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Development of an Automatic Weather Monitoring System

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Abstract: *Weather is the state of the atmosphere at a given time and place with respect to cloudiness, hotness, heat, dryness, sunshine, wind, rain, etc.and it is difficult to predict. Weather monitoring plays an important role in various human endeavor. In this paper, we present the development of a low cost server-based automatic weather station for remote locations. This work is built around a microcontroller unit (Arduino mega 2560 microcontroller), weather parameter sensors and a laptop computer. The data from the sensors were collected either hourly, daily, monthly or on a yearly basis. A webpage and a serial data capturing application were developed using notepad, hypertext markup language version 5and advanced serial data logger software respectively that logs and display real time weather conditions on the PC which can be monitored, accessed and downloaded by users remotely.The developed system worked satisfactorily.*

Keywords: *Advanced Serial Data Logger Software; Arduino Mega 2560MCU;Automatic Weather Station; Server-based; Weather Parameters*

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I. Introduction

An Automated Weather Station (AWS) is defined as an automated type of the traditional weather station which is used either to save human labour or to enable measurements from remote areas[1]. It is an electronic instrument that is made up of a microcontroller and the various weather parameters sensors which measures and records meteorological or weather parameters without human intervention. The measured weather parameters can be stored either in a storage device, a built-in data logger or can be transmitted to a remote location through a communication link. If the data is stored in a data logger, the logged data must be downloaded physically to a computer at a later time for further processing. However, this is not a feasible option especially when the weather station is located at a remote area. Therefore, the remote access and monitoring systems are essential elements in an automatic weather station.

Different automated weather stations have been developedby atmospheric equipment designing companies, research institutes, space scientists, meteorologist,researchers, and engineers[2-15]. However, these weather stations do not have the capability of remote data download and data are not logged either on hourly, daily, monthly, or yearly basis.

Thus, this work is aimed at developing a low cost server-based automatic weather station with remote data download and data logging either on hourly, daily, monthly or yearly basis capabilities.

II. Design Methodology

The design methodology is subdivided into five stagesas follows:

Stage 1–**The weather station design and prototype development**

The weather station (the hardware) was designed using an Arduino mega 2560 microcontroller and some weatherparameters sensors as given in Fig. 1(a).These sensors were connected to the respective analogue and digital pins of the Arduino board to take measurements. The measurements taken include air temperature, relative humidity, soil moisture level, rain rate, light intensity, soil temperature, wind speed, wind direction, barometric pressureand ozone (O_3) gas. Fig. 1(a) shows the block diagram of the weather station while Fig. 1(b) shows the system architecture.

