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Research Article

Network of Remote Sensors for Climate Analysis in the Bolívar Province

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ABSTRACT

This study focuses on the development of a climate monitoring system in the three climatic floors of the province of Bolívar through a network of remote and satellite sensors, in order to resolve the scarcity of accessible and scientifically processed meteorological data. The main objective of the project is to generate reliable climate information to predict climate behavior and facilitate decision-making in sectors such as agriculture, tourism and early warning systems. The methodological approach is quantitative, based on the collection of numerical data of key variables (temperature, humidity, atmospheric pressure) captured by sensors installed in different locations. This data is compared with satellite information to generate predictive models. In the first phase of the project, weather stations were installed in Guaranda, El Arenal and Chillanes, connected through GPON and GSM links. The collected data is processed and displayed on a web page in graphic and textual format. Access to satellite information from the GOES-16 satellite improves data accuracy through interpolation of ground and satellite records. This project offers a robust climate monitoring system, the first phases of which have already produced historical data that facilitates trend analysis. A second phase is planned to expand the network and improve predictive models, contributing to a better understanding of the impact of climate change in the region.

Keywords: Remote sensors, climate prediction, meteorology, GOES satellite.

INTRODUCTION

The scarcity of meteorological data technically processed and accessible to the public in the province of Bolívar has motivated the need to implement a Remote Sensing Network System. This system arises as a direct response to the lack of reliable climate information in this region, which is critical for decision-making in sectors such as agriculture, tourism, natural resource management and early warning systems. As highlighted[(1)]; Remote sensing systems are a key technological tool for the capture and analysis of environmental data, enabling not only real-time observation, but also the prediction of extreme weather events that affect daily life and long-term planning.

Climate, as a determining factor in daily life, has a direct impact on human activity and the ecology of any region. In the case of the province of Bolívar, located in a diverse geographical environment with three climatic floors, meteorological fluctuations can be significant and decisive. However, the absence of accurate and scientifically processed data has limited the ability of decision-makers to act efficiently and based on evidence, which in many cases leads to empirical responses that are not sufficiently informed or anticipated.

The purpose of the Remote Sensing Network System is to fill this gap by providing an infrastructure that collects, processes and disseminates weather information in real time. In addition to recording key variables such as temperature, humidity, atmospheric pressure, precipitation, wind speed and direction, the system will also make it possible to correlate this data with high-resolution satellite images. The combination of these technologies will enable a greater ability to predict climate behavior in the region, facilitating informed decision-making in key sectors such as agriculture, which is highly dependent on the weather, and early warning systems, vital in the event of extreme events such as storms or droughts.

A network of remote sensors is capable of capturing analogue signals that, through a conversion process, are transformed into digital data. This data can be stored and analyzed in real-time, providing a dynamic and continuous view of weather conditions in the monitored areas. This type of system is not new, and has already proven effective in a variety of geographical and climatic contexts. According to [2], the use of remote sensing in meteorology has grown exponentially in recent decades, allowing researchers and decision-makers to have accurate and up-to-date information for natural resource management and risk mitigation.

In this case, the network of remote sensors in the province of Bolívar will allow the monitoring of critical variables such as temperature, humidity and atmospheric pressure, as well as wind speed and direction. This data will be collected by specific sensors, such as anemometers (to measure wind), rain gauges (to measure precipitation), and barometers (to measure atmospheric pressure). The use of these devices, along with the implementation of a storage and processing system on on-premises and cloud servers, will provide a continuous and accessible source of data for research and planning.

The data collected will not only be available to researchers and government institutions, but will also be accessible to the general public through a web server. This transparency in access to information aims to democratize the use of weather data, allowing a wide range of users, from farmers to tourists, to benefit from this information. In addition, the data will be organized and visualized in both graphic and textual formats, facilitating its interpretation and practical use in daily decision-making.

One of the most innovative aspects of this system is the ability to correlate data obtained from ground-based sensors with satellite imagery. In particular, access to the GOES-16 satellite, which provides real-time imagery, will validate the accuracy of ground data and improve predictive models. The GOES-16 satellite, launched by NOAA (National Oceanic and Atmospheric Administration of the United States), has been a crucial tool in global weather monitoring, offering high-resolution images covering much of the American continent and the Caribbean[3].

The use of satellite data complements ground-based measurements, allowing a view from space that can identify large-scale weather patterns, such as tropical storms, cold fronts, or temperature anomalies. This ability to correlate satellite information with surface data provides a more complete picture of the climate, which in turn improves the accuracy of mathematical models used to predict weather events. As mentioned[4], the integration of remote sensing technologies with satellite imagery has proven to be an effective strategy for the development of predictive climate models.

One of the main benefits of the remote sensing network is its ability to generate predictive models. These models, based on historical and real-time data, will make it possible to predict weather phenomena and climate trends. As data accumulate, it will be possible to identify patterns that show the effects of climate change in the region. As they state[5], predictive mathematical models are a key tool for climate risk management, as they allow natural crises to be anticipated and more efficient mitigation strategies to be prepared.

