Thermal Study of Costa Rica by means Automatic Meteorological Stations

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Abstract

The National Meteorological Institute (IMN) coordinates all the meteorological activities at a national level and represents Costa Rica with international organizations and fora. The IMN keeps in operation a national network that links the automatic meteorological stations and an international telecommunications system that maintains with the regional centers and worldwide data.

The installation, recollection and data processing of the conventional/mechanical meteorological stations (EMMs) predominated until 1998, up to this moment, a new technology was launched (Automatic Meteorological Stations, EMAs), which produced a considerable change in the institutional database; thus, starting from the results from the studies of the different meteorological stations, an institutional baseline was conformed (1960-1991).

However, in the current study, it has been determined that the automatic meteorological stations of Guanacaste, Cartago and Puntarenas and their respective districts (Liberia/International Airport Daniel Oduber, Oreamuno/Irazu Volcano and Buenos Aires/Altamira), must be considered zones of priority for this research due to their impact, meteorological conditions, location and content data for a period of ten years and their adequacy of environmental measurements.

The purpose of the investigation is to define the actions that will follow for the continuous improvement of the database of the NMI, Meteorological Network and Data Processing Department (DRMPD), through the study and statistical results that will be obtained from the automatic meteorological stations located in different sites of the country for the meteorological

variable: maximum temperature and minimum temperature, to purposely use them in the decision making.

In this way, the problem to be solved through this investigation is the uncertainty accumulated with raw misleading data, missing or suspicious in the direct information gathered from EMAs and which has been considered an unsolved problem, causing significant repercussion when determining the quality controls and their results for the dispositions to be considered.

Additionally, studies have been carried out that show the increment of natural disasters associated, provoked by atmospheric conditions developed by human and a cause-effect relation is registered.

INTRODUCTION

The purpose of the research is to define the actions to be developed for the continuous improvement of the database of the National Meteorological Institute (IMN), Department of Meteorological Network and Data Processing (DRMPD), through the study and statistical results that will be obtained from the meteorological stations located in different parts of the country for the meteorological variable: maximum temperature and minimum temperature, in order to be used in early warning systems (SAT).

According to the last decades, the natural oscillation cycles have been characterized by strong deviations that lead to climatic and meteorological extremes in different parts of the planet. The anthropogenic effect, associated with the pollution with greenhouse gases, is one of the generators of greater climatic variability. In fact, some scientists agree that the effects of interannual climate variability are mixing and potentiating with the effects of climate change (Zwiers, 2003, Sinha Ray and De, 2003, IPCC, 2007).

In this way, regions that already have a clear trend of change and whose future projection indicates a reinforcement of this inclination, should be subject to constant monitoring, prioritization of attention and design of adaptation, prevention and mitigation strategies.

BACKGROUND

The interest of providing statistical information on temperature behavior has been developed considering the vulnerability situation of the study area in the face of the effects of extreme weather events, creating the need for technical strengthening for the preventive and corrective improvement of the database for the operation of a SAT in three strategic points of the country and that have a series of monthly temperature data of 10 years, as allowed by WMO in order to maintain meteorological surveillance and serve as the basis for the decision making

Another important factor is the climatic characterization of Costa Rica because it is a tropical country influenced by diverse factors and meteorological elements and that, in turn, facilitate thermal oscillation within a small country such as Costa Rica.

At the same time, it is essential to develop this research the affectation that Costa Rica has experienced with the last atmospheric phenomena, such as: Hurricane Otto, Tropical Storm Nate, incursion of cold fronts, among others. Consequently, the impact I want to achieve at the end of this research is to define guidelines for the continuous improvement of the institutional database that can be used as a SAT in the face of extreme weather events, such as: direct and indirect influence on hurricanes , cold fronts, temporary, floods, overflows, landslides, etc., by means of the reduction and / or exoneration of missing, suspicious or erroneous data that alter the results of the investigations for the decision making before the different institutions involved of the Center of Operation of Emergencies (COE) and of the outside. According to Zwiers et al 2003, detecting changes in the climate against its variability is key in climatological research.

In this sense, the IMN will guide the strategies and actions in compliance with the law of creation of the IMN and, in turn, research on weather, climate, variability and climate change among the different strategic sectors, which allow a product to be delivered to society. With added value as part of its commitments to the National Meteorological Organization (WMO) to ensure the monitoring of the atmosphere and extreme hydrometeorological events.

Within the studies developed by the National Meteorological Institute (IMN), it is assumed that the risk is present in any area of the country; however, meteorological stations were identified that, due to their data series, comply with the recommendations established by the WMO (Guide of Instruments and Methods of Meteorological Observation, 2008) and that will provide greater results for the purpose of this research.

It is also important to highlight that due to the location of our country, its tropical characteristics and its ecological environment: forests, hydrographic network, soils and climate; It has an extensive range of fauna and flora

The tropical climate of our country is modified by different factors such as relief (mountains, plains and plateaus), oceanic influence (sea breezes, among others.) and the general circulation of the atmosphere. In addition, there are other vital aspects such as the interaction of local, atmospheric and oceanic geographic factors that regionalize the country's climatology. The northwest-southeast orientation of the mountainous system divides Costa Rica into two slopes: Pacific and Caribbean. Each of these slopes presents its own regime with particular characteristics of spatial and temporal distribution (Manso, 2005).

