Electronic prototype for data collection in situ at the facilities of the Universidad Tecnológica de Altamira

Prototipo electrónico para la recopilación de datos in situ en las instalaciones de la Universidad Tecnológica de Altamira

SANCHEZ-GOMEZ, Perla Yareli†, MERINO-TREVIÑO, Marco Antonio*, SÁNCHEZ-CORTEZ, José Alfonso and ALTAMIRANO-DEL ANGEL, David

Universidad Tecnológica de Altamira

ID 1st Author: *Perla Yareli, Sanchez-Gomez* / **ORC ID:** 0009-0004-6634-9798, **CVU CONAHCYT ID**: 1307697

ID 1st Co-author: *Marco Antonio, Merino-Treviño* / **ORC ID:** 0000-0001-8901-5054, **CVU CONAHCYT ID**: 295355

ID 2nd Co-author: *José Alfonso, Sánchez-Cortez* / **ORC ID:** 0000-0002-8762-1154, **CVU CONAHCYT ID**: 500152

ID 3rd Co-author: *David, Altamirano-Del Ángel* / **ORC ID:** 0000-0007-9509-639X, **CVU CONAHCYT ID**: 1267806

DOI: 10.35429/EJDRC.2023.17.9.6.16 Received July 28, 2023; Accepted November 30, 2023

Abstract

Evaluation of renewable energy sources requires detailed and accurate information, as well as the analysis of natural parameters to discover and leverage new energy sources. This information is obtained through electronic devices. These parameters are crucial for developing policies and strategies, and for using and leveraging sustainable or clean energies. With the aim of collecting real-time weather data, a prototype weather station has been created. This prototype uses the ESP32 Nodemcu card and features Wi-Fi and Bluetooth functions to transmit data to MathWorks' "ThingSpeak" platform. In addition, various sensors have been incorporated to measure different climatic parameters, such as ambient temperature (DS18B20 sensor), humidity percentage (DHT22 sensor), barometric pressure (BMP180) and wind speed (anemometer based on a Hall effect sensor). The data collected can be analyzed with the main goa of gaining an accurate understanding of the climate in a specific region. Therefore, this prototype weather station provides a useful solution for obtaining real-time data on weather conditions.

Weather station, ThingSpeak, Esp32

Resumen

La evaluación de fuentes de energía renovable requiere información detallada y precisa, así como el análisis de parámetros naturales para descubrir y aprovechar nuevas fuentes de energía. La obtención de esta información se realiza a través de dispositivos electrónicos. Estos parámetros son cruciales para desarrollar políticas y estrategias, y para utilizar y aprovechar energías sostenibles como limpias. Con el objetivo de recopilar datos sobre las condiciones climáticas en tiempo real, se ha creado un prototipo de estación meteorológica. Este prototipo utiliza la placa ESP32 Nodemcu y cuenta con funciones Wi-Fi y Bluetooth para transmitir los datos a la plataforma "ThingSpeak" de MathWorks. Además, se han incorporado diversos sensores para medir diferentes parámetros climáticos, como temperatura ambiente (sensor DS18B20), porcentaje de humedad (sensor DHT22), presión barométrica (sensor BMP180) y velocidad del viento (anemómetro basado en un sensor de efecto Hall). Los datos recopilados pueden analizarse para obtener una comprensión precisa del clima en una región específica. Por lo tanto, este prototipo de estación meteorológica proporciona una solución útil para obtener datos en tiempo real sobre las condiciones meteorológicas.

Estación Meteorológica, ThingSpeak, Esp32

Citation: SANCHEZ-GOMEZ, Perla Yareli, MERINO-TREVIÑO, Marco Antonio, SÁNCHEZ-CORTEZ, José Alfonso and ALTAMIRANO-DEL ANGEL, David. Electronic prototype for data collection in situ at the facilities of the Universidad Tecnológica de Altamira. Journal-Democratic Republic of Congo. 2023, 9-17: 6-16

* Correspondence to Author (e-mail: mmerino@utaltamira.edu.mx)
† Researcher contributing first author.

Introduction

Nowadays, climate plays a fundamental role in our existence, as various meteorological parameters, such as rainfall, atmospheric pressure, temperature and wind, have a significant impact on numerous human processes, as well as on flora and fauna. Therefore, weather stations have become increasingly important as they are designed to observe and predict the weather. These kinds of devices collect data from different points within a region to make estimates over large areas, thus providing general information about the climate.