The analysis of historical series, that is, the collection of data over several years, will allow us to observe how climate phenomena change over time. This is critical in the context of climate change, where alterations in atmospheric variables often occur gradually and can go unnoticed without detailed long-term analysis. For example, a sustained increase in temperature or a decrease in rainfall could be indications of broader climate change that would affect biodiversity, agriculture and local infrastructure[6].

The purpose of the Remote Sensing Network System is not only to collect data for research, but also to share this information in an accessible and practical way for a variety of users. Farmers, for example, will be able to use this information to plan their crops based on weather forecasts, thus avoiding losses due to adverse weather events. Carriers will be able to use the information to plan safer routes, while tourists will be able to access up-to-date data to plan their visits more efficiently and safely. In addition, early warning systems will be able to react more effectively to potential natural disasters, such as floods or droughts, that could affect local communities.

Another important group of beneficiaries are students and teachers, who will be able to use this data to carry out academic research and develop projects that contribute to scientific knowledge about the climate in the region. The availability of open and scientifically processed data will foster greater collaboration between educational institutions and research centers, which in turn will contribute to the development of innovative solutions to local climate challenges.

METHODOLOGY

The type of research applied to the Remote Sensing Network System project in the province of Bolívar is quasi-experimental with a quantitative approach. This type of study involves the controlled manipulation of certain conditions, such as data collection through remote sensing that captures meteorological variables in real time, without a completely random assignment of conditions, which is characteristic of quasi-experimental studies[8]. The meteorological stations are strategically located in selected sites (Guaranda, El Arenal and Chillanes) to cover the different climatic levels of the province, although external climatic variables cannot be directly controlled.

The quantitative approach is crucial, since it is based on the collection of numerical data on meteorological variables such as temperature, humidity, atmospheric pressure, rainfall and wind speed; which according to [9] allows the collection of certain data that facilitate statistical analysis and thus achieve satisfactory results, these data are analyzed using statistical and mathematical tools to identify correlations and trends, which allows the development of predictive models[10]. This quantitative approach allows researchers to not only accurately measure climate variables, but also establish cause-and-effect relationships between them, which is essential for the prediction and understanding of weather phenomena.

Comparing the data collected by the sensors with GOES-16 satellite imagery adds an additional level of validity to the study, providing a broader and more accurate perspective of climate behavior in the region[3]. This allows predictive models to be adjusted based on information obtained from both terrestrial and space sources.

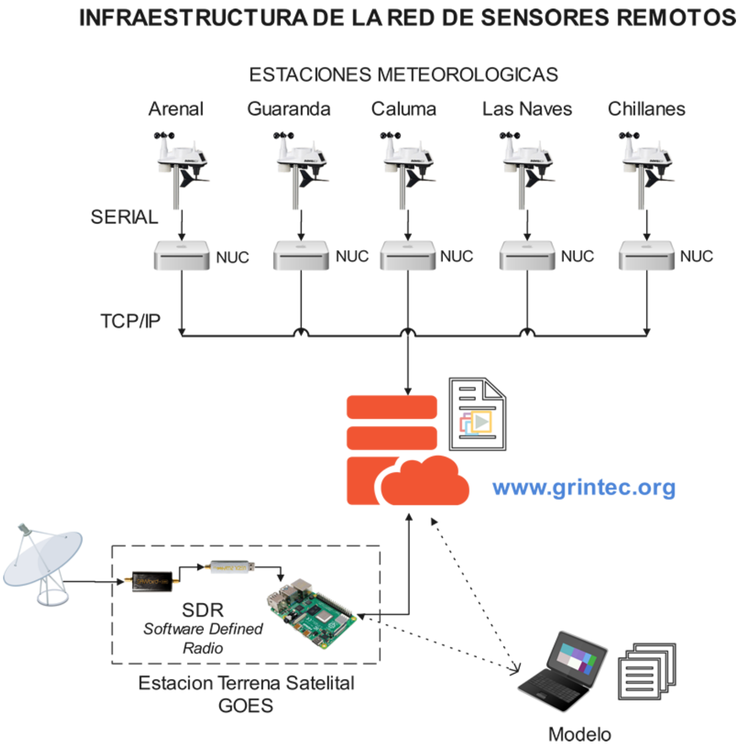
Overall, this quasi-experimental study seeks to explain climate phenomena in the province of Bolívar, through the collection and analysis of empirical data. The results obtained will contribute to improving decision-making based on scientific information, especially in sectors such as agriculture, early warning systems and natural resource management, where climate plays a determining role[5].

RESULTS AND DISCUSSION

During the development of the remote sensing network in Bolívar Province, weather stations integrated with anemometers, wind vanes, rain gauges, thermometers and barometers were used, with the aim of monitoring meteorological variables in real time. These devices are widely used in environmental monitoring, providing essential data to understand and predict weather phenomena. As he points out[10], remote sensing and weather stations enable the accurate capture of atmospheric data, facilitating real-time decision-making for various applications. The connection of the stations to a NUC/PC (Next Unit of Computing), using TCP/IP protocols, ensures efficient data transmission to a cloud server, allowing real-time access via wired (GPON) or wireless (WiFi or GSM) technologies[11]. The data collected is displayed every 60 minutes, via the website www.grintec.org.

