MASHCA: Monitoring and Hydro Climatological Analysis of the Urban Microclimate of Latacunga

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Abstract: The climate change has become one of the most studied problems in recent years. Analyses of climate behavior have traditionally been treated in a macro way, that is, large areas of territory are analyzed. The development of humanity in particular, which has been denoted by the increase in population and therefore the growth of cities, has had an effect on the climate. The change in climatic conditions within cities due to the effects of construction, urban planning, modification of territories, among others, are known as urban micro-climates. These variations require special attention, since these apparently minimal changes can have a great effect on the life of the population. The purpose of this project is to study the historical data on the behavior of the urban climate of Latacunga, through the temporal analysis of the data obtained by the meteorological station of the Universidad de las Fuerzas ESPE, later to develop micro meteorological stations that are installed in various locations of the city, finally the information generated and its corresponding reports will be presented through a web page, thus allowing to have a tool that allows to identify the behavior of the urban microclimate of the city of Latacunga. The results obtained have made it possible to identify the maximum, minimum and most frequent values of temperature, humidity, speed and wind direction. In addition, with the installation of the new stations, the monitoring of variables such as solar radiation, atmospheric pressure, among others, has increased. With the information processed, it will allow the generation of recommendations oriented to risk management, urban planning and citizen security.

1 INTRODUCTION

The dynamics of urbanization and growth of the city has been gradually occurring due to socioeconomic factors that benefit the inhabitants due to the

concentration of commercial and financial activity, but with it has also created its climatic patterns different from its geographical location (Huerta et al., 2021; Sichiqui et al., 2020; Gabriela et al., 2019), which are called artificial or urban microclimates. The origin of urban microclimates arises from negative aspects such as the smog generated by cars and local industrial facilities that prevent the entry of solar rays (Barrios-Bello et al., 2019; Garcia-Cedeno et al., 2019; Guillermo et al., 2019; Abad et al., 2019). In addition to this, the architecture of the city also intervenes, such as the morphology that generates wind turbulence, the construction materials of the buildings and the asphalt required for the mobility of the means of transport (Brozovsky et al., 2021; Ulpiani et al., 2021; Maiullari et al., 2021); All this leads to a variability in temperature, humidity among other meteorological variables with respect to its macroclimate. Consequently to these atypical climates there is the

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probability of an increase in the frequency of fog, intensity of storms, concentration of smog among others. Currently in the country several agencies provide meteorological data but at a general level since they measure the macroclimate of the provinces; These data are insufficient to take necessary measures within the urban area in the face of climatic phenomena, therefore, Latacunga does not have concise information that allows identifying potential risks due to the variability of the climate within the urban perimeter.

The Universidad de las Fuerzas Armadas ESPE, on its campus located in the downtown area of Latacunga has a meteorological station that has a large amount of scattered information that has been recorded for several years, in this context an applied research is proposed for the monitoring and analysis of climatological variables through the implementation of additional stations in the Ignacio Flores parish, which allow expanding the coverage of data acquisition to analyze the behavior of the climate and identify the evolution of the urban microclimate with respect to time, said information will be disseminated through a web application accessible to the public.

This research aims to reduce the impact of microclimates in urban areas through the analysis of climatological variations, mitigating the levels of population vulnerability to events produced by extreme changes in the variables to be monitored. Through this information, it is proposed to create a growing awareness among citizens to reduce the impact of microclimates in urban areas, evidencing the changes that have occurred over time that are imperceptible to people as these changes develop in large periods of time. weather. In this aspect, the Information and Communication Technologies are used that, through a web application, allow the user to access this information in an easy, fast and intuitive way.

The project provides solid information for decision-making within the framework of the city's centralized risk management system, strengthening local capacities through technology transfer in order to implement mitigation measures for climate variations through urban planning and ecology of the city that limits new urban development zones under concepts of environmental sustainability such as generation, protection and restoration of green areas; guaranteeing the improvement of climatic conditions in the interior of the city and the reduction of socio- environmental inequalities at the local level (Padmanabhamurty, 1990; Yoon et al., 2017).

2 METHODOLOGY

This section it is based on the analysis of historical data and the installation of the meteorological station, taking into account the manufacturer's standards, among which the selection of an appropriate geographic location is established; the position, height and orientation so that the sensors work in their ideal ranges without generating errors due to improper handling(Teichmann et al., 2021; Marando et al., 2022; Amani-Beni et al., 2022). By means of a checklist, validate the operation of each of the elements of the station, guaranteeing the fidelity of the data, an essential basis for determining the urban microclimate of Latacunga(Bonan, 2000; Brown, 2018; Barton, 2013).

