13 sites. As shown in Fig. 3, these sites belong to different entities and can determine changes in temperature in the watershed area.

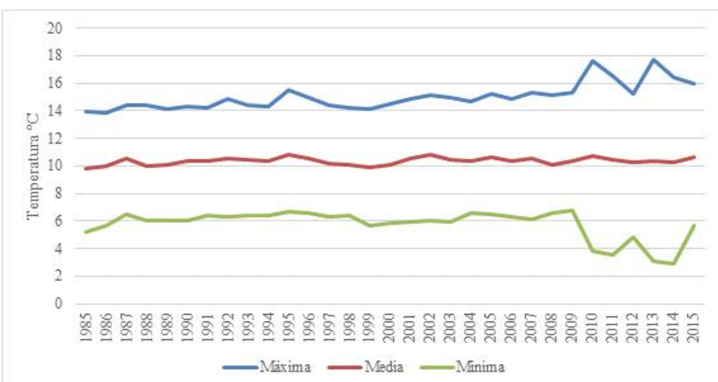

Fig. 3 Annual temperature in the Chalpi Grande River basin (EPMAPS; P46 Chalpi Grande Station Made by oneself)

The average temperature in the region is 10.2 ° C, and during the 31 years analyzed, the average temperature in the region has remained relatively stable. At the same time, the highest and lowest temperatures since 2010 have increased and decreased substantially, reaching 18 °C and 2 °C, respectively.

3.2 Precipitation

The Chalpi River Basin is located in a province near the Antizana National Park in eastern Ecuador, and therefore has the characteristics of the Amazon Andes ecosystem. This means that there is a large amount of rainfall in the region, which is incorporated into the hydrological system of the watershed. They are also utilized by people, including for other uses of rainwater. Fig. 4 shows the maximum, minimum, and average rainfall values in the Chalpi Grande River basin.

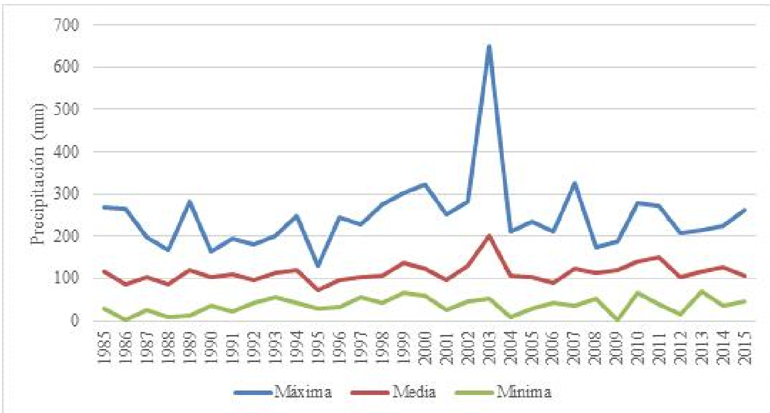

Fig. 4. Maximum, minimum, and average rainfall in the Chalpi Grande River Basin Area

(EPMAPS; Chalpi Grande P46 Station Self made)

The precipitation data are divided into 10-year periods. The variability existing between the years analyzed is shown, exposing months with extreme events of both heavy precipitation and periods of drought. This can be seen in Fig. 5 with its three items dividing the 31-year precipitation records.

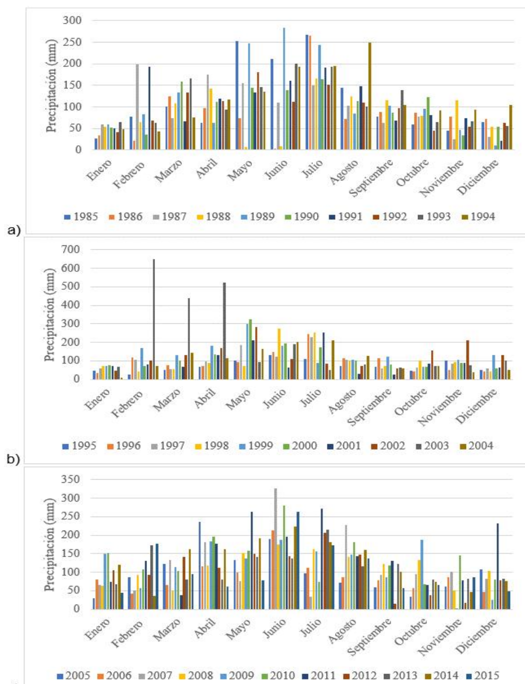

Fig. 5 (a) Precipitation from 1985 to 1994, b) Precipitation from 1995 to 2004, c) Precipitation from 2005 to 2015

