



## **A Cost Effective Weather Monitoring Device**

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### **Authors' contributions**

*This work was carried out in collaboration between all authors. Authors KEU and SOA designed the study, wrote the protocol, managed the literature searches and wrote the first draft of the manuscript. Authors ICA and IO performed the statistical and data analysis. Author LEO managed the final analyses of the study. All authors read and approved the final manuscript.*

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### **ABSTRACT**

Getting the latest weather parameters and taking the necessary precautions about the recent climate induced environmental disasters have become a major course of concern in this era of global warming. In this research a cost effective weather monitoring device was constructed using an Arduino Mega 2560 microcontroller and some contemporary suitable sensors with a real time data logger and LCD. The constructed weather monitoring system is beneficial in terms of its on-device display, smaller size, cost effective, flexibility and portability as well simplicity in its operation and would be used for some meteorological measurements. The data acquired from this constructed device were in good conformity with those obtained from other sources and would make weather data readily available for small-scale users like farmers, travellers, aircraft workers, researchers, institutions and others for the purpose of measuring, monitoring, analyzing and prognosticating of the climate in other to minimize climate-induced disasters in our environment.

*Keywords: Climate; data logger; forecast; LCD; microcontroller; sensors; weather.*

## 1. INTRODUCTION

Weather has always had a significant influence on the lives of people and shaped their cultures, habits, attitudes, behaviour and their environments in general. Man has always tried to find out the causes of different weather conditions he finds himself in and possibly monitor and forecast what the weather would be at any given time. Taking weather and trying to forecast it appropriately can make a difference for the survival and prosperity of the human race [1].

There cannot be a study of the weather neither its prediction without the knowledge of the prevailing conditions of the atmosphere. For this reason, man has always implored and devised means of measuring different elements of the weather. With the advancement of technology, new methods and equipment have been developed to measure, collect and monitor weather information and today a whole field of study; Meteorology is dedicated to it [1].

Meteorology is the science of the atmosphere. Its domain is the atmosphere of the whole universe and its practice involves the daily cooperation of every action on the universe. In meteorology, the data collected are used in monitoring and forecasting the weather; weather monitoring and forecasting which are useful in one way or the other in the course of our daily activities [2].

Weather is mostly influenced by many factors; location latitude, elevation and proximity to water bodies, it has always been a universal concern and the recent and present changes in the climate is becoming an issue, in particular [3]. It's monitoring holds great importance and has uses in several areas ranging from keeping track of agricultural field weather conditions to industrial weather conditions monitoring. Weather measuring and monitoring would help in keeping track of different climatic behaviors including temperature, humidity, atmospheric pressure, light intensity, altitude, dew point, precipitation.

## 2. ELEMENTS OF WEATHER

Meteorologically, weather is used to describe the momentary atmospheric conditions at a certain place. It is the state of the atmosphere of a given place at a particular time. Weather describes the

condition of the atmosphere over a short period of time. The climate of an area is known through the average weather over a long period of time. Climate describes the average weather conditions over a longer period of time [4].

In describing the atmospheric conditions of a given place at a given time, certain weather elements or parameters must be known, measured and quantified. Some of the most crucial weather elements are temperature, relative humidity, atmospheric pressure, wind speed and direction, precipitation, solar or light intensity.

Temperature is a widely measured variable and is a very critical factor in determining the weather; because it influences and controls other elements of the weather [3].

Weather measuring, monitoring and forecasting holds great importance and has uses in several area; it helps in keeping track of different climatic behaviors [1].

## 3. REVIEW OF LITERATURE

In the ancient times weather monitoring and forecasting was done mostly by human experiences over the cloud cover and the wind movements. Farmers were one of the most affected by the weather conditions. With the advent of time and with a rapid progress in the field of science and technology various electronic devices were invented to measure, monitor, predict and forecast the various weather parameters. All the observational, theoretical and technological development through centuries contributed to our knowledge of the atmosphere and individuals at scattered location began to make, measure, monitor and record atmospheric measurements [5].

At present in developed countries of the world, there are various satellites orbiting in the atmosphere just to monitor the climatic conditions, also there are various kinds of radars available for the same purpose. But it is notable that such devices are very robust, expensive and are associated with high end technologies. So there is a need for a system which can monitor the weather parameters precisely and also is cost efficient, robust and real time operational so that it can be installed at any place like small industries, institutions, home [3].