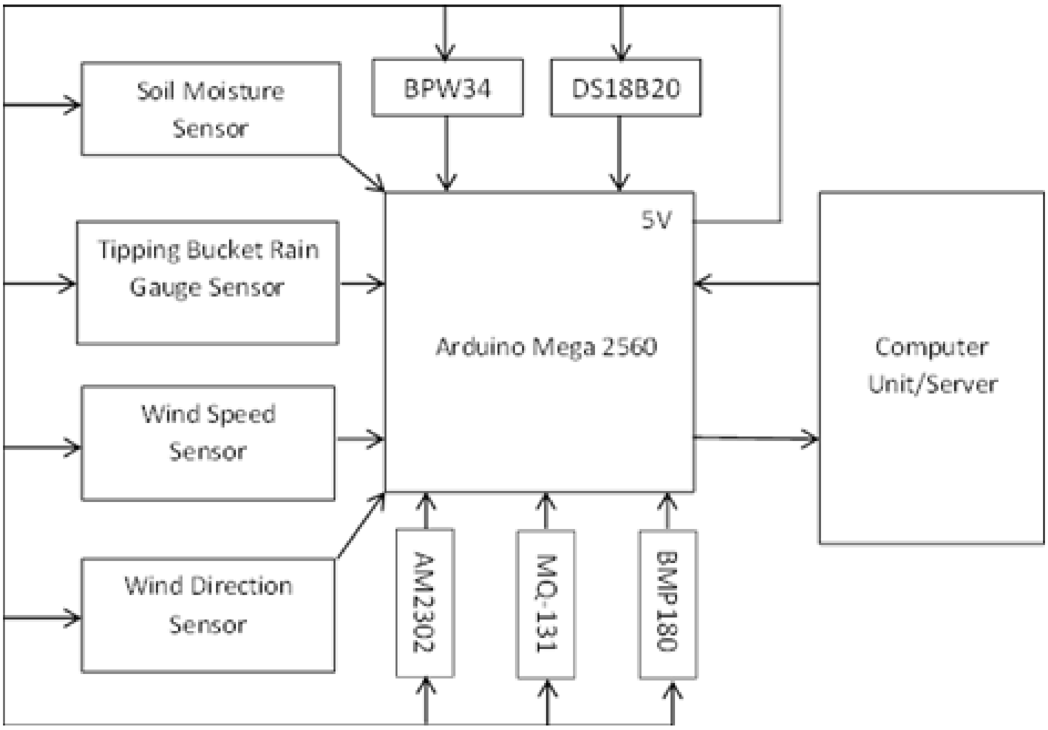


Fig. 1(a): Block diagram of the weather station

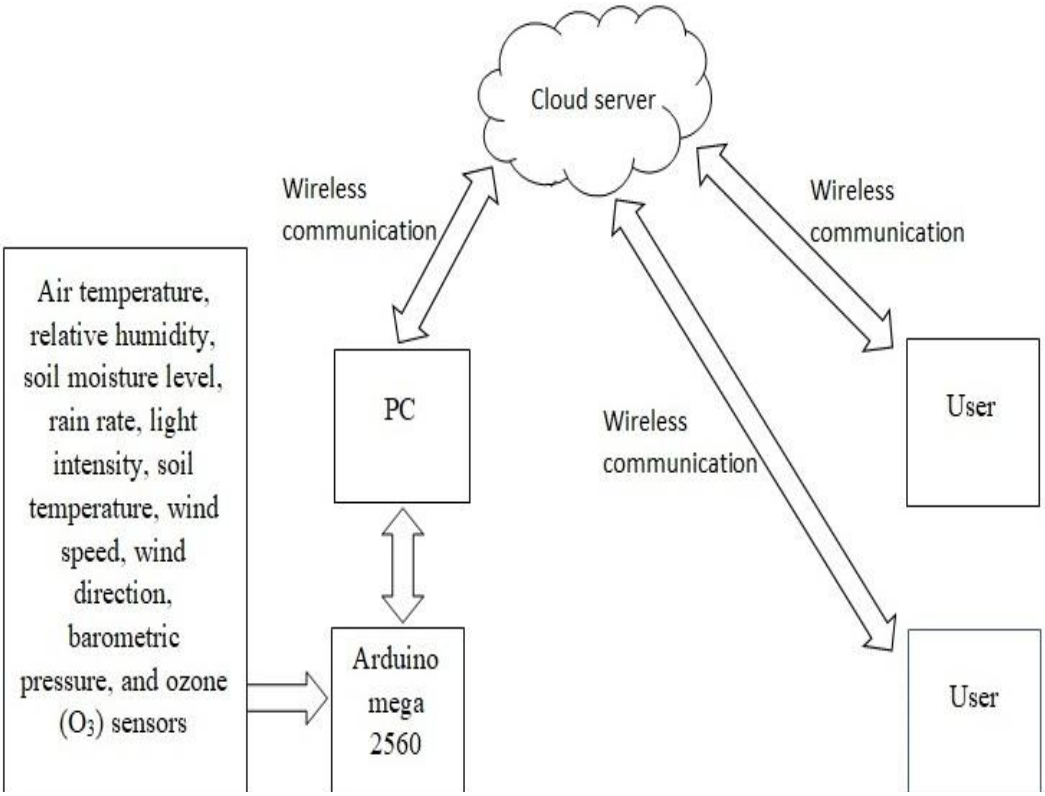


Fig. 1(b): The system architecture.

Presented in Table 1 is thelist ofcomponents and the different atmospheric parameters sensors that wereconnected together to develop the low cost server-basedautomatic weather station.