EPMAPS; P46 Chalpi Grande Station Made by oneself

From the precipitation characteristics recorded in 31 years, it can be seen that the precipitation in the region has remained unchanged. It must be pointed out that the existence of extreme events marks the trend of possible social conditions in the region, such as landslides and river flooding. In text b), it is observed that during periods of low rainfall, the rainfall is less than 100 millimeters. It can be seen that in the first period (a), the rainfall was high, which is due to the El Niño phenomenon during the drought period. During the analyzed period, it has been noted that events considered extreme can be seen in Fig. 6.

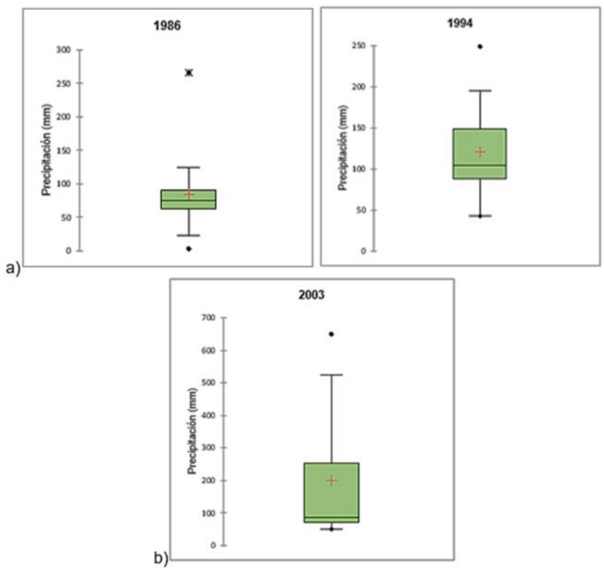

Fig. 6 a) Block diagram of extreme events in 1996 and 1994 b) Block diagram of extreme events in 2003 c) Block diagram of extreme events in 2009

From the graph, it can be seen that literally (a) the 1986 data is concentrated between 22.3 millimeters and 124.7 millimeters of rainfall in 1986. However, they emphasize that two values, 2.8 millimeters and 256.4 millimeters, which are considered maximum and minimum, are considered as extreme events, respectively. For the year 1994, we can see the outlier of the data series. The precipitation of 249.3 mm is the maximum this year.

The diagram in b) shows the precipitation records for 2003. The value of 649 mm is considered an outlier because it is above the records that correspond to 95 % of the data.

It can be seen that half of the months' records are inside the box, while the remaining six are at the limits of the diagram. Also, the median is above the mean. This is due to the dispersion of the maximum and minimum values, which respectively affect the normality of the data for this specific year.

3.3 Flow rates

For the development of the multitemporal analysis, we divide the 31-year data into groups of 10 years and analyze the relationship between the multi temporal nature of ENOS conditions and precipitation in the same way, in order to determine how the flow of the Chalpi Grande River behaves during continuous periods. This can be seen in Fig. 7, which shows three periods of monthly value analysis around the Chalpi Grande River.

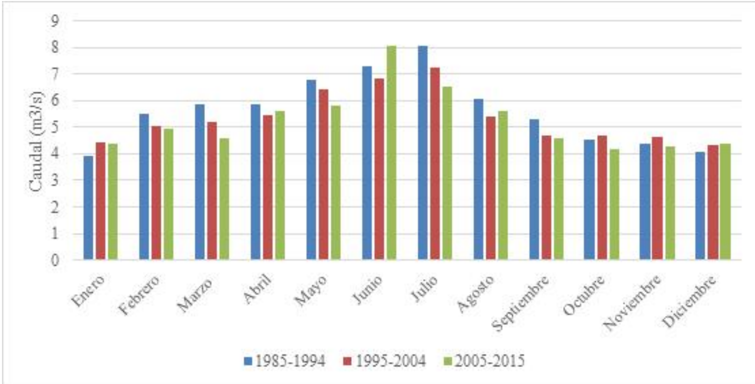

Fig 7. Average monthly flow of Chalpi Grande River from 1981 to 2015 (EPMAPS; Chalpi Grande P46 Station Self made)

In the 31 years study, it has been found that the flow rate increased with the passage of months, with June and July being the months when the flow rate reaches its peak for each period and year analyzed. A few months later, the flow of the Chalpi Grande River tends to decrease, reaching a stable flow rate of 3 to 4 m/s.