Although, many low cost portable weather monitoring systems and weather stations projects like the one on this work have been proposed and implemented all over the world recently but one or more improvement still need to be implemented in some of these proposed devices in terms of cost, simplicity and corrections of some other defaults. Akhilesh Chawla et al. in their Bluetooth based weather station designed a system that can only gives valuable information about temperature and humidity [3]. Sutar in his economical weather monitoring system developed a system like that of this research but did not consider the measurement of light intensity, pressure and precipitation parameters [6]. Nisha Gahlot et al. [7] also designed a Zigbee based weather monitoring system and Pengfei et al. [8] and Singh et al. [9] both designed a wireless temperature monitoring system using ZigBee technology in their papers respectively. ZigBee technology is a common and popular choose for data transmission, nevertheless, it will require enormous amount of work to execute it in small or medium sized applications compared to the one that was used for this research because of it complexity in terms of cost and operation.

So the need for a weather monitoring system and device which can measure and monitor the various weather parameters precisely and cost efficient, robust, portable and also with real time operations so that it can be installed or move to any place like small industries, farms, institutions, schools, homes, remote and interior villages where agricultural activities is eminent.

Previous studies carried out revealed that the utilization of inadequate climate information for environmental planning and inaccurate monitoring and forecasting of the state of the atmospheres resulted in widespread climate-induced inundation of cities, mud-flows on the streets, ravine formation on the highways, destruction of farm produce, deteriorated and impaired visibility on the roads and in airports and collapse of several buildings. Also, standard meteorological stations which could provide authentic climate information for public consumption are inadequate and in most cases not functional in the country. In addition, adequate meteorological monitoring and forecasting are partly retarded in the country owing to few practicing meteorologists [10].

In the current 21st century, the destructions caused by natural disasters such as

earthquakes, volcanic eruptions, distraction of flight, flood and landslides are still on the rise throughout the world. However, in some places, the destructive impacts of weather-related hazards have been harnessed over the years. In Hong Kong, for example, over the few decades, owing to consistent utilization of authentic meteorological information in her national activities, the recorded statistics of destroyed lives and properties caused by tropical cyclones including human injuries have fundamentally declined. Meteorological services in developed countries of the world are coordinated by meteorological stations under the specialist management of central national agencies. In Nigeria, for example, the Nigerian Meteorological Agency (NMA) carries out this essential service. Challenges related to inadequate funding on the part of government and corporate bodies, presence of few experts and poor maintenance of installed apparatus have weakened the institutional efficacy and viability of meteorological services in Nigeria [10].

In reality, it is not genuine to accept holistically that all weather reports from both private and government-owned meteorological stations throughout the country are completely pooled and documented at the NMA. Besides, most rural areas in the country do not have functional meteorological stations. Even when weather satellites reports are utilized to cover these areas, realistic land based weather stations are required to verify the authenticity of these reports. This situation reveals a major weakness with regard to documentation and provision of accurate weather and climate information for utilization in weather predictions and forecasting for disaster prevention in our community [10].

In Nigeria, recent and current scientific studies on proper and effective meteorological services for preventing frequent occurrences of environmental climate related disasters are non-existent. Most often, inadequate and incorrect weather reports which do not indicate the exact location, period and time of occurrence of climatic induced hazards are broadcast in televisions, radios and even published in newspapers, magazines and journals [10].

Weather is a very complex phenomenon. Trying to understand the weather and trying to forecast it correctly has being going on over the centuries and a lot of knowledge and data has been gathered which have helped researchers in extrapolating new methods [11].

It is against this background that this device will be advantageous for meteorological services for climatic related disaster risk prevention and mitigation in our community in particular and country at large. This proposed device will allow measurement of the major weather parameters in a cost effective, flexible and easily deployable structure.

#### 4. MATERIALS AND METHODS

Several components and devices (that when assembled are called an embedded system) were used for this research. These components and devices were properly selected to meet the Directive 2002/95/EC of the European Parliament and of the Council on the Restriction on the use of certain hazardous substances in Electrical and Electronic Equipment, the Institute of Electrical and Electronic Engineering (IEEE), The standard Organization of Nigeria and other regulatory bodies on instrumentation standards for obtaining valid and accurate measurements.

The devices and components used for the construction of this works are:

- (i) Arduino Mega 2560 Microcontroller [12].
- (ii) Some Modern Reliable Sensor; DHT 11 digital temperature and humidity sensor, BMP 180 Pressure and Temperature Sensor and TSL 2561 Light Intensity Sensor [13,14].