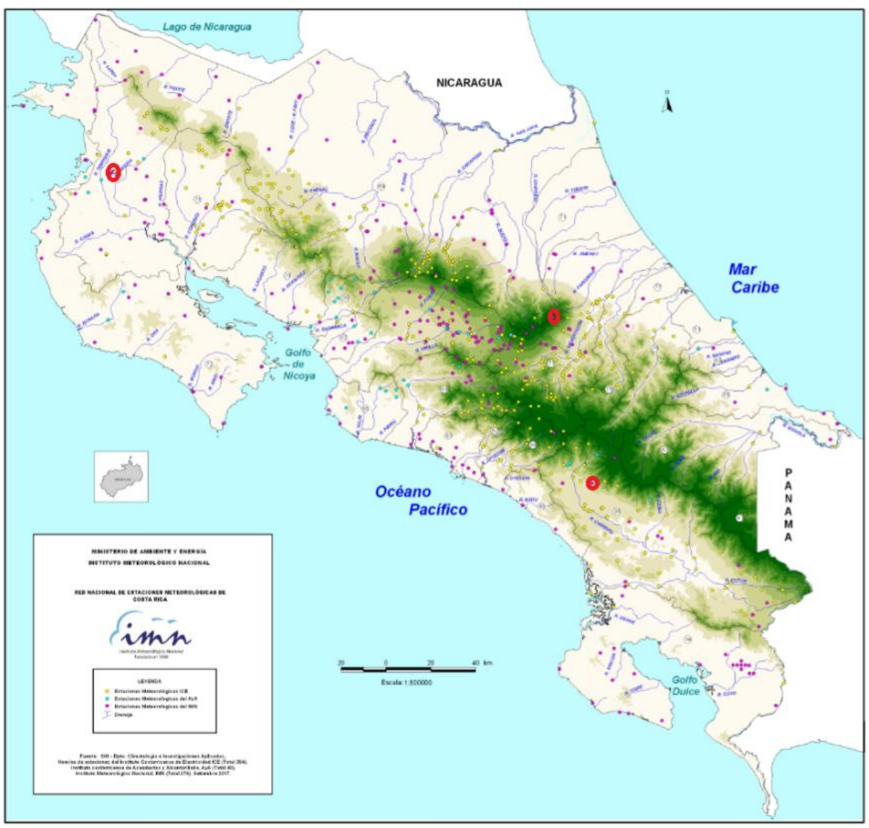
METHODOLOGICAL DESIGN

The investigation will be based on the study of three meteorological stations, in which the quality of the raw data collected in the field trips will be observed according to the monthly tour plan and the analysis of the conditions of their territorial environment.

Table 1. Weather stations in the study area

WS	Name	Cimate zone	LATITUDE (NORTH)	LONGITUDE (WEST)	Altitude (msnm)
73137	VOLCAN IRAZU, AUT.	Central Valley	9º58'8"	83º50'21"	3331
74051	AEROP.LIBERIA OESTE 07	North Pacific	10º35'54"	85º32'24"	70
98095	ALTAMIRA	South Pacific	8º52'48"	82º53'39"	1371

In Figure 1, the spatial distribution of the stations indicated in Table 1 is shown, which are distributed in the study area of the investigation.



This study will be supported by the combination of quantitative and qualitative data. It is considered that the mixed method is appropriate, since the research is focused on statistical calculations. In addition, it will be involved with an early warning system; this should consider the impact on different sectors (population, livestock, agriculture, trade, etc.).

In this way, the problem to be solved with this research is the uncertainty that has been accumulating with erroneous, missing or suspicious raw data in the direct intake of meteorological stations and that has been considered an unresolved problem, generating significant repercussion when determining quality controls and their results for decision making. Additionally, if one considers that natural disasters are increasing due to the change that has occurred in the atmospheric conditions resulting from human behavior, a cause-effect relationship is recorded.

For the above-mentioned, the research will use techniques of collection, analysis and processing of raw information (collected directly from the meteorological station for the purpose of analysis) and information with a basic analysis (review of data series according to the collected block).

The monthly tour plan by regions of the meteorological stations (MS) will be used and the optimum conditions of the installation of the MSs will be evaluated (equipment, sensors, preventive and corrective maintenance, data extraction and transfer to the Data Processing area).

Within the meteorological stations (MS) under study, two main types can be mentioned:

The type U weather station. Contains the following equipment:

- 10m high tower with tensioners
- Lightning rod
- Meteorological shelter
- Solar panel, battery and regulator
- Storage / measurement / processing module (Data Logger)
- Basic sensors: Precipitation, temperature (maximum and minimum) and humidity of the air, wind (speed and direction)
- Optional sensors: Solar radiation, atmospheric pressure, ultraviolet radiation, etc.
- Protective mesh of the station with a maximum height of 2 meters, in an area of 100 m² (10 m X 10 m)
- Communication equipment: Radio frequency (VHF, UHF, SHF, satellite) IP, rad modem, cellular connections, etc.
- Data monitoring team: IMN website

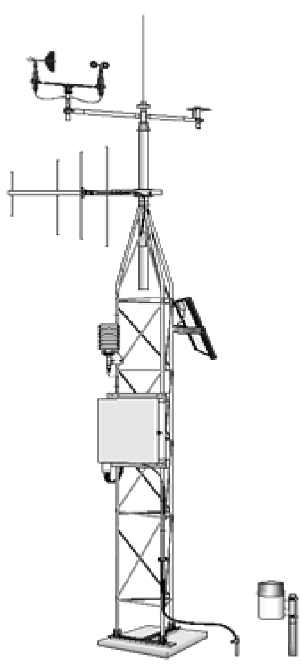


Figure 2: Weather station Type U.

Campbell Scientific (2012).

The UTP type weather station.

The difference of the type U and UTP station is that it does not have a wind sensor. It contains the following equipment:

- 3 m high tower
- Meteorological shelter.
- Solar panel, battery and regulator
- Storage module
- Basic sensors: Precipitation, temperature (maximum and minimum) and humidity of the air
- Protective mesh of the station according to the zone and safety criteria
- Optional communication equipment: Radiofrequency (VHF, UHF, SHF, satellite) IP connections, rad modem
- Data monitoring system: IMN website.

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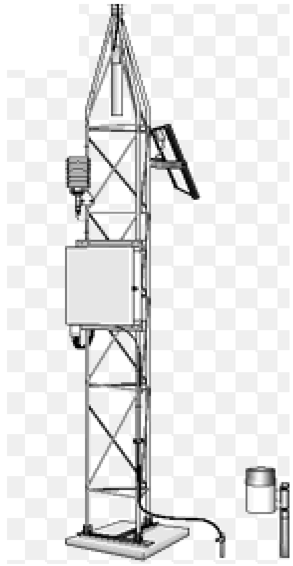


Figure 3: Weather station Type UTP.
Campbell Scientific (2012).

However, for the purposes of this investigation both types of MS that we will study have a temperature sensor (maximum and minimum). In this sense, the most relevant is the installation and correct subtraction of datalogger data and on-site verification by means of a graphic behavior over time, which allows visual observation at the time of maintenance (in situ).

Subsequently, the files are transferred to the Data Processing area accompanied by the tour report, these are stored in a folder (tour data) divided by climatic zones and weather stations.