The period from 1985 to 1994 is considered the main period because the flow during this period has exceeded the range considered as the average flow of the basin today. July is a month with an average of 9.13 m/s. Lower traffic values are entering normal, such as January, October, November, and December for each time period.

3.4 Correlation: precipitation and flow

The correlation between precipitation and flow variables is determined based on the monthly average of each year. We divide them into 10-year time periods for multi time analysis, where existing relationships can be seen. Correlation has been performed based on Pearson's correlation coefficient to study the relationship between the continuous variables of precipitation and flow. In this way, the intensity and direction of the relationship of the variables within the watershed area of the Chalpi Grande river can be determined. Table 1 shows the Pearson correlation matrix for the period 1985 to 1994.

Table 1 mentions Pearson's correlation, where the bold values differ from 0 and the significance level is α=0.05. There, we can associate the two precipitation and flow variables identified in the table with the letters "P" for precipitation and "C" for flow with their respective years.

Table 1. Pearson correlation matrix of precipitation and flow variables from 1985 to 1994 (Self made)

Variables	1995P	1996P	1997P	1998P	1999P	2000P	2001P	2002P	2003P	2004P	1995C	1996C	1997C	1998C	1999C	2000C	2001C	2002C	2003C	2004C
1985P	**1**	0.398	0.463	-0.126	**0.903**	**0.721**	**0.654**	**0.830**	**0.794**	**0.681**	**0.994**	**0.649**	0.465	0.561	**0.911**	**0.783**	**0.804**	**0.772**	0.559	0.519
1986P	0.398	**1**	0.110	**0.709**	0.234	0.512	0.180	0.453	0.401	0.279	0.329	**0.871**	0.130	**0.641**	0.215	0.375	0.213	0.563	0.285	0.123
1987P	0.463	0.110	**1**	0.031	0.421	0.301	**0.831**	0.506	0.256	0.156	0.473	0.236	**0.998**	0.326	0.460	0.296	**0.691**	0.484	0.503	**0.596**
1988P	-0.126	**0.709**	0.031	**1**	-0.270	0.112	0.097	0.068	0.025	0.187	-0.177	0.528	0.069	**0.626**	-0.290	-0.037	0.032	0.292	0.181	0.217
1989P	**0.903**	0.234	0.421	-0.270	**1**	**0.745**	**0.598**	**0.724**	**0.878**	0.489	**0.924**	0.557	0.404	0.479	**0.994**	**0.842**	**0.779**	**0.661**	**0.673**	0.329
1990P	**0.721**	0.512	0.301	0.112	**0.745**	**1**	0.337	**0.774**	**0.804**	0.541	**0.693**	**0.652**	0.289	**0.599**	**0.718**	**0.966**	0.516	**0.782**	0.478	0.367