This research is based on procedures related to theoretical and experimental research with data collection since October 12, 2020, which consists of a main station, a mini station and four micro stations with a sending frequency per minute, of the which have been collected 400,000, 3,000 and 170,000 records respectively; The diagram is shown in Fig. 1. The methodology applied to carry out the proposed objectives involves the general guidelines of the scientific method, differentiating itself into four phases:

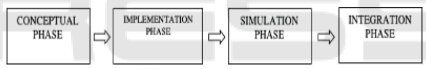

Figure 1: Diagram of the methodology.

2.1 Implementation Phase

This section it is based on the analysis of historical data and the installation of the meteorological station, taking into account the manufacturer's standards, among which the selection of an appropriate geographic location is established; the position, height and orientation so that the sensors work in their ideal ranges without generating errors due to improper handling. By means of a checklist, validate the operation of each of the elements of the station, guaranteeing the fidelity of the data, an essential basis for determining the urban microclimate of Latacunga.

2.2 Simulation Phase

In this section it is argued the individual operation of each element in charge of the digitization of the information based on the conceptual dimensioning, it is done using specialized software and steps such us:

The logical part of the meteorological station schedules the sending of the variables in an adequate format with a sampling time that allows gathering as much information as possible and reporting in the event of sensor failures or power shortages; Regarding the technological infrastructure, it corresponds to the configuration of the database server, design of the database with its respective tables and access to the database through a WAN network; The analysis of the stored data carried out through a workflow that performs the data processing according to the design of the database and must be replicable for the data available from the station of Universidad de las Fuerzas Armadas ESPE. The information monitored is validated through a dashboard on the web.

2.3 Integration Phase

In this part of the investigation each of the stages is incorporated, verifying the flow of information through each equipment to determine the validity of the data, the rate of information loss, errors in the information frames generated, possible interruptions in communication and detection of common errors produced by damage or malfunction of the station. A sampling is carried out to verify the data published in the web instrument panel and using a tool to observe the traffic of the web page to determine the influence of the information provided within the citizens of Latacunga.

3 RESULTS

For process and analyze the historical information obtained by the station of Universidad de las Fuerzas Armadas ESPE, the following procedure was followed with the data collected during 2019 by the station with geographic coordinates (0°56'09.3"S 78°36'45.6"W) that have been stored in flat files. The Fig. 2, represents the extraction, transformation and loading (ETL) model; The data is extracted from the different files that are transformed into the date and time format, erroneous values are also eliminated and the decimal number format is converted to be able to perform the operations necessary for their analysis.

The data is dumped to the database by means of a synchronization from the transformed flat file.

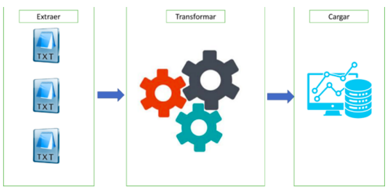

Figure 2: ETL Big data.

After this process, it can be detailed that during the established period of time (01/01/2019 to 12/31/2019), 2,627,951 records have been obtained between the variables humidity, temperature, wind speed and wind direction with a 1 minute sampling period.

3.1 Temperature Analysis

From the analyzed data it can be observed the dispersion of temperature values behaved according to Table 1, where the maximum values have been 25.58 °C in the month of November, while the lowest values 2.97°C are reported in September; The Fig. 3, describes that 50% of the data are in the range of 11.96 °C to 16.49 °C.

Table 1: Statistics of the temperature variable.

Temperature (°C)	
Min.	2.97
Q1	11.96
Median	13.25
Average	14.21
Q3	16.49
Max	25.58

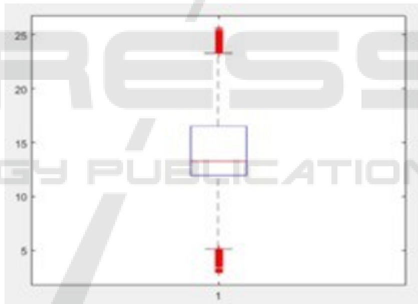

Figure 3: Temperature dispersion.