However, conventional weather stations have limitations in terms of accuracy and data availability in specific areas, making them difficult to apply in projects and processes that require detailed and up-to-date climate information.

Therefore, based on this problem, the need to develop a chain of weather stations that can provide accurate and detailed, reliable data in real time at specific geographical locations was proposed. These electronic devices must be placed and mounted in dedicated structures, which can be equipped with the ESP32 board, responsible for storing Arduino code specifically designed to collect data from each sensor. This data is periodically sent to a web page, where it is stored indefinitely for analysis and use in various processes or future projects.

This chain of weather stations provides a valuable source of climate information, enabling comprehensive and detailed monitoring in specific areas. The data collected offer opportunities for the study of climatic behaviour or variations, which, over time, have been perpetuated, thus generating a series of precise knowledge on meteorological parameters.

1. Background

1.1 Meteorological station

In the broad and varied concept of meteorology, a Weather Station is an infrastructure, consisting of various electrical or electronic devices, designed to capture and record environmental changes or disturbances that may exist in real time.

These stations play a key role in measuring and collecting weather data, which are periodically sent to a database server. These stored data are used both for climate analysis and studies, and to feed numerical models, which allow accurate weather forecasts to be made, thus promoting the development of strategies and policies related to the use and exploitation of clean and sustainable energies.

In this way, weather stations play a crucial role in monitoring and understanding the climate, as they provide valuable information on a continuous basis for decision-making in various fields related to the ecosystem and environment (Villalta Cruz H. & Sorto Perdomo G., 2013).

Figure 1 Water, C. (2023). Climate measurement stations
Source: https://www.gob.mx/conagua/articulos/estaciones-para-medir-el-clima

An efficient weather station must be equipped with a variety of key measuring instruments to capture and record accurate data on atmospheric conditions. These instruments include specialised sensors designed to measure specific weather parameters. The following is a description of the devices used in the development of the above-mentioned prototype.

1.1.1 Thermometer

As is well known, it represents an instrument used to measure ambient temperature, it is essential for collecting accurate temperature data and detecting significant changes in the climate.

This climate parameter represents one of the most important parameters and its accurate measurement is crucial in various applications, including the implementation of renewable energies.

To achieve a reliable temperature measurement, the DS18B20 sensor will be used, which is renowned for its high accuracy and ease of use.

Figure 2 DS18B20 submersible temperature sensor - Electrónica Valtierra (2023).
Source:https://electronicavaltierra.com.mx/producto/sensor-de-temperatura-sumergible-ds18b20/.

The DS18B20 is a single-wire digital temperature sensor that provides accurate and stable readings. Its compact and waterproof design makes it suitable for deployment in weather stations, as most of the time natural conditions can be adverse.

By measuring temperature with the DS18B20 sensor, valuable information is obtained to evaluate the performance of renewable energy systems, such as solar panels and air conditioning systems. This accurate measurement enables constant monitoring of environmental conditions, which in turn contributes to better planning and optimisation of renewable energy resources.

This data is essential for making informed and efficient decisions in the design and implementation of sustainable energy systems.

1.1.2 Barometer

An instrument designed and capable of measuring atmospheric pressure, adapting to the geographical location present. Its main function is to monitor and record changes in air pressure, which is essential for predicting changes in climate and weather patterns.

Atmospheric pressure measurement plays a key role in many scientific applications, from meteorological monitoring to assessing the performance of renewable energy systems.

To obtain accurate atmospheric pressure measurements, the BMP180 sensor, renowned for its high accuracy and reliability, will be used.

Figure 3 Sensor de presión barométrica con compensación de temperatura_BMP180. (2023)
Source: https://store.fut-electronics.com/products/barometric-pressure-sensor-w-temperature-compensation-bmp180

The BMP180 sensor uses a method based on piezoelectric pressure measurement technology to obtain reliable and accurate atmospheric pressure data. Its advanced design and temperature compensation capabilities ensure high quality measurements in a wide range of climatic conditions. Thanks to its compact design and low power consumption, the BMP180 sensor is widely used in weather stations.

December 2023 Vol.9 No.17 6-16

By measuring atmospheric pressure with the BMP180 sensor, crucial information can be obtained for climate analysis, weather forecasting and optimisation of energy systems.