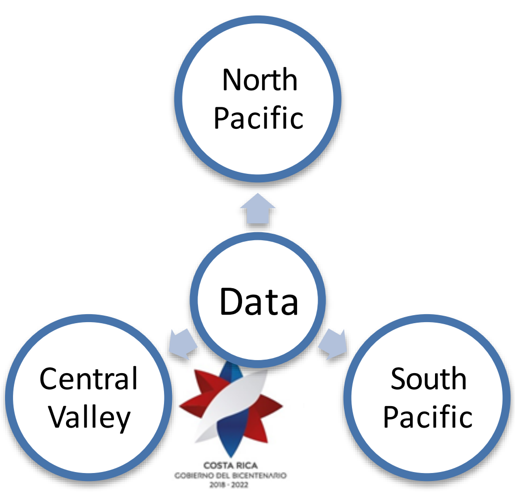


Figure 4: Scheme data storage.

The data processing contains different stages, where you should have the tour reports, review report, data entered (SEMA)

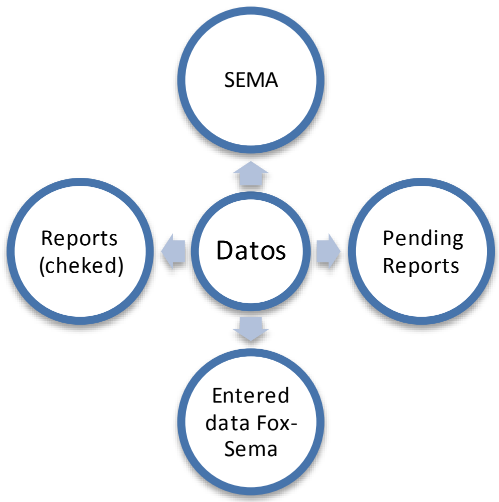


Figure 5: Scheme data processing.

The fundamental basis for quality control is the MeteoQC software created with the programming language R, like RmetCC, for the quality control of meteorological data, creating graphs by meteorological variable. In addition to the corrections and modifications of the file format for data entry, this automatically corrects data (out of range and filters different validation tests (eliminate or modify them and their respective flagging).

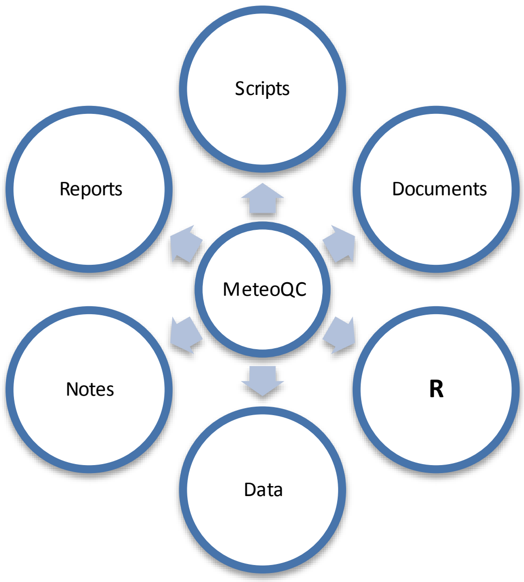


Figure 6: Outline RmetCC Folder

The data to be reviewed is placed in Data-> logger_data, the R console is opened and the text file is opened immediately. After this activity, you paste in R to display the menu, where you interact with the program for quality control. The results will be in the Reports folder and the data to be imported in the Data-> SEMA folder so that the internal users, according to the permissions granted access the information for the different routines.

Also, different graphs will be elaborated, where the analysis, conclusions and recommendations of the data subtracted from the MSs are obtained

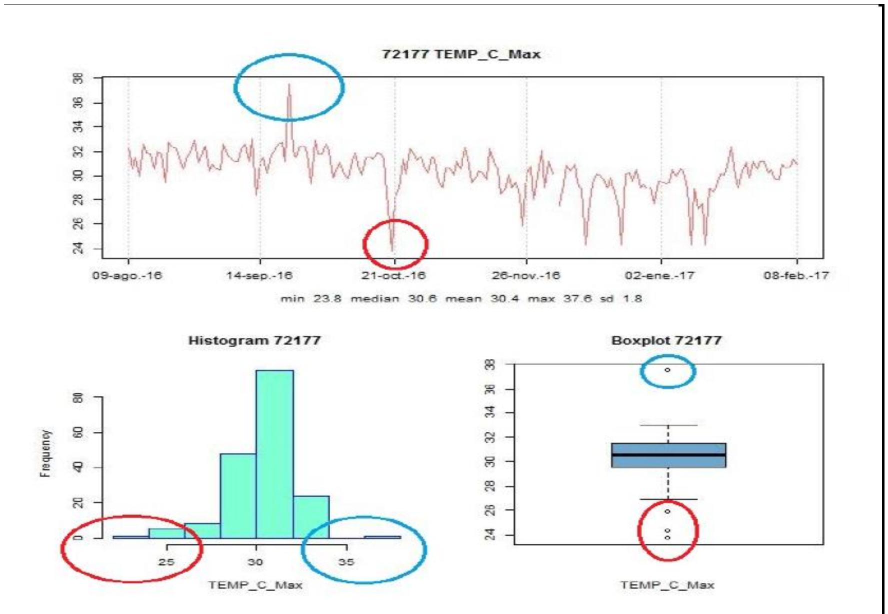


Figure 7: Time data graphics included in reports generated by MeteoQC.

Likewise, it is important to know the statistical range of the variables to be treated (maximum and minimum value) since this allows us to obtain an idea of the dispersion of the data. Other necessary elements to consider:

- Battery Voltage, which is not less than 13 V
- Temperatures below 6 ° C
- Any other anomaly that you consider important.

Station does not exist

Value out of precision range

Start date overlaps with previous batch

Differences between time file and journal

With a "vacuum" in the same batch> = 15 hours

After reviewing the data, the data is entered into the database. The dates of both files must be the same, if the daily batch starts one day after the schedule due to the cut at 7:00 a.m., the date of the time file must be respected.
From the study area we can see in Photographs 1 and 2 the variety of natural disasters that occur throughout the year and the alterations that are generated within the community and other local dimensions, which feedback the tendency for the formulation of the SATs

Photograph 1: High temperatures in Liberia.
National Meteorological Institute, August 19, 2015.