The integration of sensors in Guaranda, El Arenal and Chillanes not only allows the monitoring of local climate, but also contributes to the analysis of climate trends at the regional level. According to ([12], the implementation of distributed sensor networks in key geographical areas improves the ability to correlate data with satellite information, such as GOES satellite images, which are essential to validate the accuracy of atmospheric models. In this project, an infrastructure was established capable of receiving daily satellite data, storing it and comparing it with the records of the ground stations, in order to improve climate predictions by analyzing correlations between atmospheric variables[12]. Each station is installed as visualized in Figure 1 and the cloud connection is configured as described in Figure 2.

Graph 1 – Guaranda Station



Graph 2 – Remote Sensing System Configuration

Interpolation of terrestrial and satellite data is key to developing a predictive mathematical model. As mentioned(14), the combination of data sources improves the accuracy of weather models, allowing more reliable predictions in the short and medium term. Through statistical tools and simulation techniques(15), the climate prediction model can be validated, adjusting it as more data is collected in real time. This adjustability is essential to ensure the validity and accuracy of weather forecasts, as indicated(16).

Graph 3 – Satellite Station Antenna

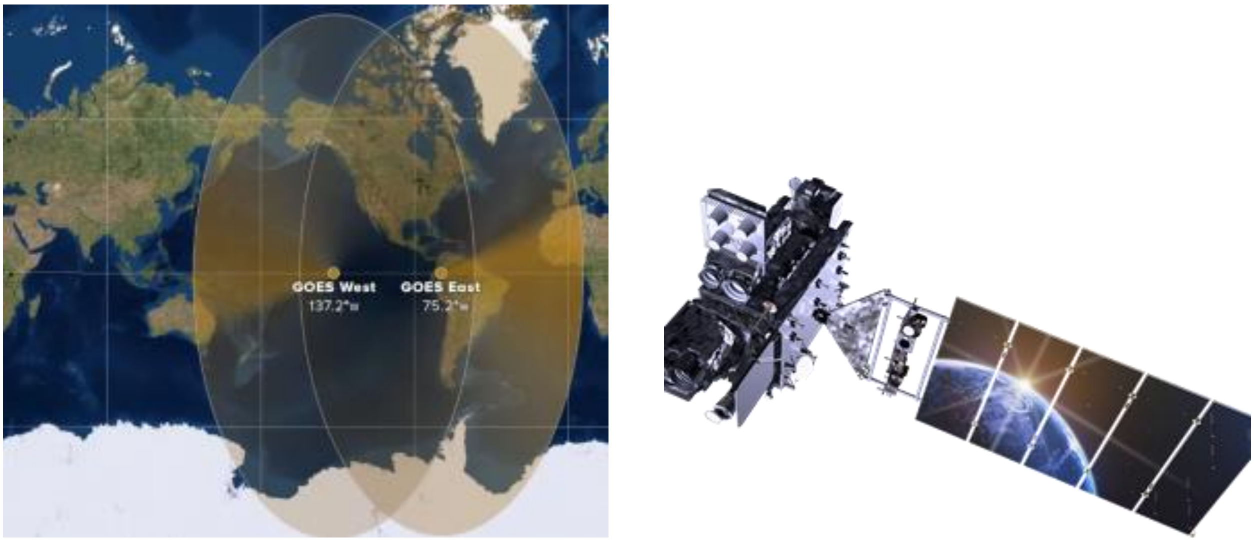


Figure 4 – GOES-16 Satellite and Satellite Footprint – NOAA - NASA

In similar studies, [17] and [18] highlight the importance of developing dynamic climate prediction models based on historical and real-time data, which allows the identification of atmospheric patterns and behaviors that can be fundamental for informed decision-making in the face of adverse natural phenomena. The validation of the predictive model in this research follows an iterative approach, as suggested[19], where initial predictions are compared with recent data to improve the accuracy of the system through machine learning techniques.

The process of data collection and analysis will be fundamental to evaluate the effects of climate change over time in the different areas of the Bolívar Province. Research by [20] and [21] has shown that the implementation of long-range sensor networks, such as the one described in this study, allows detecting gradual changes in weather and climate conditions, offering an invaluable tool for decision-makers in environmental planning issues.

CONCLUSIONS

The implementation of a Remote Sensing Network System in the province of Bolívar represents a key innovation in the collection and analysis of meteorological data. This system will not only meet the urgent need for accurate and accessible climate information, but will also allow the development of predictive models that will contribute to more efficient decision-making in climate-vulnerable sectors.

The combination of ground and satellite sensor technologies provides a comprehensive view of climate behavior, allowing crises to be anticipated and the negative effects of climate change to be mitigated in the region.

Public accessibility to this data will ensure that a wide range of users can benefit from the information, improving community resilience in the face of future climate challenges.

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