In the frequency distribution presented in Fig. 4, it is observed that the value that is repeated the most is 15°C followed by a value of 10°C, the atypical values are found in the values lower than 5°C and higher at 20°C.

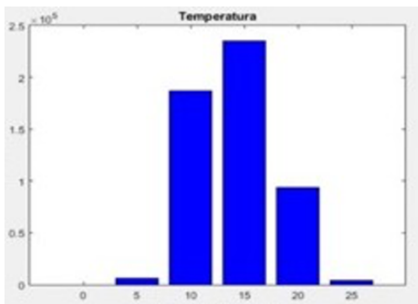

Figure 4: Temperature distribution.

The behavior of the average temperature throughout the months is observed in Fig. 5; It is determined that the month of November has a high value while the months of June and July have low values, in the scale of the first one month is January and the last months is December.

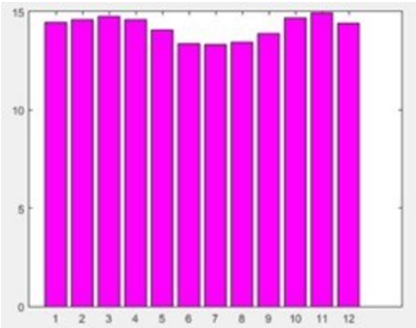

Figure 5: Average monthly temperature distribution.

In the Fig. 6, presents the dynamics of the average temperature within 24 hours of the day; In the 7 :00 range it has an average of 12.11°C, while at 12:00 the average is 18.33 ° C and at 18:00 the average has been 14.50°C. It is also determined that the temperature increases from 7:00 to 14:00 and decreases from 15:00 to 21:00; the highest temperature values are from 12:00 to 15:00 and the lowest from 5:00 to 6:00, the scale represents 24 hours.

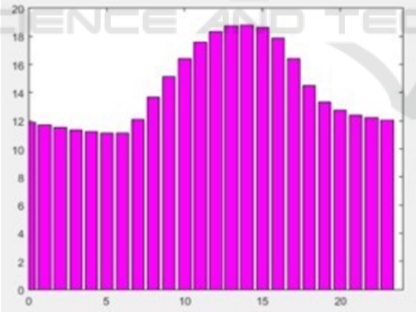

Figure 6: Average hourly temperatures.

3.2 Humidity Analysis

The registered values of this variable show that the months from June to December present the highest level of humidity 100% while in the months of September and November the lowest levels are 16.81% and 13.87%. Half of the recorded data are in the range of 67.97% to 93.66% Table 2, its median is at a value of 86.19%, which shows that there is a greater dispersion between the values of 67.97% and 86.19% Fig. 7.

Table 2: Statistics of the humidity variable.

Humidity (%)	
Min.	13.87
Q1	67.97
Median	86.19
Average	80.20
Q3	93.66
Max.	100

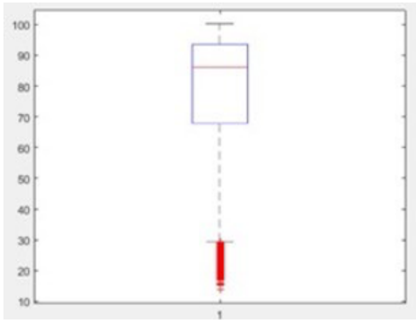

Figure 7: Moisture dispersion.

In Fig. 8, it is observed that the value that is repeated the most within the year is 90% and the atypical values are distributed among the values less than 30%.

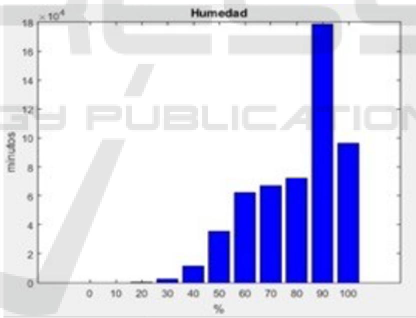

Figure 8: Moisture distribution.

The incidence of average humidity in the month of September is the lowest, on the other hand, the highest is registered in the month of February. The Fig. 9, in general, the annual average humidity is 80.20%.

The distribution of the average humidity with respect to the hours of the day is shown in The Fig. 10, in which it is observed that the lowest values of average humidity are in the range of 13:00 to 15:00; There is also the decrease in humidity from 6:00 to 12:00 and increases from 16:00 to 21:00.