- (iii) Data Logger which consist of the Real Timer; DS 1307 [15], Memory Card Module [16].
- (iv) HD444780 LCD [17].
- (v) Other Materials/Circuit Elements like Connectors, Resistors (1000Ω Pot Resistor and Fixed 470Ω Resistor), Power source.

#### 5. BLOCK DIAGRAM

The block diagram of the overall device is shown in Fig. 1. The diagram consists of the Microcontroller (Arduino Mega 2560 Microcontroller) which the heart of the system that control the entire system, Sensors (DHT11 digital temperature and humidity sensor which is used to measure the temperature and the relative humidity, TSL 2561 Light Intensity Sensor which is used to measure the light intensity and BMP 180 Pressure and Temperature Sensor which is used to measure the atmospheric pressure and temperature as well), Data Logger which consist of the Real Timer (DS 1307) that programs the timing of the data recording, Memory Card which is used in storing measured data, LCD Display (HD 444780 LCD) which is used to display measured data and other materials and circuit elements like Connectors, Resistors (1000Ω Pot Resistor and Fixed 470Ω Resistor) were all connected to the microprocessor from Proteus using computer software code, thereafter the hardware

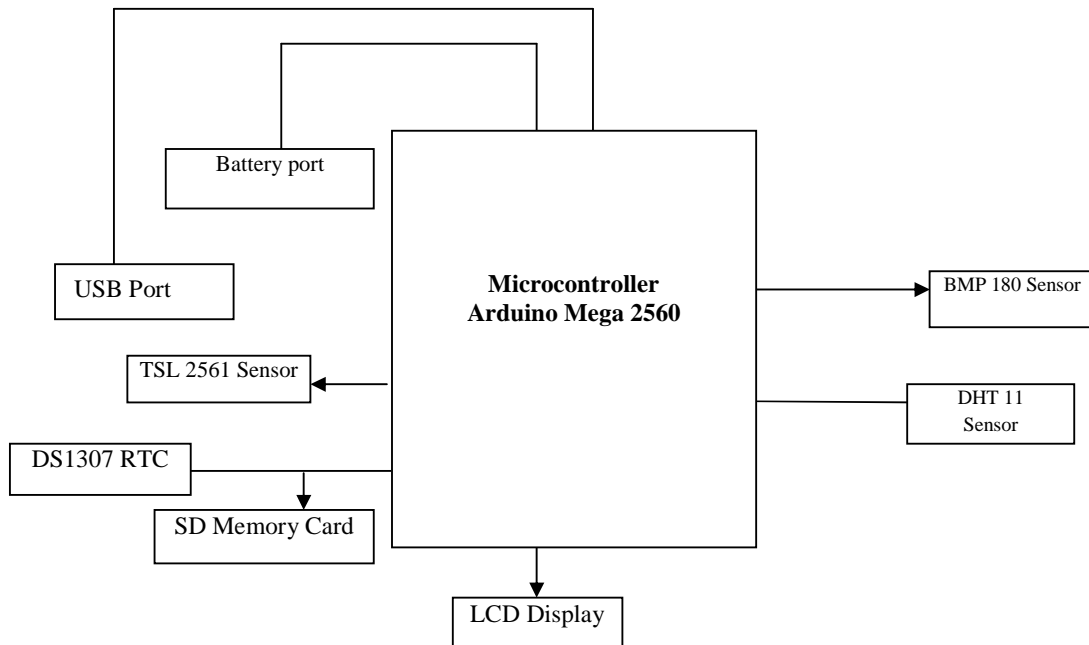
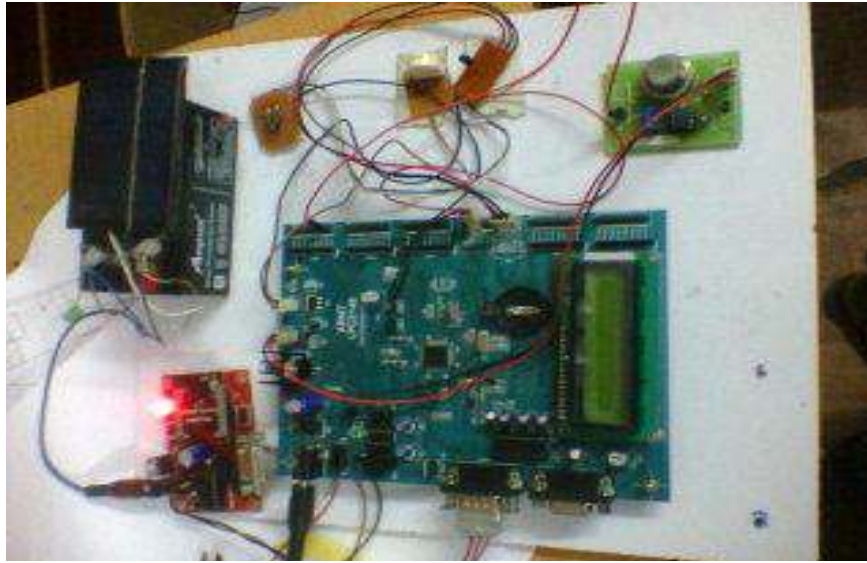