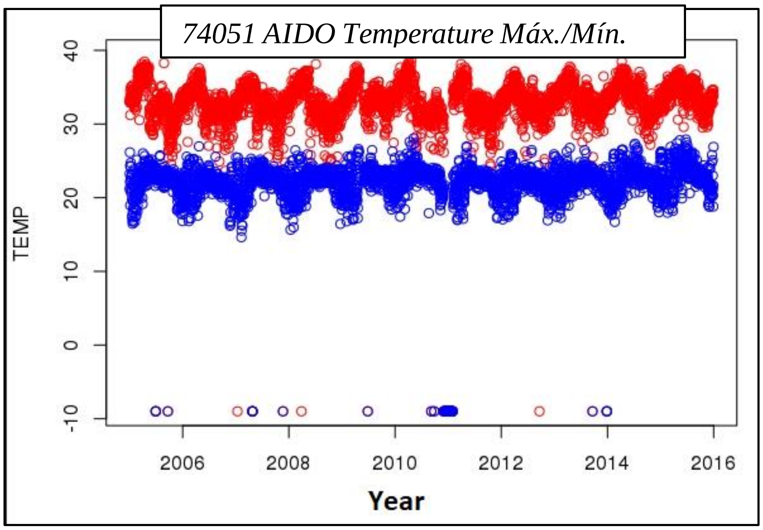
Photograph 2: Low temperatures in the Irazu Volcano National Meteorological Institute, January 20, 2017.

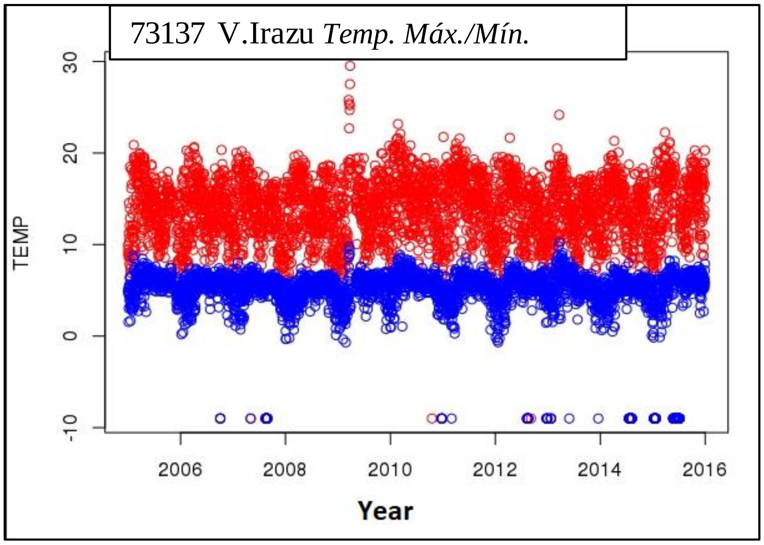
RESULTS

When starting the revision of the maximum and minimum temperature data, the statistical range of the variable is known in advance, that is, the interval between the maximum value and the minimum value that will allow to define the dispersion of the data, considering the given standards by WMO for meteorological observations

In figure N.8, the oscillation of the maximum and minimum temperature between the meteorological stations can be appreciated, this basically to the thermal behavior that prevails in Costa Rica and its location above sea level. In the Irazú Volcano, there is an important characteristic, since it is mainly influenced by the conditions of the Pacific Slope and the Caribbean Sea, meanwhile, in the AIDO and Altamira, the conditions of the Pacific influence more and here the main characteristic is the displacement of the Intertropical Convergence Zone, where warmer temperatures are recorded in the AIDO over Altamira.

With regard to the analysis, the presence of erroneous and suspicious data that exceeded its maximum and minimum allowed values was obtained and for this, extraordinary maintenance tours were made to check the temperature sensor, corroborate its useful life, location, among others. Subsequently, the prevailing weather conditions are corroborated and as a last level the quality of the data processed with greater emphasis on the minimum temperature data that projects greater anomalies.





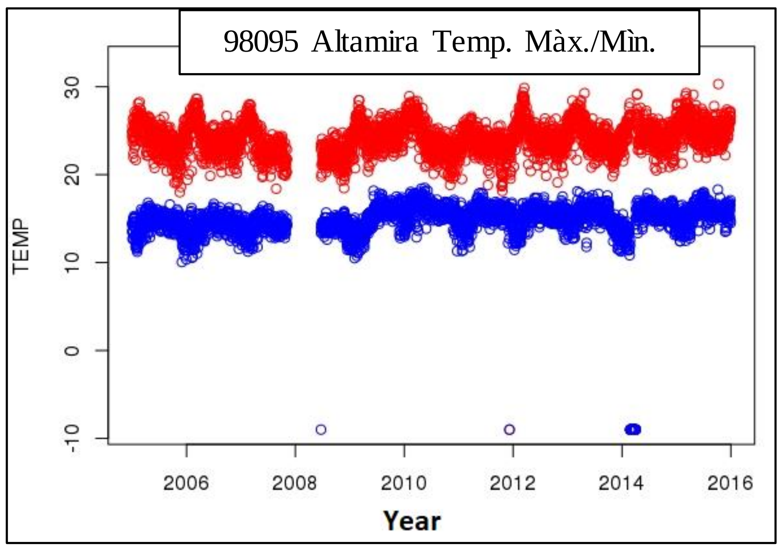
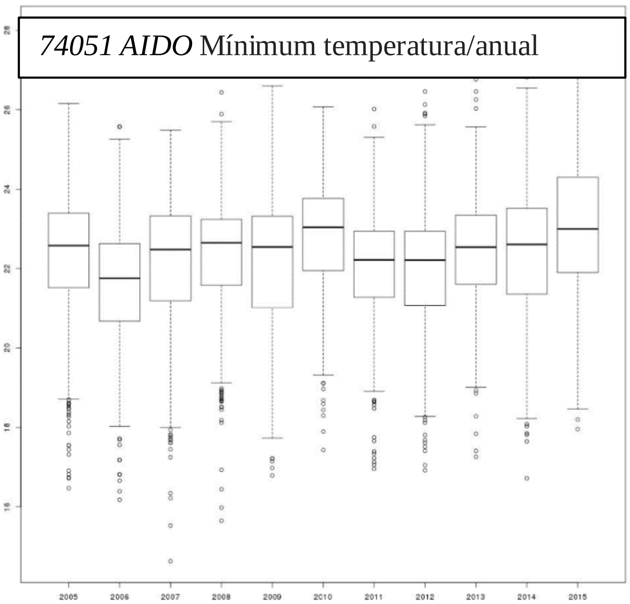
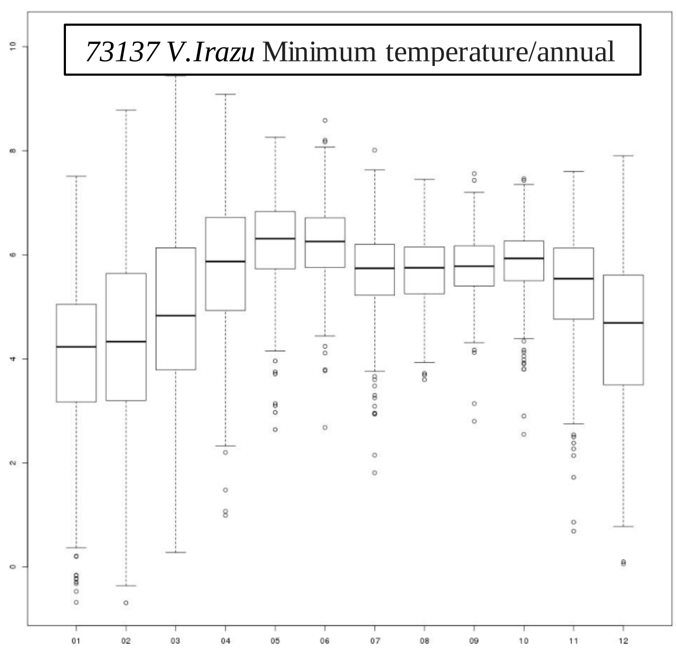