3.3 Wind Speed Analysis

This meteorological variable describes a maximum value of 10.8 m / s in the month of October, 50% of

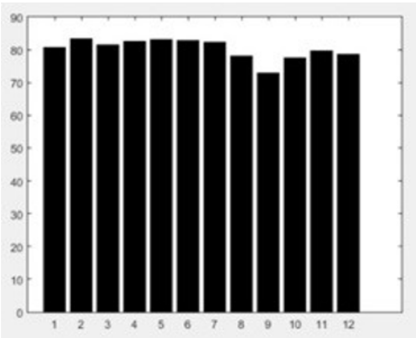

Figure 9: Average monthly humidity distribution.

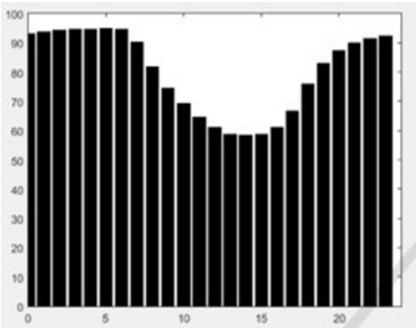

Figure 10: Hourly average humidity.

the data are clustered between 0.7 m/s and 2.5 m/s, Table 3. The lower part of the box (Q1-median) is less than the upper one (median-Q2); This means that the values between 25% and 50% of the data are less dispersed than between 50% and 75%, Fig. 11.

Table 3: Statistics of the variable wind speed.

Wind speed (m/s)	
Min.	0
Q1	0.7
Median	1.4
Average	1.78
Q3	2.5
Max.	10.8

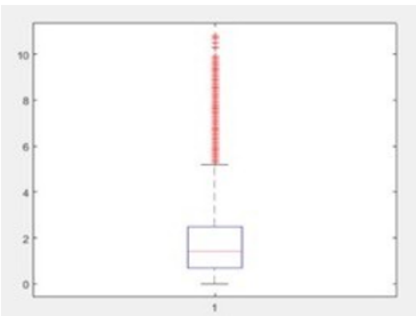

Figure 11: Wind speed dispersion.

The Fig. 12, presents the histogram with the frequency of the different wind speeds with a value of 0.5 m/s that is repeated more frequently, followed by 1 m/s and outliers in an interval of 6 m/s onwards.

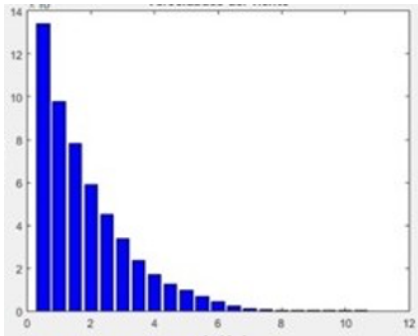

Figure 12: Wind speed distribution.

The distribution of the average monthly wind speed is not uniform as shown in Fig. 13, having a maximum average value in the month of June and a minimum in the months of April, May and November, it could be argued that its value It tends to 1.78 m/s which represents its annual average value. In Fig. 14, it can be contrast whit the month in which there is less wind is in the month of May.

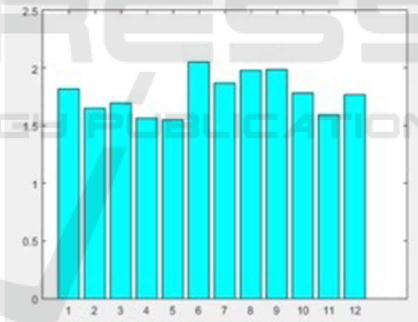

Figure 13: Average monthly distribution of wind speed.

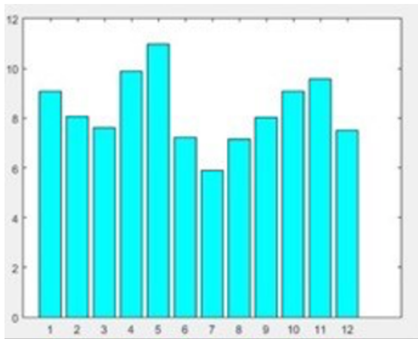

Figure 14: Monthly percentage of calm minutes.

The wind speed distributed by hours presents an interval from 7:00 to 13:00 in which the wind speed increases until it reaches a maximum value at 14:00, after which it begins to decrease in the interval from 15:00 to 19:00, in the rest of the hours. presents a uniform value with slight variations, Fig. 15.