1991P	**0.654**	0.180	**0.831**	0.097	**0.598**	0.337	**1**	0.477	0.435	0.475	**0.682**	0.406	**0.850**	0.507	**0.627**	0.383	0.941	0.521	**0.602**	**0.740**
1992P	**0.830**	0.453	0.506	0.068	**0.724**	**0.774**	0.477	**1**	**0.783**	0.518	**0.799**	**0.616**	0.498	**0.658**	**0.708**	**0.781**	**0.589**	**0.939**	**0.644**	0.520
1993P	**0.794**	0.401	0.256	0.025	**0.878**	**0.804**	0.435	**0.783**	**1**	0.521	**0.807**	**0.726**	0.243	**0.658**	**0.837**	**0.891**	**0.653**	**0.832**	**0.809**	0.386
1994P	**0.681**	0.279	0.156	0.187	0.489	0.541	0.475	0.518	0.521	**1**	**0.671**	0.493	0.187	**0.660**	0.500	**0.586**	**0.653**	**0.598**	0.267	**0.689**
1985C	**0.994**	0.329	0.473	-0.177	**0.924**	**0.693**	**0.682**	**0.799**	**0.807**	**0.671**	**1**	**0.618**	0.473	0.533	**0.931**	**0.777**	**0.833**	**0.748**	**0.594**	0.534
1986C	**0.649**	**0.871**	0.236	0.528	0.557	**0.652**	0.406	**0.616**	**0.726**	0.493	**0.618**	**1**	0.251	**0.789**	0.530	**0.632**	0.532	**0.764**	**0.598**	0.346
1987C	0.465	0.130	**0.998**	0.069	0.404	0.289	**0.850**	0.498	0.243	0.187	0.473	0.251	**1**	0.350	0.444	0.280	**0.706**	0.487	0.494	**0.625**
1988C	0.561	**0.641**	0.326	**0.626**	0.479	**0.599**	0.507	**0.658**	**0.658**	**0.660**	0.533	**0.789**	0.350	**1**	0.460	**0.583**	**0.622**	**0.785**	**0.670**	0.523
1989C	**0.911**	0.215	0.460	-0.290	**0.994**	**0.718**	**0.627**	**0.708**	**0.837**	0.500	**0.931**	0.530	0.444	0.460	**1**	**0.812**	**0.796**	**0.632**	**0.641**	0.328
1990C	**0.783**	0.375	0.296	-0.037	**0.842**	**0.966**	0.383	**0.781**	**0.891**	**0.586**	**0.777**	**0.632**	0.280	**0.583**	**0.812**	**1**	**0.601**	**0.793**	0.568	0.415
1991C	**0.804**	0.213	**0.691**	0.032	**0.779**	0.516	0.941	**0.589**	**0.653**	**0.653**	**0.833**	0.532	**0.706**	**0.622**	**0.796**	**0.601**	**1**	**0.639**	**0.668**	**0.730**
1992C	**0.772**	0.563	0.484	0.292	**0.661**	**0.782**	0.521	**0.939**	**0.832**	**0.598**	**0.748**	**0.764**	0.487	**0.785**	**0.632**	**0.793**	**0.639**	**1**	**0.726**	**0.650**
1993C	0.559	0.285	0.503	0.181	**0.673**	0.478	**0.602**	**0.644**	**0.809**	0.267	**0.594**	**0.598**	0.494	**0.670**	**0.641**	0.568	**0.668**	**0.726**	**1**	0.441
1994C	0.519	0.123	**0.596**	0.217	0.329	0.367	**0.740**	0.520	0.386	**0.689**	0.534	0.346	**0.625**	0.523	0.328	0.415	**0.730**	**0.650**	0.441	**1**