Figure 8: Maximun and minimum temperature (2001-20016)

In figures from N.9 to 12, an overview of the symmetry of the data distribution is provided, which were analyzed annually and monthly (maximum and minimum temperature). In general, a tendency of atypical values is observed in the lower end for both temperatures (maximum and minimum) and in lower tendency in the upper end, the data are not symmetric values, the dispersion is concentrated between the average and Q3, it is say, between 50% and 75% of the distribution.





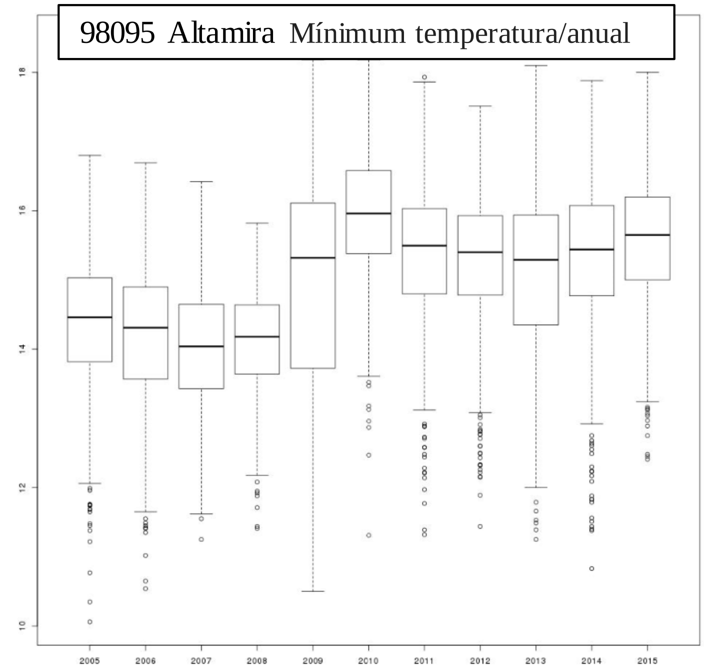
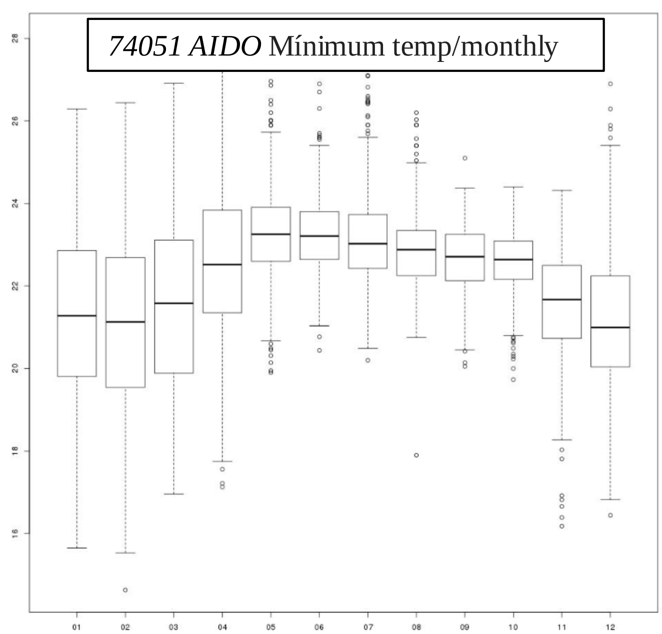
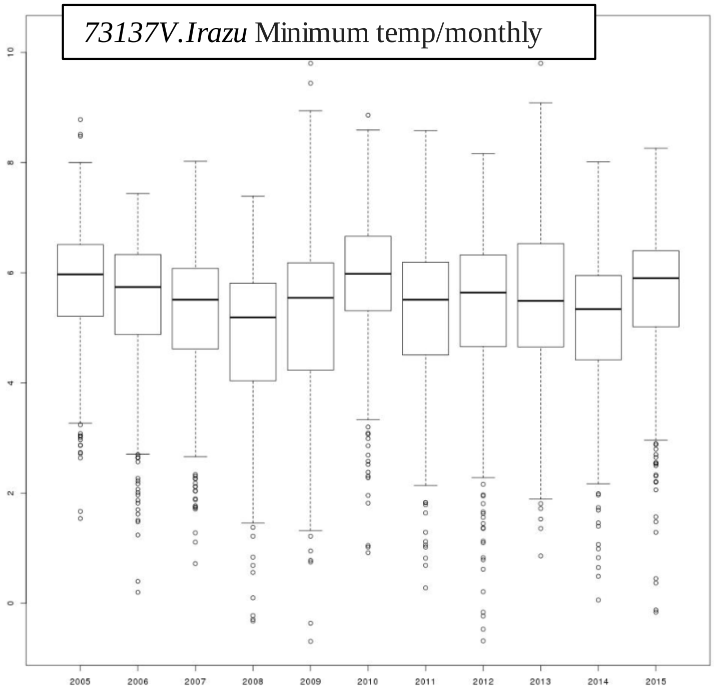


Figure 9: Mínimum temperature/annual.