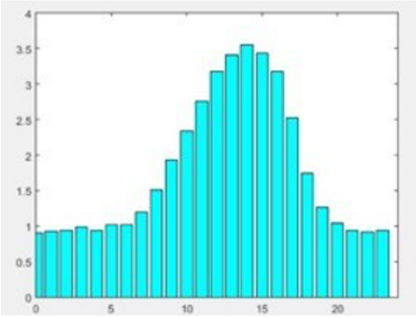

Figure 15: Hourly average wind speed.

3.4 Wind Direction Analysis

This variable is described in degrees having as reference points 0°, 90°, 180° and 270° that represent North, East, South and West. Table 4 shows that 50% of the data are distributed between the values from 99° to 189°, with more dispersed values from 189° onwards, Fig. 16.

Table 4: Wind speed dispersion.

Wind direction (°)	
Min.	0
Q1	99
Median	150
Average	146.01
Q3	189
Max.	354

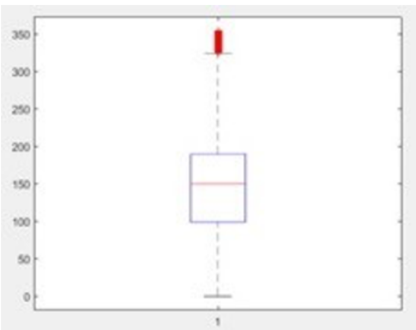

Figure 16: Wind speed dispersion.

The frequency distribution of the wind direction Fig. 17, describes that most of the time it has a value of 170 ° and 180 ° that represent a trend towards the South.

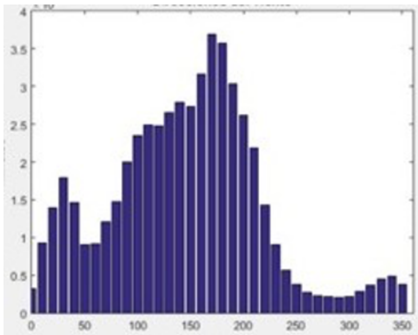

Figure 17: Wind direction distribution.

The Fig. 18, describes a clearly preferential direction in the South-East quadrant that concentrates the greatest amount of data, emerging on the South side.

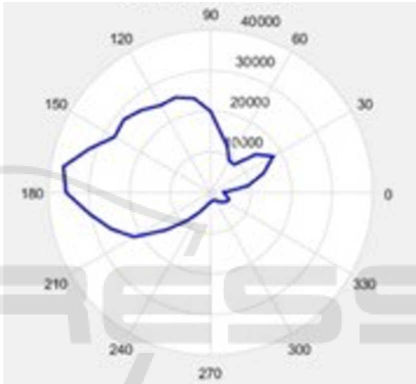

Figure 18: Polar representation of the annual wind direction.

In this part can see in Fig. 19, that in the months of April, May and November there is a partial accumulation towards 30 ° with a high concentration of values, which contrasts with the minimum monthly average values of wind speed, while in June and Julio a symmetry is detected with respect to 180 ° (South).

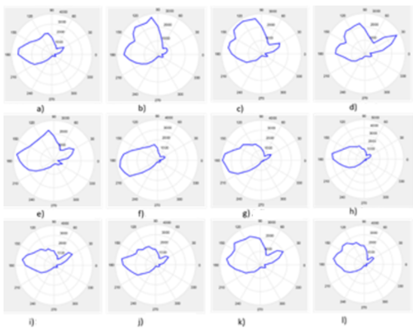

Figure 19: Polar representation of every months of the year wind direction.

3.5 IoT Implementation

In order to meet the second specific objective which mentions the implementation of a meteorological station for the acquisition of data in situ, this station was selected according to the following criteria: number of sensors, connectivity, power supply and the availability of a platform in the cloud. In Table 5, the meteorological variables and their measurement ranges are detailed with their respective accuracy value that guarantees that the obtained value is close to the real value.

Table 5: Measurement ranges.