1.1.3 Hygrometer

A device used for the measurement of relative humidity of air. Its main function is to provide accurate information on the amount of water vapour present in the environment, which is vital for understanding and predicting atmospheric humidity. This generates different kinds of benefits in many areas ranging from agriculture and air conditioning to climate monitoring.

For accurate and reliable humidity measurements, the DHT22 sensor, known for its high accuracy and stability, will be available.

Figure 4 dht22 humidity and temperature sensor (2023)
Source:https://mvelectronica.com/producto/sensor-de-humedad-y-temperatura-dht22

The DHT22 sensor employs a combination of temperature and humidity sensors to provide simultaneous measurements of both parameters. Its compact design and easy integration make it a popular choice in weather stations and humidity control systems. Measuring humidity with the DHT22 sensor provides essential information for agricultural planning, indoor climate monitoring and control of humidity-sensitive environments.

1.1.4 Anemometer

A device commonly used to measure wind speed. It provides crucial information for understanding wind dynamics and behaviour at a specific location. Accurate wind speed measurement plays a key role in a variety of applications, from meteorology to wind power generation.

The anemometric sensor used in this study is based on the Hall effect principle. This principle refers to the physical phenomenon in which an electric potential difference is generated in a conductor when it is subjected to a magnetic field perpendicular to the electric current flowing through it. The anemometric sensor exploits this effect to measure wind speed.

Figure 5 [Hot Item] Rk Hall Effect 100-02 cheap plastic cup mechanical wind speed anemometer wind transmitter with CE (2023)
Source: https://es.made-in-china.com/co_rikasensor/product_Rk100-02-Hall-Effect-Cheap-Plastic-Cup-Mechanical-Wind-Anemometer-Wind-Speed-Transmitter-with-CE_errrusorg.html

The design of the anemometric sensor is based on the use of a Hall effect element that detects the variations in the magnetic field produced by the movement of the air. These variations are converted into an electrical signal proportional to the wind speed. By means of calibration and signal processing techniques, accurate and reliable wind speed measurements are obtained. This Hall-effect based approach offers several advantages, such as fast response to changes in wind speed and the ability to measure over a wide range of speeds. In addition, the Hall-effect based anemometric sensor is highly sensitive and has a high linearity in the relationship between electrical signal and wind speed.

Such a Hall-effect based anemometric sensor used in this study takes advantage of the Hall-effect phenomenon to accurately and reliably measure wind speed. This approach offers significant advantages in terms of sensitivity, linearity and fast response, making it a suitable choice for wind speed measurement in scientific and meteorological applications (Madsen, H. A., & Crossley, A. C., 2001).

ISSN 2414-4924

1.1.5 ESP32

The ESP32 is a microcontroller developed by Espressif Systems that combines a dual-core processor with integrated Wi-Fi and Bluetooth connectivity. It is popular in IoT projects due to its versatility and low power consumption. It offers a variety of interfaces such as GPIO, UART, SPI and I2C, along with integrated peripherals such as ADCs and DACs. Its flash memory allows it to store programs and data, and it is compatible with development environments such as Arduino and the Espressif SDK. With an extensive community and online resources, the ESP32 is a powerful choice for applications requiring wireless connectivity and processing power.
.

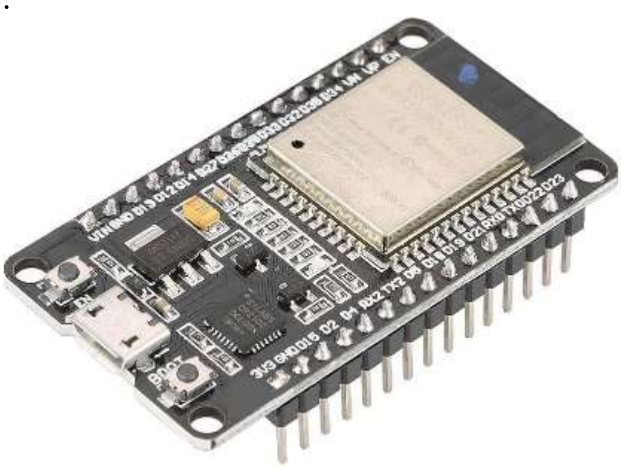


Figure 6 ESP32 development board Dual-core WiFi + Bluetooth dual-mode 2.4 GHz dual-core microcontroller processor integrated with AMP RF filter AMP AP antenna for IoT, module (2023).
Source: https://www.amazon.com.mx/desarrollo-Procesador-microcontrolador-Bluetooth-integrado/dp/B07RY9MVCV

2. Methodology

In the development process of this prototype weather station, a careful selection of sensors compatible with the ESP32 board was carried out. To measure the ambient temperature, the DS18B20 sensor was used, while the DHT22 sensor was used to measure the humidity. To obtain accurate atmospheric pressure data, the BMP180 sensor was used.