Los valores en negrita son diferentes de 0 con un nivel de significación alfa=0.05

We can see the diagonal formed by linking 1985P with 1985C, indicating a value exceeding 60%, which gives us a positive correlation between these two variables because precipitation responds to annual flow.

It is worth noting that in 8 out of 10 years, the correlation between precipitation and flow is very high, with a value close to 1. It is worth noting that the increase in flow is directly proportional to the increase in rainfall in Table 2.

Table 2. Pearson correlation matrix of precipitation and flow variables from 1995 to 2004 (Self made)

Variables	1995P	1996P	1997P	1998P	1999P	2000P	2001P	2002P	2003P	2004P	1995C	1996C	1997C	1998C	1999C	2000C	2001C	2002C	2003C	2004C
1995P	**1**	0.538	**0.637**	**0.780**	0.320	**0.677**	0.431	0.282	-0.402	**0.662**	**0.896**	0.493	0.474	**0.755**	0.139	**0.594**	0.435	0.397	0.457	**0.662**
1996P	0.538	**1**	**0.779**	**0.729**	0.080	0.383	0.496	-0.263	-0.030	**0.748**	0.431	**0.987**	**0.770**	**0.765**	-0.097	0.341	0.569	0.109	**0.607**	**0.747**
1997P	**0.637**	**0.779**	**1**	**0.594**	0.395	**0.748**	**0.864**	0.255	-0.138	**0.733**	0.551	**0.811**	**0.908**	**0.598**	-0.197	0.545	**0.595**	**0.633**	**0.703**	**0.733**
1998P	**0.780**	**0.729**	**0.594**	**1**	-0.059	0.372	0.364	-0.166	-0.262	**0.699**	**0.769**	**0.662**	0.487	**0.992**	0.135	0.405	**0.626**	0.075	0.413	**0.699**
1999P	0.320	0.080	0.395	-0.059	**1**	**0.794**	0.351	**0.646**	0.294	0.421	0.170	0.069	0.432	-0.053	0.299	**0.595**	0.304	0.534	0.567	0.422
2000P	**0.677**	0.383	**0.748**	0.372	**0.794**	**1**	**0.675**	**0.577**	-0.116	**0.703**	0.569	0.389	**0.698**	0.368	0.080	**0.778**	0.502	**0.754**	**0.734**	**0.703**
2001P	0.431	0.496	**0.864**	0.364	0.351	**0.675**	**1**	0.442	-0.071	0.537	0.407	0.566	**0.788**	0.342	-0.193	0.294	0.418	**0.708**	**0.668**	0.538
2002P	0.282	-0.263	0.255	-0.166	**0.646**	**0.577**	0.442	**1**	0.037	0.160	0.368	-0.252	0.167	-0.223	-0.041	0.261	-0.104	**0.744**	0.304	0.161
2003P	-0.402	-0.030	-0.138	-0.262	0.294	-0.116	-0.071	0.037	**1**	0.067	-0.513	-0.045	0.144	-0.273	0.488	-0.160	0.065	-0.137	0.208	0.066
2004P	**0.662**	**0.748**	**0.733**	**0.699**	0.421	**0.703**	0.537	0.160	0.067	**1**	**0.588**	**0.694**	**0.778**	**0.725**	0.123	**0.597**	**0.747**	0.327	**0.792**	**1.000**
1995C	**0.896**	0.431	0.551	**0.769**	0.170	0.569	0.407	0.368	-0.513	**0.588**	**1**	0.377	0.314	**0.734**	-0.047	0.514	0.295	0.445	0.340	**0.588**
1996C	0.493	**0.987**	**0.811**	**0.662**	0.069	0.389	0.566	-0.252	-0.045	**0.694**	0.377	**1**	**0.795**	**0.695**	-0.147	0.325	0.515	0.177	**0.596**	**0.694**
1997C	0.474	**0.770**	**0.908**	0.487	0.432	**0.698**	**0.788**	0.167	0.144	**0.778**	0.314	**0.795**	**1**	0.496	-0.145	0.418	**0.616**	0.523	**0.869**	**0.778**
1998C	**0.755**	**0.765**	**0.598**	**0.992**	-0.053	0.368	0.342	-0.223	-0.273	**0.725**	**0.734**	**0.695**	0.496	**1**	0.119	0.420	**0.681**	0.020	0.420	**0.725**
1999C	0.139	-0.097	-0.197	0.135	0.299	0.080	-0.193	-0.041	0.488	0.123	-0.047	-0.147	-0.145	0.119	**1**	0.275	0.262	-0.227	-0.058	0.123
2000C	**0.594**	0.341	0.545	0.405	**0.595**	**0.778**	0.294	0.261	-0.160	**0.597**	0.514	0.325	0.418	0.420	0.275	**1**	0.506	0.549	0.308	**0.597**
2001C	0.435	0.569	**0.595**	**0.626**	0.304	0.502	0.418	-0.104	0.065	**0.747**	0.295	0.515	**0.616**	**0.681**	0.262	0.506	**1**	0.033	0.517	**0.747**
2002C	0.397	0.109	**0.633**	0.075	0.534	**0.754**	**0.708**	**0.744**	-0.137	0.327	0.445	0.177	0.523	0.020	-0.227	0.549	0.033	**1**	0.434	0.328
2003C	0.457	**0.607**	**0.703**	0.413	0.567	**0.734**	**0.668**	0.304	0.208	**0.792**	0.340	**0.596**	**0.869**	0.420	-0.058	0.308	0.517	0.434	**1**	**0.792**
2004C	**0.662**	**0.747**	**0.733**	**0.699**	0.422	**0.703**	0.538	0.161	0.066	**1.000**	**0.588**	**0.694**	**0.778**	**0.725**	0.123	**0.597**	**0.747**	0.328	**0.792**	**1**

Los valores en negrita son diferentes de 0 con un nivel de significación alfa=0.05

According to Pearson's correlation, there is a significant correlation between precipitation and flow variables during the second recording period. However, for 1999, 2001, and 2003, the correlation does not exceed 50%, indicating a correlation between variables. However, due to the maximum and minimum values between these two variables, this correlation was not high.