Sensors	Values	Accuracy
Temperature (C)	-40 a 65	±1ºC
Humidity(%)	10 a 99	± 5%
Barometric Pressure (inHg)	8.85 a 32.50	± 0.08 inHg
Solar radiation (lx)	0 a 200000	±15%
UV index	0 a 15	± 1
Rain (mm)	0 a 10000	± 10%
Direction of the wind	0 a 360	± 1º
Wind speed (km / h)	0 a 160	±10%

The equipment that meets these characteristics is the WS2902-B model manufactured by Ambient Weather, this station is currently installed at the Universidad de las Fuerzas Armadas ESPE campus Latacunga. After the implementation of this equipment, the following trend graphs were obtained for each of the climatological variables Fig. 20, the same ones that represent the data of a complete week

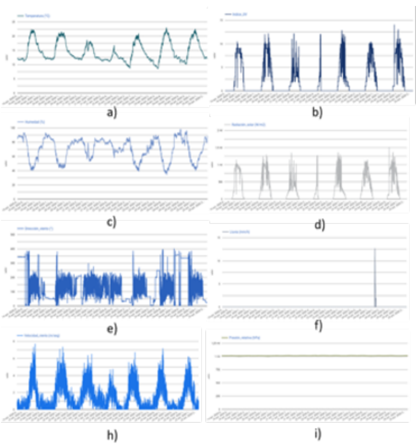

Figure 20: Trends of meteorological variables: a) Temperature, b) UV Index, c) Humidity, d) Solar Radiation, e) Wind Direction, f) Rain, g) Wind Speed and h) Relative Pressure.

In order to increase the measurement points, remote micro stations are designed which have as a characteristic the measurement of temperature and humidity with storage in the cloud. These teams are developed in the following architecture that is detailed in Fig. 21, where the design of devices was done through the use of Wireless technology. Data Analytics in the Cloud is carried out through the communication of data between the device and the development platform, the use of data involves the study of the historical analytics of the data with statistical techniques.

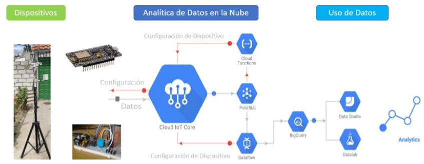

Figure 21: Data Architecture.

In order to begin, the platform used for the development of the architecture is described. This is GOOGLE CLOUD PLATFORM. Thanks to all the characteristics of integration, programming and use of data, through friendly programming interfaces, with different ecosystems of devices connected to the internet, once the hardware has been designed, implemented and installed, the measurement processes and their corresponding adjustments are carried out through comparative calibration techniques with standard instruments.

Figure 22: Instances of standard equipment development, Mini-MASHCA.

The information acquired by these points was contrasted with the Fluke-971 (TEMPERATURE, HUMIDITY METER) and Fluke-923 (AIR VELOCITY METER) standard equipment. Obtaining a measurement error between the standard instrument and the micro stations with the following quantities: 9.2% for temperature and 2.5% for humidity, this can be seen in Fig. 22 where the value acquired by the micro station is displayed versus the data acquired by the standard equipment.

In order to comply with the following specific objective in which it is mentioned developing a web application to visualize the data and interpret the analysis thereof, a website has been implemented according to the following characteristics.

3.6 Web Site Diagram

In the following URL: (https://sites.google.com/view/mashca), the information of the station installed in the Universidad de las Fuerzas Armadas ESPE campus Latacunga and the micro meteorological stations installed in urban areas are displayed, In this web application you can see the time values of each of the variables with their respective trends in a 24 hour range and the table of values of the previous day, Fig. 23.

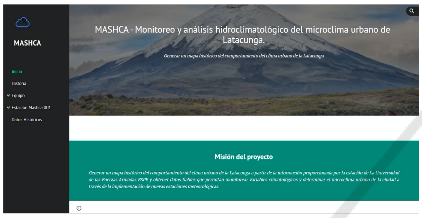

Figure 23: MASHCA Web Application.

Using the GOOGLE ANALYTICS tool, as shown in Fig. 24, it has been possible to observe the behavior of the users who enter the website, the data that are most consulted. It has been determined that measurement of data visited by users. (where the number of page views is shown, the page value, as well as the active users.

Figure 24: Measurement of data visited by users.