Fig. 1. Block diagram of the constructed weather monitoring device



**Fig. 2. Snapshot of the constructed weather monitoring device**

connection were later done. The various sensors and other components were connected to the microcontroller and would record the various weather parameters with the help of the data logger and send to the microcontroller from there the data will be store on the SD memory card via the Arduino SD Card Module and design the data on the LCD accordingly, the data can still be transfer to the computer via the USB cord for further processing as the case may be.

When the construction process was completed; all the components and devices have been mounted and embedded. Both hardware and software testing were carried out. It was found that all the circuits were working properly and there were no loose connection between the components.

## 6. DISCUSSION OF RESULTS

The device is constructed in such a way that it can be used remotely and the readings are displayed on the user friendly LCD display in numerical digital values and can also be sent to computer via the programmed micro SD card or through the serial port (The Arduino SD Card Module).

The weather measurements of temperature, humidity, pressure, ambient light intensity also for the approximation of the dew point temperature using the Thumb rule (Eqn. 1) and calculation of altitude using the Barometric Formula (Eqn. 2).

$$Td = T - \left( \frac{100 - RH}{5} \right) \quad (1)$$

Also we can use a complex formula;

$$Td = Tn \frac{\ln \left( \frac{RH}{100} \right) + \left( \frac{mT}{Tn} + T \right)}{m - \ln \left( \frac{RH}{100} \right) - \left( \frac{mT}{Tn} + T \right)} \quad (2)$$

Where  $Td$  is the dew point,  $T$  is the temperature,  $RH$  is the relative humidity. For the temperature range  $-40^{\circ}\text{C}$  to  $0^{\circ}\text{C}$ ,  $Tn = 272.62^{\circ}\text{C}$  and  $m = 22.46$  while for the temperature range  $0^{\circ}\text{C}$  to  $50^{\circ}\text{C}$ ,  $Tn = 243.12^{\circ}\text{C}$  and  $m = 17.62$ . The dew point value is approximated after receiving the air temperature and relative humidity values from the weather station. The dew point value can be calculated automatically from the computer using MATLAB after receiving the temperature and relative humidity values [18].

With the measured pressure  $P$  and the pressure at sea level  $P_s$  e.g. 1013.25hPa, the altitude in meters can be calculated with the international barometric formula;

$$\text{Altitude} = 44330 \left[ 1 - \left( \frac{P}{P_s} \right)^{1/5.255} \right] \quad (3)$$

Hence, change in pressure of  $\Delta P = 1\text{hPa}$  corresponds to 8.43m at sea level [18].

Experimentations were carried out to measure some weather parameters in Benin City,

Edo State Nigeria (Latitude: 6°20'17" N, Longitude: 5°37'32" E and Elevation above sea level: 87.88 m  $\approx$  288 ft) using this weather monitoring device and the results were compared with weather data obtained from other sources; the Nigerian Meteorological Agency; NMA and online weather reports [19]. For the purpose of conformity the values of some measured weather

parameters are tabulated on Table 1 to Table 6 respectively.

From these Tables and using some statistical analytic tools precisely the average mean and the mean percentage error it was observed that the measured data from this constructed system were in good conformity with those data obtained from other sources.