The correlation between other years is relatively strong, exceeding 70%. The case study in 2004 shows a perfect correlation between precipitation and flow, with 100 % at a confidence level of 95 % , as shown in Table 3.

Table 3. Pearson's correlation matrix of precipitation and flow variables from 2005 to 2015 (Self made)

Variables	2005P	2006P	2007P	2008P	2009P	2010P	2011P	2012P	2013P	2014P	2015P	2005C	2006C	2007C	2008C	2009C	2010C	2011C	2012C	2013C	2014C	2015C
2005P	**1**	**0.593**	0.543	0.335	0.316	0.573	0.451	0.416	0.077	**0.583**	0.312	**0.999**	**0.587**	0.493	0.229	0.243	0.466	0.452	0.464	0.275	**0.584**	0.103
2006P	**0.593**	**1**	**0.732**	0.563	0.517	**0.822**	0.358	0.394	0.224	**0.742**	**0.625**	**0.598**	**0.999**	**0.931**	**0.682**	0.505	**0.690**	0.493	0.379	0.521	**0.665**	0.470
2007P	0.543	**0.732**	**1**	0.363	0.420	**0.835**	0.005	0.185	-0.158	0.541	0.509	0.534	**0.731**	**0.819**	0.313	0.230	0.556	0.271	0.275	0.214	0.459	0.312
2008P	0.335	0.563	0.363	**1**	0.574	0.298	**0.716**	0.433	**0.580**	0.575	0.493	0.330	0.566	0.519	**0.858**	0.376	**0.707**	**0.770**	0.336	**0.652**	**0.600**	0.392
2009P	0.316	0.517	0.420	0.574	**1**	0.357	0.110	0.498	0.082	**0.693**	0.231	0.323	0.513	0.416	0.506	**0.577**	0.151	0.115	0.440	0.047	**0.732**	0.233
2010P	0.573	**0.822**	**0.835**	0.298	0.357	**1**	0.130	0.212	-0.061	0.557	0.461	0.573	**0.821**	**0.811**	0.304	0.462	0.571	0.312	0.271	0.216	0.405	0.356
2011P	0.451	0.358	0.005	**0.716**	0.110	0.130	**1**	0.524	**0.611**	0.453	0.283	0.442	0.356	0.197	0.507	0.274	**0.661**	**0.862**	0.450	**0.604**	0.491	0.232
2012P	0.416	0.394	0.185	0.433	0.498	0.212	0.524	**1**	0.526	**0.770**	0.497	0.412	0.379	0.166	0.295	**0.757**	0.428	0.324	**0.971**	0.404	**0.754**	**0.593**
2013P	0.077	0.224	-0.158	**0.580**	0.082	-0.061	**0.611**	0.526	**1**	0.256	**0.653**	0.081	0.226	0.140	**0.632**	0.530	0.526	0.553	0.403	**0.814**	0.225	**0.692**
2014P	**0.583**	**0.742**	0.541	0.575	**0.693**	0.557	0.453	**0.770**	0.256	**1**	0.397	**0.583**	**0.740**	**0.576**	0.463	**0.631**	0.548	0.291	**0.713**	0.425	**0.964**	0.340
2015P	0.312	**0.625**	0.509	0.493	0.231	0.461	0.283	0.497	**0.653**	0.397	**1**	0.314	**0.618**	**0.650**	**0.651**	**0.582**	**0.648**	0.514	0.521	**0.759**	0.300	**0.906**
2005C	**0.999**	**0.598**	0.534	0.330	0.323	0.573	0.442	0.412	0.081	**0.583**	0.314	**1**	**0.592**	0.496	0.238	0.250	0.456	0.440	0.457	0.278	**0.583**	0.105
2006C	**0.587**	**0.999**	**0.731**	0.566	0.513	**0.821**	0.356	0.379	0.226	**0.740**	**0.618**	**0.592**	**1**	**0.936**	**0.685**	0.498	**0.689**	0.490	0.360	0.526	**0.663**	0.458
2007C	0.493	**0.931**	**0.819**	0.519	0.416	**0.811**	0.197	0.166	0.140	**0.576**	**0.650**	0.496	**0.936**	**1**	**0.649**	0.363	**0.611**	0.452	0.179	0.526	0.503	0.403
2008C	0.229	**0.682**	0.313	**0.858**	0.506	0.304	0.507	0.295	**0.632**	0.463	**0.651**	0.238	**0.685**	**0.649**	**1**	0.379	**0.651**	**0.643**	0.192	**0.746**	0.452	0.543
2009C	0.243	0.505	0.230	0.376	**0.577**	0.462	0.274	**0.757**	0.530	**0.631**	**0.582**	0.250	0.498	0.363	0.379	**1**	0.294	0.222	**0.710**	0.355	0.542	**0.695**
2010C	0.466	**0.690**	0.556	**0.707**	0.151	**0.571**	**0.661**	0.428	0.526	0.548	**0.648**	0.456	**0.689**	**0.611**	**0.651**	0.294	**1**	**0.735**	0.397	**0.722**	0.446	**0.583**
2011C	0.452	0.493	0.271	**0.770**	0.115	0.312	**0.862**	0.324	0.553	0.291	0.514	0.440	0.490	0.452	**0.643**	0.222	**0.735**	**1**	0.310	**0.621**	0.322	0.380
2012C	0.464	0.379	0.275	0.336	0.440	0.271	0.450	**0.971**	0.403	**0.713**	0.521	0.457	0.360	0.179	0.192	**0.710**	0.397	0.310	**1**	0.327	**0.688**	**0.595**
2013C	0.275	0.521	0.214	**0.652**	0.047	0.216	**0.604**	0.404	**0.814**	0.425	**0.759**	0.278	0.526	0.526	**0.746**	0.355	**0.722**	**0.621**	0.327	**1**	0.360	**0.606**
2014C	**0.584**	**0.665**	0.459	**0.600**	**0.732**	0.405	0.491	**0.754**	0.225	**0.964**	0.300	**0.583**	**0.663**	0.503	0.452	0.542	0.446	0.322	**0.688**	0.360	**1**	0.213
2015C	0.103	0.470	0.312	0.392	0.233	0.356	0.232	**0.593**	**0.692**	0.340	**0.906**	0.105	0.458	0.403	0.543	**0.695**	**0.583**	0.380	**0.595**	**0.606**	0.213	**1**