After fulfilling the aforementioned objectives, which have corroborated the general objective of this project, which is "To develop a monitoring and analysis system of the urban microclimate of Latacunga." , where a historical record of the behavior of the urban climate of Latacunga with respect to the year 2019 has been generated, based on the information provided by the station of The Universidad de las Fuerzas Armadas ESPE. Finally, the urban microclimate of the city was determined through the implementation of new meteorological stations, among the indicators is information such as the date of consultation of each tag (device), the number of consultations made to the tag and the respective events of the Climatological variables collected according to the season that is accessed. All this is shown in Fig. 25. As a final result, it has been shown that under the cloud computing scheme where historical data has been used, new data stored in the cloud, through meteorological stations under the IoT paradigm, it has been possible to monitor the different nuances of the urban microclimate of the city of Latacunga.

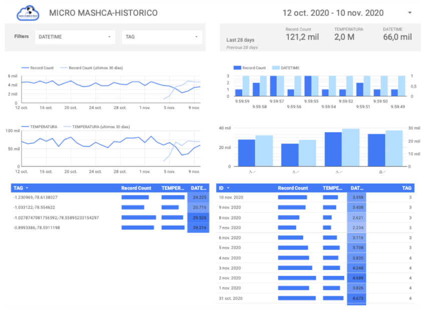

Figure 25: Dynamic data trend.

4 CONCLUSION

The study of urban microclimates at present is serving not only the knowledge of the behavior of the climate in a certain geographical area of the country, but also in the planning of study disciplines in the social field such as tourism; This by virtue of the data collected, processed and exposed, since in the field of tourism in general and in the same sector of the economy but in Latacunga in particular, due to its architectural composition, allows public or private entities involved in tourism, forecast the behavior of the weather at certain hours, which in the case of this recommendation is tourism, that is, the data will allow tourists to know how the weather will behave in the urban part of Latacunga on a given day, this since The city is a purely urban or cultural tourist destination, and the weather factor is a transcendental point in the daily planning of the tourist, no travelers wants to go to the beach in cold weather, so neither does any cultural tourist want to visit the city in a day of heavy rain.

With the fulfilment of the general objective and the specific objectives, the hypothesis that mentions that from the analysis of the data obtained by the meteorological stations can be made a map of the behavior of the urban microclimate of Latacunga can be considered, this can be done when the quantity of existing data acquires the necessary density to capture the resource, which could be verified through the implementation of micro meteorological stations, developed to measure, with temperature and humidity measurement characteristics, within the standardized measurement ranges for the stations meteorological conditions and with an average error of less than 3%.With the application of the measurement of the climate carried out by the meteorological stations installed in strategic points of the urban area of Latacunga, the changes generated by urban development and the presence of microclimates, due to structural changes of buildings throughout history, were demonstrated. of the city since the synergy of new and old constructions in the environment give way to confirm this change in the data, with comparisons with historical data of the climate registered in the city especially using databases of state entities. It can also be mentioned that the historical information of the climate in Latacunga that was recorded by the station was contrasted with the information acquired in real time through the Data Studio software which generates reports of the behavior of the climate in the city, having an appreciation of data taken in urban environments.

The dissemination of the results obtained as a test has been registered among a limited group of people who have generated recommendations to improve the graphic interface of the website, the ways of presenting the data, navigation schemes among others, thus allowing improve interaction with users. In this section, the participation of teachers and students of the participating universities, members of local government bodies, citizens in general, among others, who present a wide spectrum of points of view on the presentation of the information acquired and processed, can be noted. Where it was determined that the most appropriate way for researchers to access this data is through a web page, due to the versatility of sharing information regardless of the operating system, which is used due to the expertise of the developers. Realizing that it is the most appropriate form of presentation of data for technical reasons such as: data availability, latency, ability to mine data in this type of web applications.

The reports generated from the analyses carried out present a glimpse of the climate behavior within the city. This information was obtained through the analysis of large volumes of data, for which cloud servers were used where the data generated by the professional weather station and the weather microstations are stored, the reports are processed and generated. are presented on the website, which can be accessed by any citizen to consult the behavior of the climate in real time of the climatological variables that affect the microclimate, it should be noted that all the information contained in the site has been described in the previous sections, where the parameters of time, amount of data, frequency of use as well as climate variables are clearly identified in detail.

FUTURE WORKS

The future lines to follow are the use of artificial intelligence in order to generate algorithms for predicting climate behavior, adding other types of variables such as urban maps, urban planning, among others. In the design of devices, the implementation of spaces connected to the internet with 5G can be considered, improving the capacity of the devices to collect information as well as becoming pioneers in the development of this type of technology. On the other hand, a dissemination plan for the project must be carried out at the level of social networks, citizen groups.

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