Each sensor was individually tested to evaluate its performance and the corresponding codes were adapted in the Arduino IDE development environment. It is important to note that the Hall-effect sensor required the construction of a specific structure prior to testing, ensuring its correct configuration and operation.

Once the codes for each sensor were stabilised, they were integrated into a single sequence, allowing the simultaneous and consistent execution of all measurements. This integration ensures efficient and accurate collection of meteorological data relevant to the weather station system.

Figure 7 Arduino IDE platform with sensor data (2023)
Source: Own Elaboration

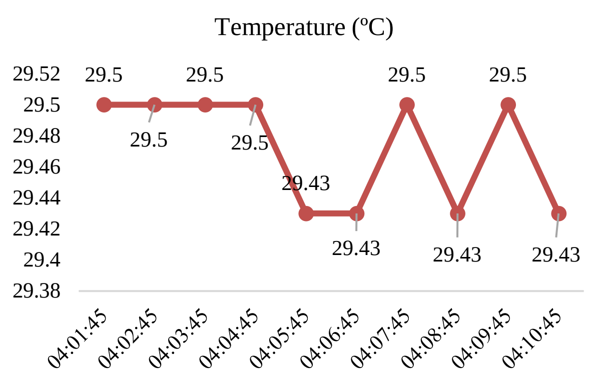
An additional functionality was included by enabling the WiFi connection (Figure 8) on the ESP32 board. This allowed a connection to be established with the MathWorks "ThingSpeak" platform, recognised for its accessibility and ease of use. Through this connection, the data collected by the sensors are sent to the platform at predefined time intervals via the programmed code.

Figure 8 Captive portal for WiFi selection (2023)
Source: Own Elaboration

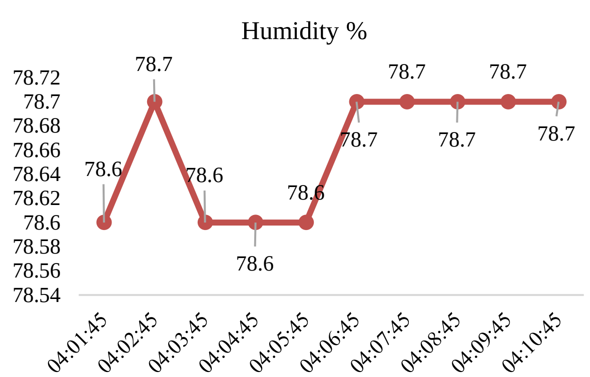
ISSN 2414-4924

The integration with the "ThingSpeak" platform provides the possibility for real-time observations and analysis of the data. This facilitates the study and evaluation of the collected data, allowing for a deeper understanding of climate patterns and trends. In addition, the platform offers tools to visualise and share the data, facilitating its interpretation and the exchange of information with other users and experts in the field.

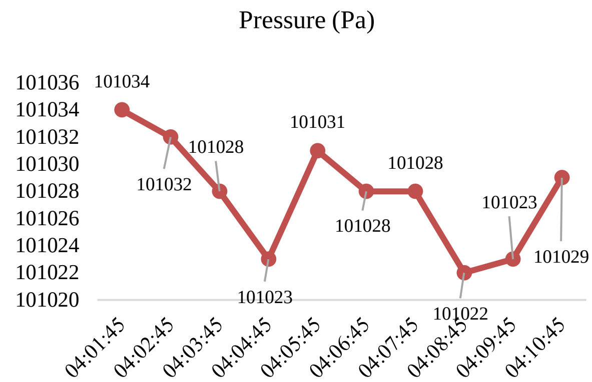
This kind of information results in the addition of WiFi connectivity and the integration with the "ThingSpeak" platform strengthens the weather station's capacity for real-time data observation and analysis, thus contributing to a better understanding of the climate and its impact on renewable energy systems. Graphs of some of the data sent to the platform are shown below:



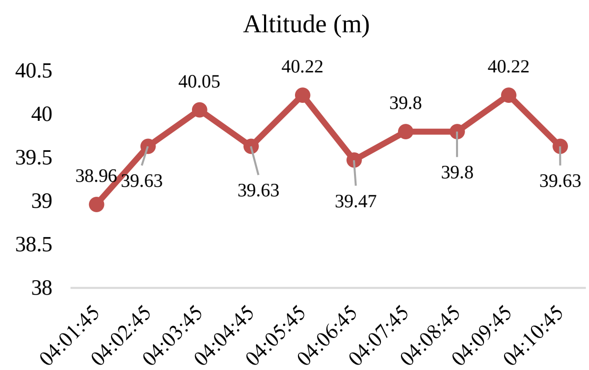
Graph 1 Temperature values (2023)
Source: Own Elaboration



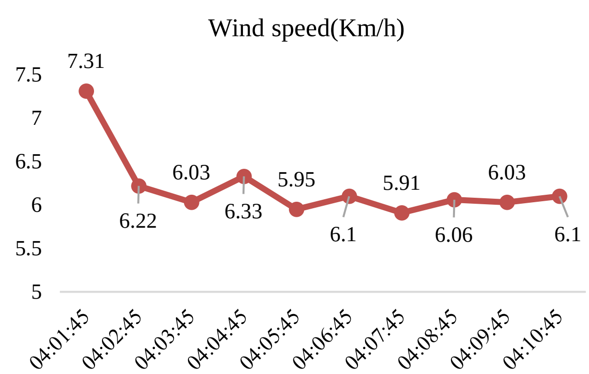
Graph 2 Moisture Values (2023)
Source: Own Elaboration



Graph 3 Pressure values (2023)
Source: Own Elaboration



Graph 4 Altitude values (2023)
Source: Own Elaboration



Graph 5 Wind speed values (2023)
Source: Own Elaboration

The data collected by the weather station are permanently stored in the "ThingSpeak" platform, which guarantees their availability at any time (Annex 1 and 2). This feature allows historical data to be accessed and used for further analysis. In addition, the platform offers the option to download the data in an Excel document format, which provides flexibility for manipulation and analysis in various tools and applications.

The ability to download the data in Excel format facilitates its integration with other platforms and analysis tools, which expands the opportunities for exploiting the data collected. This functionality gives researchers, scientists and practitioners greater flexibility and control over the data, allowing them to perform customised analysis and apply different statistical and visualisation techniques to extract relevant information.

The option of indefinite data storage and the ability to download data in Excel format to the "ThingSpeak" platform contribute to an efficient and versatile management of the data collected by the weather station, providing flexibility and facilitating its analysis and use in various applications and projects.

Created_at	Temp. °C	Humidity %	Pressure Pa	Altitude m	Wind speed Km/h
2023-08-22 04:01:45	29.5	78.6	101034	38.96	7.31
2023-08-22 04:02:45	29.5	78.7	101032	39.63	6.22
2023-08-22 04:03:45	29.5	78.6	101028	40.05	6.03
2023-08-22 04:04:45	29.5	78.6	101023	39.63	6.33
2023-08-22 04:05:45	29.43	78.6	101031	40.22	5.95
2023-08-22 04:06:45	29.43	78.7	101028	39.47	6.10
2023-08-22 04:07:45	29.5	78.7	101028	39.80	5.91
2023-08-22 04:08:45	29.43	78.7	101022	39.80	6.06
2023-08-22 04:09:45	29.5	78.7	101023	40.22	6.03
2023-08-22 04:10:45	29.43	78.7	101029	39.63	6.10

Table 1 Data from the Excel file downloaded from the ThingSpeak platform (2023)
Source: Own Elaboration

In order to achieve automated and continuous operation, a programming approach was implemented on the ESP32 board. The code required for data processing was permanently loaded into the board's memory, avoiding the need for repeated loading.

Thanks to this initial programming, the ESP32 board is able to periodically and constantly send the information obtained by the sensors to the designated platform. This allows for continuous monitoring of the data without interruption, ensuring a constant and reliable flow of information to the target platform. This automated, single code-loading configuration on the ESP32 board optimises the performance and efficiency of the prototype weather station.

It ensures uninterrupted data monitoring and simplifies maintenance by eliminating the need for repeated code uploads, contributing to a smoother and more reliable data collection experience.