Los valores en negrita son diferentes de 0 con un nivel de significación alfa=0.05

Pearson's correlation indicates that in the third stage of data analysis, the relationship between 2005 and 2006 is almost perfect, with a value of 99 % for each year. Similarly, it can be said that the correlation of each variable is positive, as 9 out of 11 months have a correlation of 0.81%. However, there is a low positive correlation between 2009 and 2010 with values above 57%.

4 Discussion

According to a study submitted by Serano and collaborators (2012), statistical analysis is conducted on meteorological data to determine climate variability and change in the Quito metropolitan area. Researchers have recorded 30 years of precipitation, temperature (highest and lowest), humidity, and cloud cover in the Quito metropolitan area, but due to the limited number of records, this trend can not be evaluated with sufficient statistical significance. Compared to current research, there is an important similarity, since a greater amount of data is necessary to establish different proposals based on different methodologies that generate more reliable results based on their construction (Serrano Vincenti et al., 2012).

Similarly, in this study, different events considered extreme are observed due to the high or low temperature, high or low precipitation in the region. Compared to Serano's work (2012), these events are more pronounced in the study area. Because it is an important basin in the Amazon and EPMAPS, it injects raw water into the Papalacata integrated system to provide drinking water for the city of Quito. Meteorological and hydrological stations must respond promptly to the region, and the stations used to determine DMQ climate variability and climate change have deficiencies in temperature and precipitation records due to information gaps or significant gaps (Serrano Vincenti et al., 2012).

An important similarity between Serano (2012) and current research is that the increase in greenhouse gases leads to a general increase in temperature, irregular and multifunctional patterns of increased rainfall and extreme events in the Quito metropolitan area. Similarly, the same phenomenon has occurred in the area of the Chapigrand River Basin, where the rise or fall of temperature and rainfall has led to extreme events, leading to disasters affecting population and environment every year (Serrano Vincenti et al., 2012).