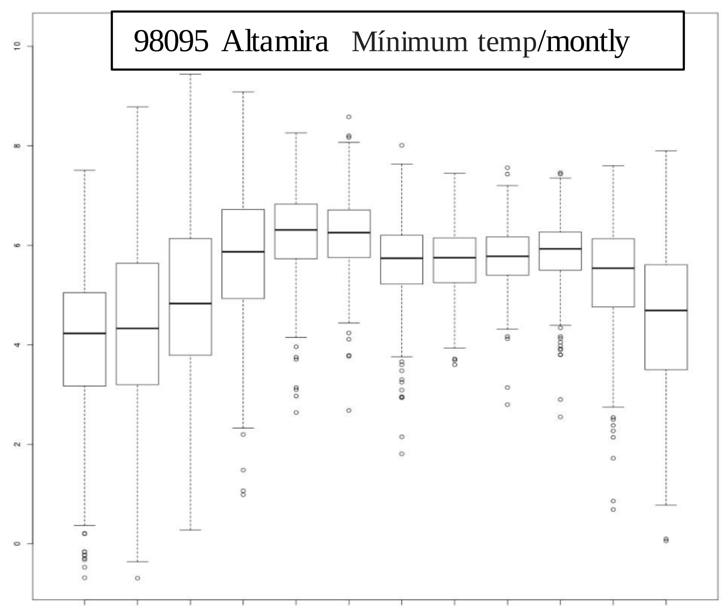
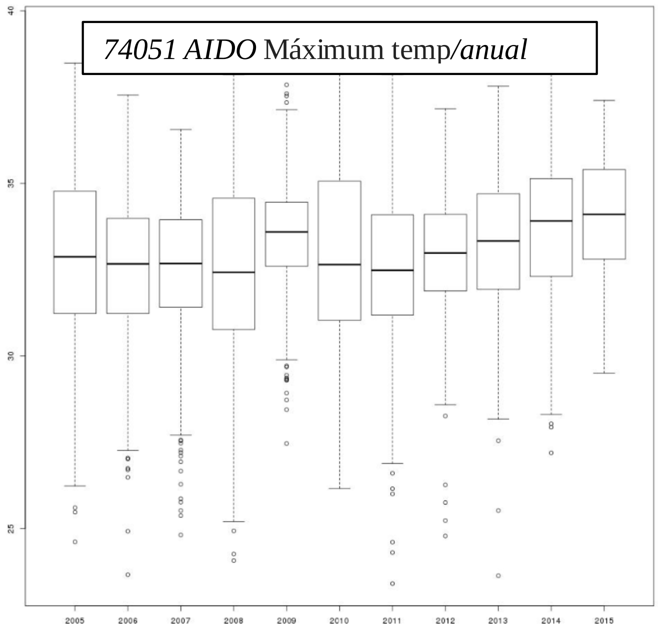


Figure 10: Mínimum temperature/monthly.


74051 AIDO Máximum temp/anual
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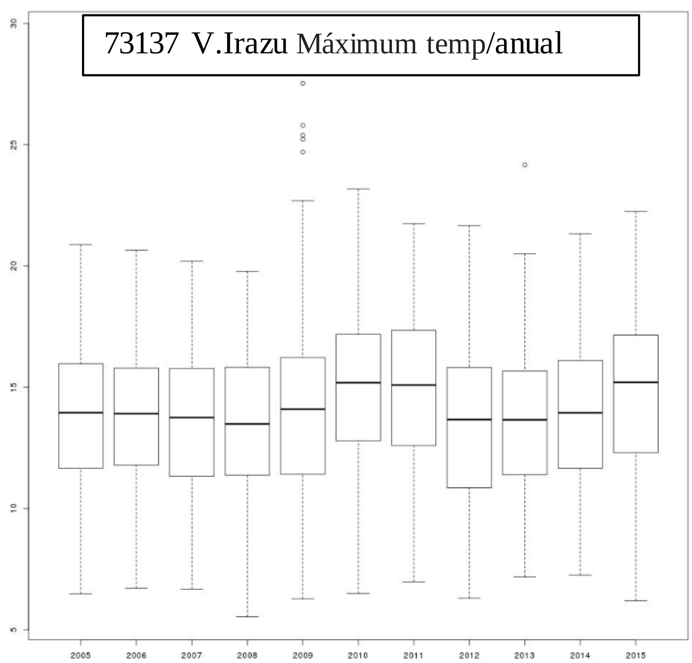
73137 V.Irazu Máximum temp/anual
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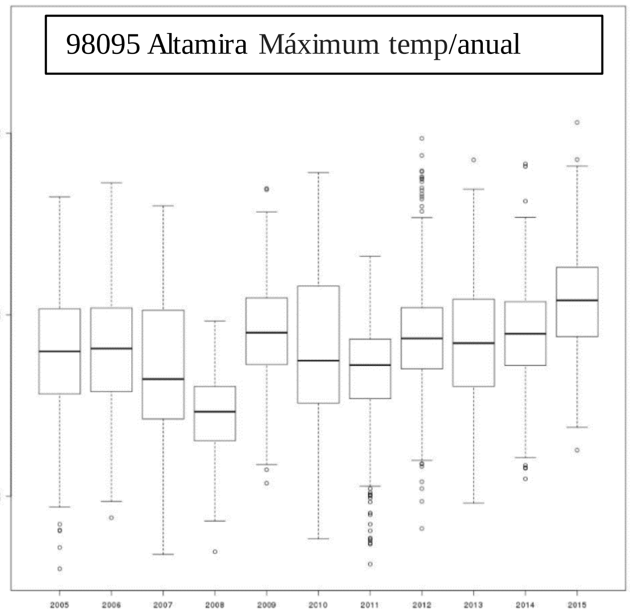
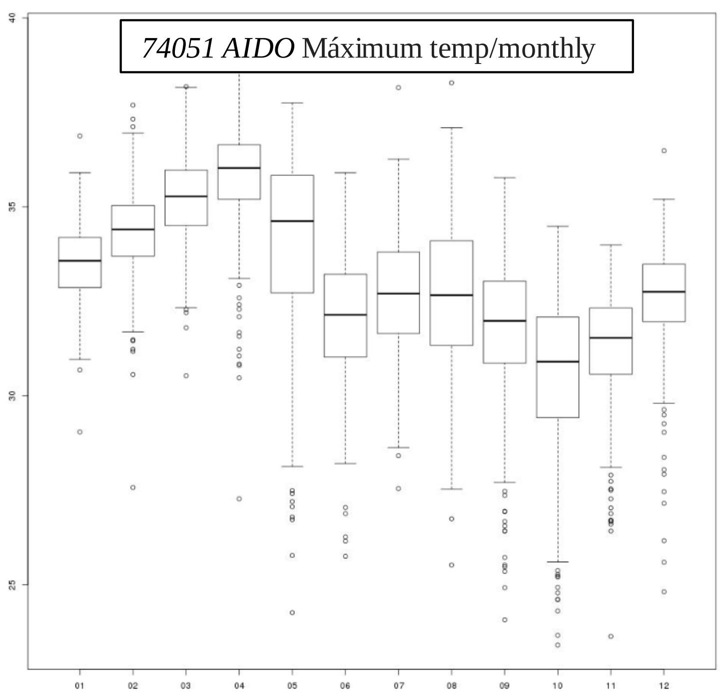


Figure 11: Máximum temperature/annual.