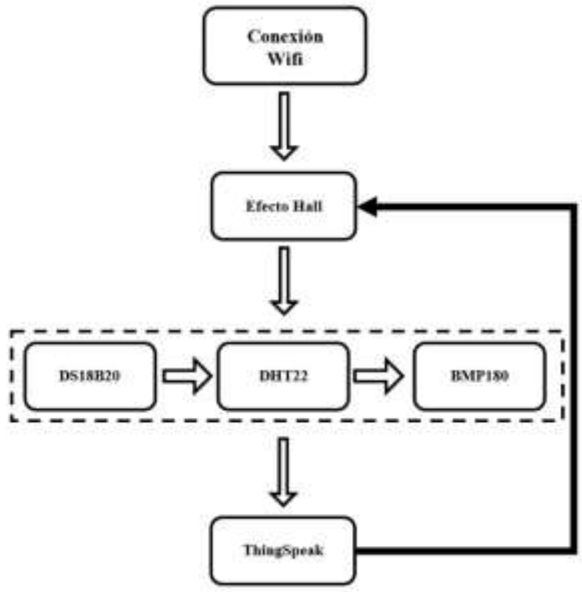


Figure 9 Flowchart of the Arduino IDE code of the weather station (2023)
Source: Own Elaboration

After establishing the operation and data recording in the cloud, we proceeded to build the physical structure of the weather station. The structure was designed in a simple and replicable way, taking into account the ease of assembly. Specific sections were incorporated to house the sensors and their connections securely, ensuring a precise design that favours efficient data collection.

3. Structure

Among the essential components that were developed was the anemometer, a crucial device for measuring wind speed. In the process of creating both the anemometer and the weather station as a whole, the Autodesk Fusion 360 design tool was used. This platform enabled the design of a highly adaptable and efficient model that met the precise measurement requirements.

Once the design was completed, the anemometer was fabricated. Figure 9 provides a detailed visualisation of the final design of the prototype anemometer, revealing its appearance and particular features. This component stands as a key component in the collection of accurate wind speed data, thus enriching the overall functionality of the weather station.

Figure 10 Prototype anemometer usable for testing (2023)
Source: Own Elaboration

Annex 3 shows the initial design of the prototype developed in Fusion 360, which served as the basis for its physical construction. This design was refined to achieve a more practical, solid structure capable of withstanding various weather conditions without compromising the integrity of the sensors and internal equipment. In addition, a power solution was implemented for the ESP32 using a powerbank, guaranteeing a continuous power supply for approximately 5 days.

In order to extend the measurement time, a solar power supply system was incorporated. This involved the inclusion of a 6V solar module connected to a 5V, 2.1A regulator, which in turn supplies power to the battery (Figure 10).

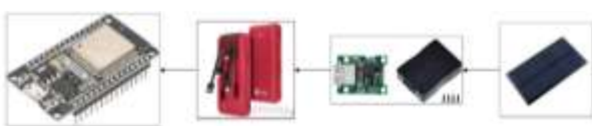


Figure 11 Alternating energy connection (2023)
Source: Own Elaboration

This optimised approach increased the efficiency of the system and extended the survey period to around 8 days, subject to weather conditions and the number of sunny days available. Figure 11 provides a view of the prototype fully equipped and ready to carry out measurements. This comprehensive solution ensures a sustainable and reliable energy supply, enabling continuous operation and accurate collection of meteorological data in different environments and weather situations.

Figure 12 Prototype weather station (2023)
Source: Own Elaboration

4. Results

Based on the previously described methodology, it was found that the real-time data obtained from specialised sensors (temperature, atmospheric pressure, humidity and wind speed measurements) at a specific location were regularly transmitted via a Wi-Fi connection to the ThingSpeak platform. Here, the data was securely stored. This platform provided the possibility to download the data for further analysis, facilitating its use in future climate and renewable energy projects.

In addition, an optimisation of the time interval during which the prototype continuously sends data was implemented, allowing it to operate without interruption for several days thanks to additional energy management from a renewable source. In this way, the objective of obtaining and using accurate and up-to-date information was successfully achieved, contributing to the advancement of the field of meteorology and the development of sustainable energy sources.