**Table 1. Temperature**

Date/Time	Measured average temperature (°C)	Source average temperature (°C)	
		NMA	Online weather report
01/03/2017	29	28	28
02/02/2017	28	28	27
03/02/2017	30	29	28
04/02/2017	30	30	31
05/02/2017	27	26	27
06/02/2017	28	29	28
07/02/2017	31	30	31
08/02/2017	32	33	32
Mean total	29.38	29.13	29.00
Mean percentage error (%)		0.87	1.31

**Table 2. Relative humidity**

Date/Time	Measured average relative humidity (%)	Source average relative humidity (%)	
		NMA	Online weather report
01/03/2017	70	71	72
02/02/2017	79	80	80
03/02/2017	87	87	86
04/02/2017	91	87	90
05/02/2017	99	99	98
06/02/2017	93	94	92
07/02/2017	83	83	85
08/02/2017	58	59	60
Mean total	82.50	82.50	82.86
Mean percentage error (%)		0	0.43

**Table 3. Atmospheric pressure**

Date/Time	Measured average atmospheric pressure (mbar)	Source average atmospheric pressure (mbar)	
		NMA	Online weather report
01/03/2017	1012	1009	1011
02/02/2017	1009	1011	1010
03/02/2017	1008	1009	1009
04/02/2017	1009	1008	1009
05/02/2017	1011	1012	1010
06/02/2017	1010	1009	1009
07/02/2017	1010	1010	1009
08/02/2017	1008	1007	1008
Mean total	1009.63	1009.48	1009.36
Mean percentage error (%)		0.02	0.03

**Table 4. Light intensity**

Date/Time	Measured average light intensity (lux)	Source average light intensity (lux)	
		NMA	Online weather report
01/03/2017	1700	1700	1800
02/02/2017	1500	1600	1600
03/02/2017	1400	1400	1400
04/02/2017	1300	1200	1300
05/02/2017	1100	1100	1000
06/02/2017	1200	1100	1100
07/02/2017	1200	1200	1100
08/02/2017	1300	1200	1300
Mean total	1337.50	1312.50	1325.00
Mean percentage error (%)		1.91	0.94

**Table 5. Dew point temperature**

Date/ Time	Approximated average dew point (°C)	Source average dew point (°C)	
		NMA	Online weather report
01/03/2017	23.00	22	23
02/02/2017	23.80	24	23
03/02/2017	27.40	27	26
04/02/2017	28.20	28	29
05/02/2017	26.80	27	28
06/02/2017	26.60	27	26
07/02/2017	27.60	26	26
08/02/2017	23.60	24	25
Mean total	25.88	25.63	25.75
Mean percentage error (%)		0.98	0.51

**Table 6. Altitude**

Date/Time	Calculated average altitude (m)	Source average altitude (m)	
		NMA	Online weather report
01/03/2017	12327.24	12300	12350
02/02/2017	15645.96	15650	15640
03/02/2017	16294.96	16300	16200
04/02/2017	15645.96	15650	15640
05/02/2017	13951.94	13950	13900
06/02/2017	14856.89	14900	15000
07/02/2017	14856.89	14900	15000
08/02/2017	16294.96	16300	16200
Mean total	14984.35	14993.75	14991.25
Mean percentage error (%)		0.06	0.05

## 7. CONCLUSION

Weather monitoring plays an important role in human life, so the collection of information about the temporal dynamics of weather changes is very paramount [20].

This research demonstrates the construction of an inexpensive weather monitoring device that ensures flexibility, portability, scalability and user friendly operations which can provide data of some weather variables including temperature, humidity, pressure, ambient light intensity with

Real Time Data Logger and the dew point temperature was approximated for using the Thumb Rule also the altitude was calculated using the Barometric Formula.

With the help of the data logger we can maintain all records of the various parameters measuring, monitoring and controlling. The outputs are displayed on LCD display and stored on the micro SD card. The data can also be transmitted to computer via the micro SD card or the serial port. The system is convenient for users as it does not require external calibration.

The measurement results from this constructed device were in good conformity with those data obtained from other sources.

There is no doubt that an accurate measurement and proper observation and monitoring of the atmospheric conditions using standard meteorological instruments would help guide against the occurrences of climate induced environmental disasters in our community [11]. This weather monitoring system to the best of our knowledge from the reviewed literatures have many advantages compared to some other weather measuring system in terms of its on-device display, smaller size, low cost, flexibility, portability as well simplicity in its operation and would be used for meteorological measurements of temperature, humidity, pressure, ambient light intensity, the dew point temperature was approximated for using the Thumb Rule and altitude was calculated for using the Barometric Formula.

This would make weather related data readily available for small-scale users like farmers, travellers, aircraft workers, researchers, schools or institutions and others that may need it without huge financial implications for the purpose of measurements, estimation, modelling, prognostications and spatial planning so as to prevent climate-induced environmental disasters in our communities.

## COMPETING INTERESTS

Authors have declared that no competing interests exist.

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