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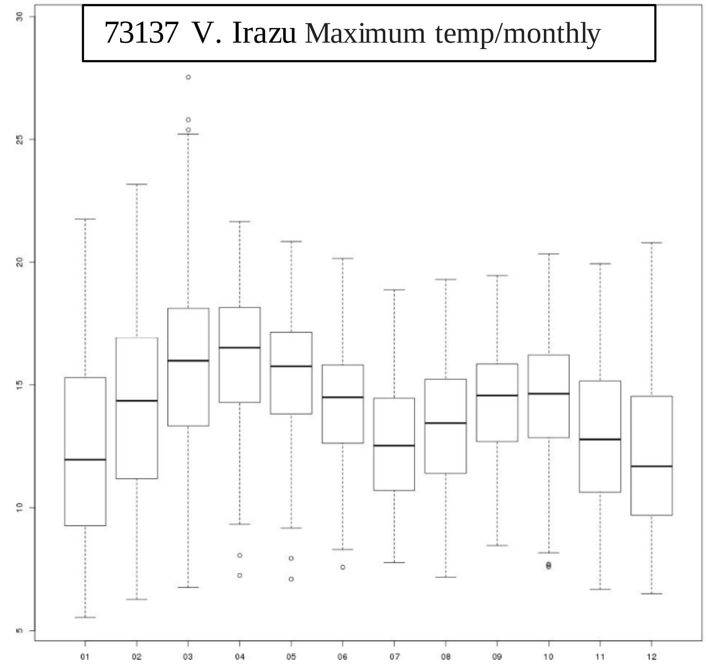


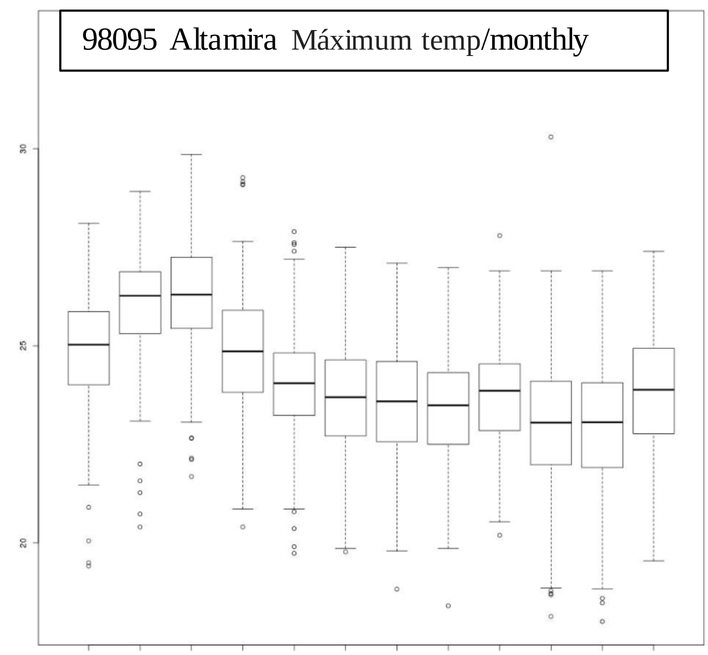
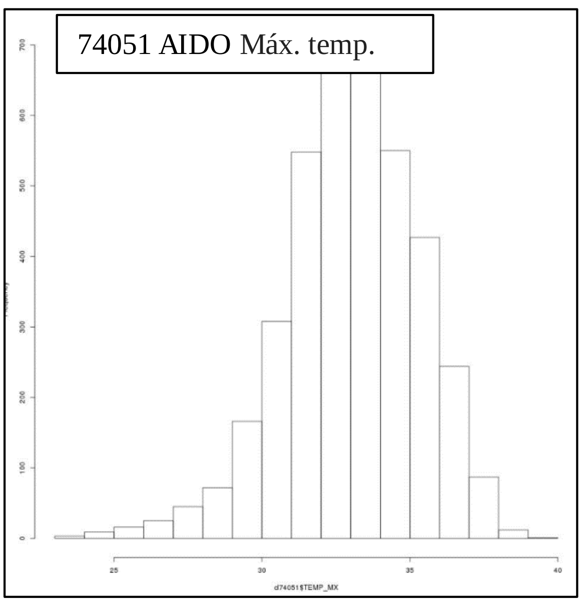
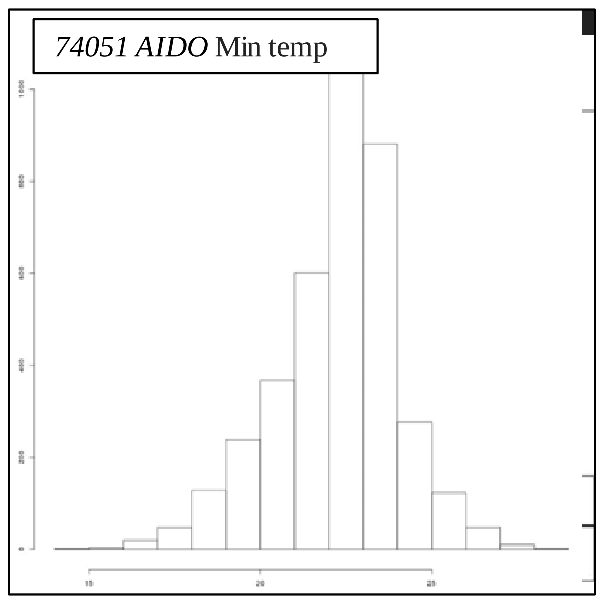


Figure 12: Maximum temperature/monthly.