ISSN 2414-4924

5. Annexes

Annex 1

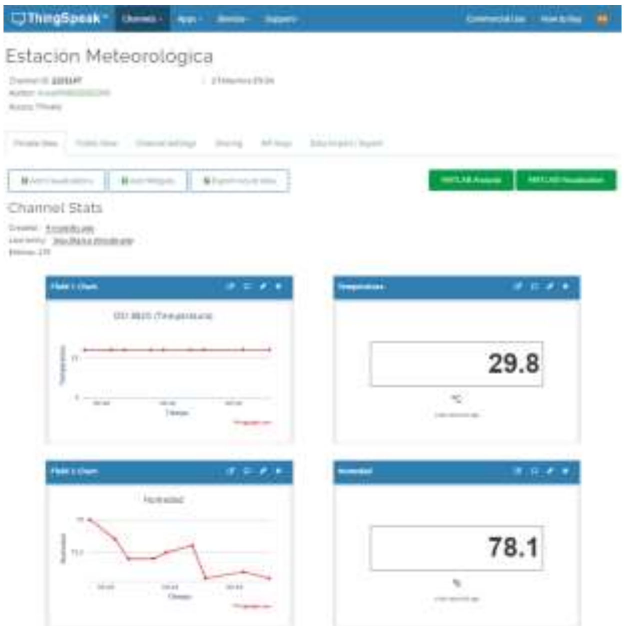


Figure 13 Sensor data collection on the ThingSpeak platform. Part 1
Source:https://thingspeak.com/channels/2103147/private_show

Annex 2

Figure 14 Sensor data collection on the ThingSpeak platform. Part 2
Source: https://thingspeak.com/channels/2103147/private_show

Annex 3

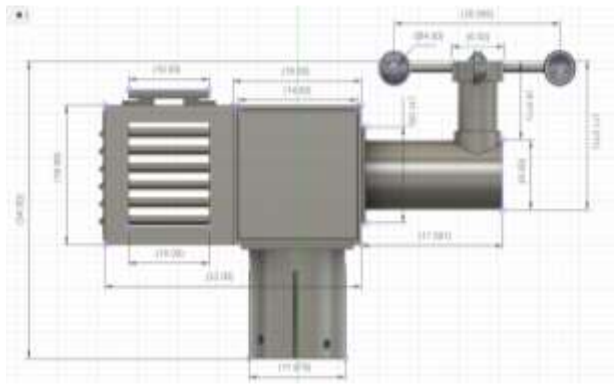


Figure 15 First design of the prototype weather station (2023)
Source: Own Elaboration

6. Acknowledgements

Sincere thanks are expressed to the Universidad Tecnológica de Altamira for the generous funding provided for this article. Their support has been fundamental to the research. The opportunity provided and the constant support of the university team in the development of this work is greatly appreciated.

7. Funding

This work has been funded by the Universidad Tecnológica de Altamira.

8. Conclusions

The present study has reaffirmed the feasibility and effectiveness in the construction of a weather station based on the versatility and advantages provided by the ESP32 development board. This station has the ability to acquire, transmit and store data in a cloud platform. The developed prototype has successfully achieved the objectives set, providing reliable and accurate information on a wide range of meteorological parameters.

The implementation of an adapted physical structure has ensured the ability to replicate the station in strategic locations, a crucial aspect to obtain representative information from different areas and to analyse the specific climatic characteristics of each one. The creation of a customised anemometer has proven to be an effective solution to accurately measure wind speed.

The connection established with the "ThingSpeak" platform has facilitated continuous storage and uninterrupted access to the collected meteorological data, providing an essential tool for real-time monitoring and further analysis. The ability to download these data in Excel document format has increased their usefulness and availability for a wide variety of related applications and projects. In summary, this study has laid the foundation for future research and applications in the field of meteorology and climate monitoring.

The convergence of technologies such as ESP32, 3D modelling and cloud platforms provides a wide range of promising opportunities for the creation of innovative solutions in the field of meteorology and energy. This work not only provides a robust approach to real-time weather data collection, but also lays the foundation for the future integration and optimisation of renewable energy systems, thus contributing to a deeper understanding of weather patterns and moving towards a more sustainable and energy-efficient future.

9. References

Amazon.com. (2023). 1 Hora Power Bank 10000 mAh Ultra Slim de Bateria Portatil con 4 Cables Incorporados Tipo C USBc y Luz Carga Powerbank 10000 Compatible para IP, Samsung, Xiaomi, Rojo. Fuente: https://www.amazon.com.mx/Hora-Portatil-Incorporados-Powerbank-Compatible/dp/B08XWJVC2P/ref=asc_df_B08XWJVC2P/.