El Niño - La Niña in the territory has generated several events leading to disasters or losses for the population of the area in economic and public health issues. However, this phenomenon is not specific, i.e. the same characteristics are present in Andean countries such as Colombia and Peru, as reported by Montealegre and Pabón (2000) and González and collaborators (2014). In Colombia, El Niño - La Niña has reported that during the occurrence of these phenomena, there is a decrease in air temperature in the early morning hours generating frosts in mountainous areas (Gonzales et al., 2014; Montealegre and Pabón, 2000).

By comparing the information generated by Montealegre and Pablon (2000) on the Chalpi Grade River basin from 1991 to 1992 and 1997 to 1998, it was found that these events had the greatest impact and were similar to the climate conditions proposed in this study. As in the months when this phenomenon occurred, the temperature increased during the hours of the day and also decreased in the early morning, resulting in frost. Due to the basin being studied located over 3200 meters above sea level, it has the characteristics of Andean and Amazon ecosystems (Montealegre y Pabón, 2000).

When assessing the impact at the social level, environmental variability and climate change must play an important role in the development of different activities such as agriculture, animal husbandry, tourism, and food. All these activities must rely on human components, that is, relying on people to drive the economic development of the region, as reported by Gonzalez and his collaborators (2014) in their study on *Environmental pollution, climate variability, and climate change: examining the impact on the health of the Peruvian population* (González et al., 2014).

The population of Peru is constrained by the climate variability caused by the El Niño phenomenon, which has different consequences for the population, with public health being the most important. The problems generated are in water and air. As these environmental vectors are the main ones for the subsistence of the population, the low quality of food, water, and air harms people's health (Gonzales et al., 2014).

By comparing the results of Gonzalez and collaborators (2014) with current research, the issues of climate variability have been proven in natural phenomena, such as increased river flow leading to river flooding, low food quality, and water pollution. This can even lead to health defects in people. Considering the variables of climate change, it can be foreseen that these issues will tend to grow, causing greater losses to the economic sector, society, and health levels (Gonzales et al., 2014).

By comparing rainfall with river flow, it can be concluded that they are closely related under hydrological principles. According to Pearson's research results, precipitation has a direct response to flow. Comparing the results of Martinez and Rivera (2015), as well as Lujano and collaborators (2020), it is found that Pearson's correlation can determine the relationship between environmental variables of precipitation and flow. This can establish different prediction and evaluation hydrological models, opening the door to predicting situations that may change certain conditions in the watershed or hydrological cycle level (Lujano et al., 2020; Martínez Figueroa y Rivera Hebert, 2015).

5 Conclusion and suggestions

From 1985 to 2015, the climate variability of the Chalpigrand River Basin changed slightly in terms of temperature, precipitation and flow. Similarly, the development of these changes also showed the extreme events of temperature and precipitation, leading to the increase or decrease of the flow of the Chalpigrand River.

In 2010, the highest value of extreme events related to temperature was 18 ° C and the lowest value was 2 ° C. Similarly, in terms of rainfall, 2010, along with 2003 and 2011, was the year with the highest rainfall in the 31-year study. Due to the recorded maximum rainfall exceeding 600 millimeters, 2003 was considered the extreme of research.

The analysis of the 31-year flow shows that between 1993 and 1994, the flow increased to 6.59 m/s, which is considered the peak of the study year. The lowest recorded value in 1995 was 4.68 m/s.

Pearson's correlation shows that there is a relationship between the rainfall in the Chalpigrand River basin and the river itself. The correlation is greater than 70%, and the confidence level is 95% (α=0.05). This indicates that precipitation has a direct response to winter and summer seasons, i.e., the increase or decrease in the flow of the Chalpi Grande river.

Climate change is a problem in the contemporary world that must be addressed in various fields such as politics, economy, society, environment, and international relations. The impact of these issues has now become apparent. All measures must be developed in a timely manner to promote adaptation and/or mitigation of climate change. For example, it is recommended to establish watershed water protection zones by dividing the watershed into small watersheds, or to empower people with water resources to achieve comprehensive water resource management.

The characterization of climate variability in the Chapigrand River basin based on temperature, precipitation and flow variables shows that the error is the smallest when comparing hydrological and meteorological stations with remote sensors, so the validation and systematization of these elements are correct and suitable for the development of this study.

Conflicts of interest

The author declares no conflicts of interest regarding the publication of this paper.

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