The trend of the data has been the location between symmetric frequencies for the maximum temperature with a normal variability. While, the minimum temperature, has a small bias to the left (negative), which indicates that the minimum temperature was higher than the average. In the case of the Daniel Oduber International Airport, the average was reported between 19.5ºC and 35.2ºC and the lowest temperature at 14.6ºC and the highest at 38.8ºC. The tendency of the Irazú Volcano, being 3331 meters above sea level, logically reports lower temperatures (-0.7ºC in the month of January and 23.4ºC in March), in both cases it is related to one of the most windy months in our country due to the influence of the systems of high pressure and warmer, since the sun is perpendicular to our latitude. In the same way, the meteorological station of Altamira, reports the following average temperature 13.0ºC and 26.3ºC and its extreme values in 10.0ºC and 30.3ºC.





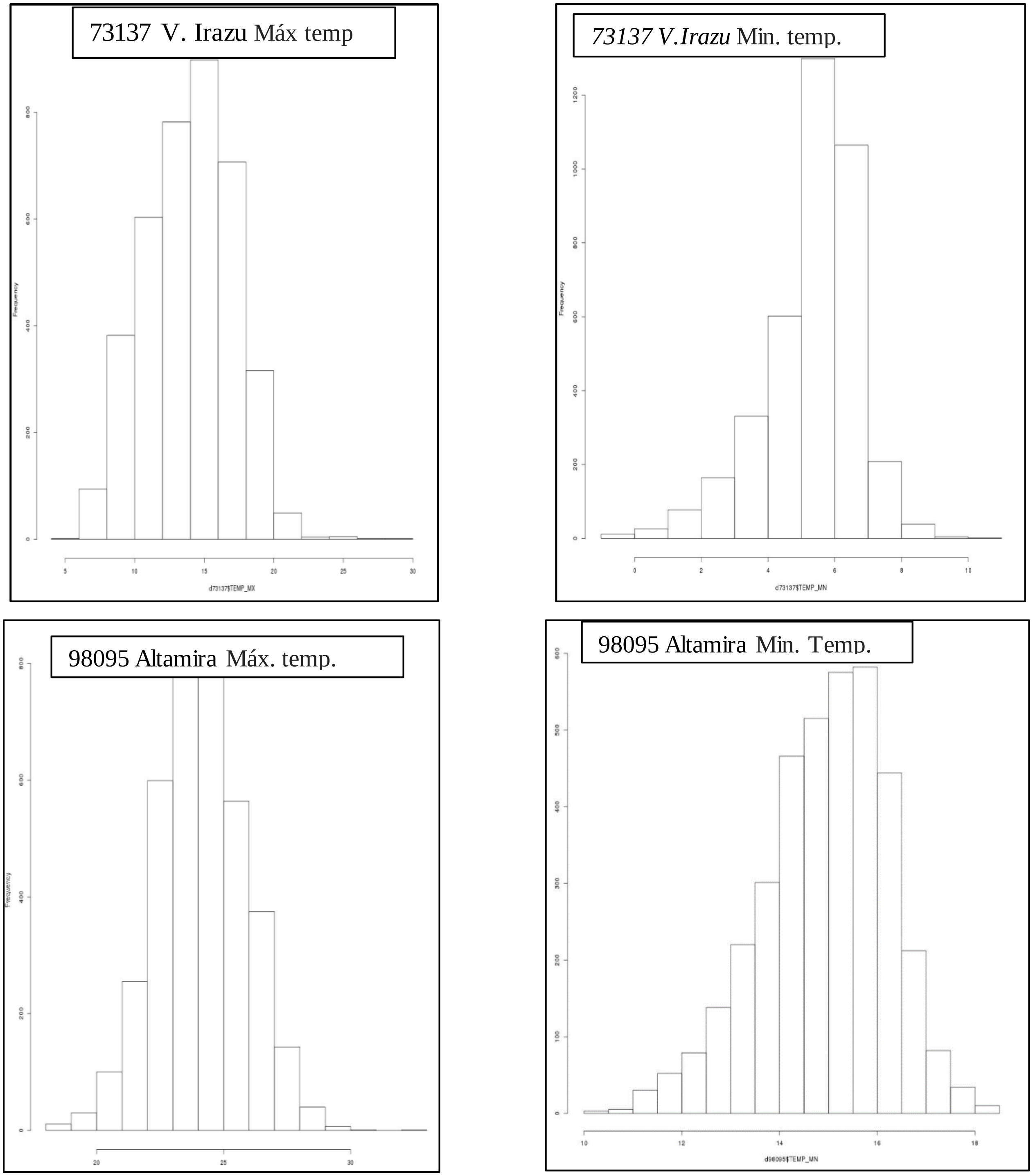


Figure 13: Maximum temperature (annual and monthly).

DISCUSSION

The meteorological stations are composed of several devices, quality control systems that can have different problems and solutions; the ideal is to have a base of the typical problems and solutions of weather stations and data to rule out possible anomalies.

Among the most common problems, it has been determined that the power supply has low voltage, the panels have not achieved the power required by weather conditions, damage to the battery causing loss of data, therefore, it is suggested to make a control in real time and more frequent visits.

Likewise, there have been failures in the transmission, in this sense the IMN depends on private owners, which implies that we depend on them to keep the equipment turned on, the internet active, personnel available, etc. Due to this situation, a project of digital transmission (via cell) was proposed so as not to depend 100% on the conditions provided by the owners. In the first stage the communication was installed 60 automatic meteorological stations, currently, they are in trial period, since the signal has been lost occasionally.

It is recommended after the installation of the meteorological stations to do a field verification and later, an in situ analysis of the devices, duality of sensors as a preventive method in case of any anomaly, this process while verifying the behavior of the station meteorological On the other hand, we must analyze: the installation, location, raw data files, data processing, quality control, etc., to take a criterion in case of erroneous, missing, suspicious data, among others.

It has been recommended to return to the field visits every two months and not every three months, so that there is not so much time between the field visits and there are incidents that affect the data or the meteorological station itself.

Also, a project aimed at the modernization of the data processing and quality control platform was presented in order to constantly monitor the behavior of the sensors and recorded data, at the same time with the purpose of complying with the Guide of instruments and methods of meteorological observation, N. 8.

In the same way, changes have been made in the different levels of quality control and metadata with the aim of reducing the repercussions between meteorological stations, data processing, quality control and data storage for the internal and external user and to use for a SAT in extremely weather conditions.

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