Amazon.com. (2023). HIIGH 5V 2A Panel Solar Banco de energía Controlador de Voltaje de Carga USB Regulador 6-20V a 5V Módulo Reductor con indicador LED 1 Piezas. Recuperado de: https://www.amazon.com.mx/HIIGH-Controlador-Regulador-Reductor-indicador/dp/B0BQDLD3MP.

Dahlbom, C. y Gustafsson, P. (2023). Una investigación Cómo 3DP Afecta el Modelo de Negocio en la Industria de la Construcción.

Díaz Ronceros, E. (2020). Relevancia de la ejecución experimental de proyectos con microcontroladores en el aprendizaje de la ingeniería electrónica. Educación, 29(56), 48-72. Recuperado de http://www.scielo.org.pe/scielo.php?script=sci_arttext&pid=S1019-94032020000100048.

Dillon, A. (2023). Comprender a los usuarios: diseñar la experiencia a través de capas de significado. Taylor y Francisco.

Innova Domotics. (2017). 27 Curso Arduino - Módulos - DHT22 - Arduino Uno, Esp8266, Esp32. [Video]. Recuperado de: https://youtu.be/6QW0mRyQw9w.

Iotdesign pro. (2023). ESP32 and ThingSpeak: How to send Data to Cloud using ESP32. Recuperado de: https://iotdesignpro.com/projects/how-to-send-data-to-thingspeak-cloud-using-esp32.

Jadsa Tech. (2022). SENSORES Y MÓDULOS #33: DS18B20 SENSOR DE TEMPERATURA - WATERPROOF. [Video]. Recuperado de: https://youtu.be/WKpMxtr5-BU.

Jadsa Tech. (2022). SENSORES Y MÓDULOS #35: SENSOR DE PRESIÓN - TEMPERATURA - ALTITUD BMP180 - ARDUINO - ESP32. [Video]. Recuperado de: https://youtu.be/G_KETIZR5JU.

Jadsa Tech. (2023). SERIE ESP32 #19: WIFIMANAGER Gestiona tus redes WIFI Dinámicamente. [Video]. Recuperado de: https://youtu.be/RSKU4f5l9SA.

Julus, LJ, Roobert, AA y Athanesious, JJ (2023). Papel de la Fotónica en la Crisis Energética. En Photonic Crystal y sus aplicaciones para sistemas de próxima generación (págs. 205-222). Singapur: Springer Nature Singapur.

Madsen, H. A., & Crossley, A. C. (2001). Anemometers for wind energy systems: A review. Wind Engineering, 25(5), 309-317.

Maxim Integrated. (s.f.). DS18B20 High-Precision 1-Wire Digital Thermometer. Recuperado de https://www.maximintegrated.com/en/products/analog/sensors-and-sensor-interface/DS18B20.html.

Mechatronics. (2022). Anemómetro con Arduino #4 - Mechatronics. [Video]. Recuperado de: https://youtu.be/3v2JIm-Bdks.
mm, C. (2023). Celda solar 6V 200mA (110x60) mm - aelectronics. Fuente: https://aelectronics.com.mx/metepec/celdas-solares/1814-celda-solar-6v-200ma.html.

Prof. Madeleine Renom. (2011). Principios básicos de las mediciones atmosféricas. Unidad de Cs. de la Atmósfera. Fac. de Ciencias-UdelaR. [Archivo PDF].

Rehman, S., Mahmood, R., & Ahmed, J. (2018). Weather stations as a tool for renewable energy resource assessment: A review. Renewable and Sustainable Energy Reviews, 81(2), 2361-2370.

Rodríguez, F. (2023). Imaginarios socioambientales discutidos sobre el agua y los ríos en tiempos de expansión hidroeléctrica en Costa Rica. Alternativas de agua, 16 (2), 730-749. Kamaraj, SK, Thirumurugan, A., de la Torre, SD, Balasingam, SK y Dhanabalan, SS Materiales magnéticos nanoestructurados.

Villalta Cruz H. & Sorto Perdomo G. (2013). Implementación de una estación meteorológica. Universidad De El Salvador Facultad De Ingeniería Y Arquitectura Escuela De Ingeniería Eléctrica. [Archivo PDF].

YAMAMOTO, K., KIRIMOTO, T., & NAKAJIMA, K. (2018). The Analysis of the Humidity Sensor DHT22. Proceedings of the 18th International Conference on Electronic Measurement & Instruments (ICEMI), 1-4.