Table 1: Components and atmospheric parameters sensors

Sensors/Components	Type	Characteristics
Microcontroller	Arduino mega 2560	It has 54 digital input/output pins[16]. It is used to power all the sensors.
Soil moisture sensor	Spark fun	Conductivity between the pads is proportional to soil moisture level[17]
Temperature and relative humidity sensor	AM2302	Calibrated digital output signal[18]
Light intensity sensor	BPW34	High speed and highly sensitive photodiode
Soil temperature sensor	DS18B20	Accurate to ±0.5°C in the range of -10°C to +85°C and its working range is -55°C to +125°C
Barometric pressure sensor	BMP180	Best low cost that can be used as an altimeter
Wind speed sensor	Locally made available using $V = P\left(\frac{2.25}{T}\right) \times 0.44704$	Where V is speed in miles per hour. P is number of pulses per sample period. T is the sample period in second
Wind direction sensor	Locally made	Low cost
Rainfall sensor	Locally made tipping bucket	0.01 inches or 0.03cm of rain was collected as at the time of this work
Ozone sensor	MQ-131	Senses O_3 concentration in the range of 10ppm to 1000ppm
Computer	Laptop	It is used for software installation of Arduino IDE, advanced serial data logger and displays sensor data

Stage 2 – Firmware development for the Arduino mega 2560 MCU

The Arduino IDE was used to develop the firmware for the Arduino mega 2560 board. After the firmware was developed, it was sent to the Arduino board through the USB to the serial cable. The flowchart for developing the firmware is shown in Fig. 2(a), while the process of developing the firmware is shown in Fig. 2(b)

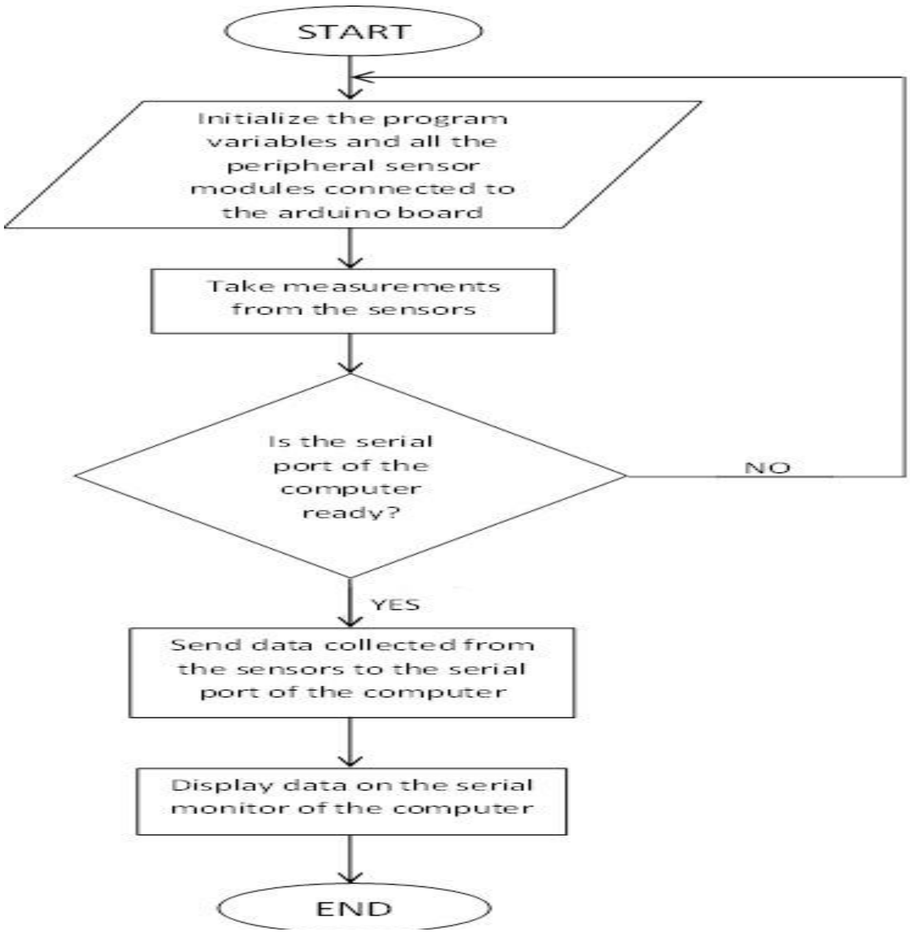


Fig. 2(a): The flowchart for developing the firmware

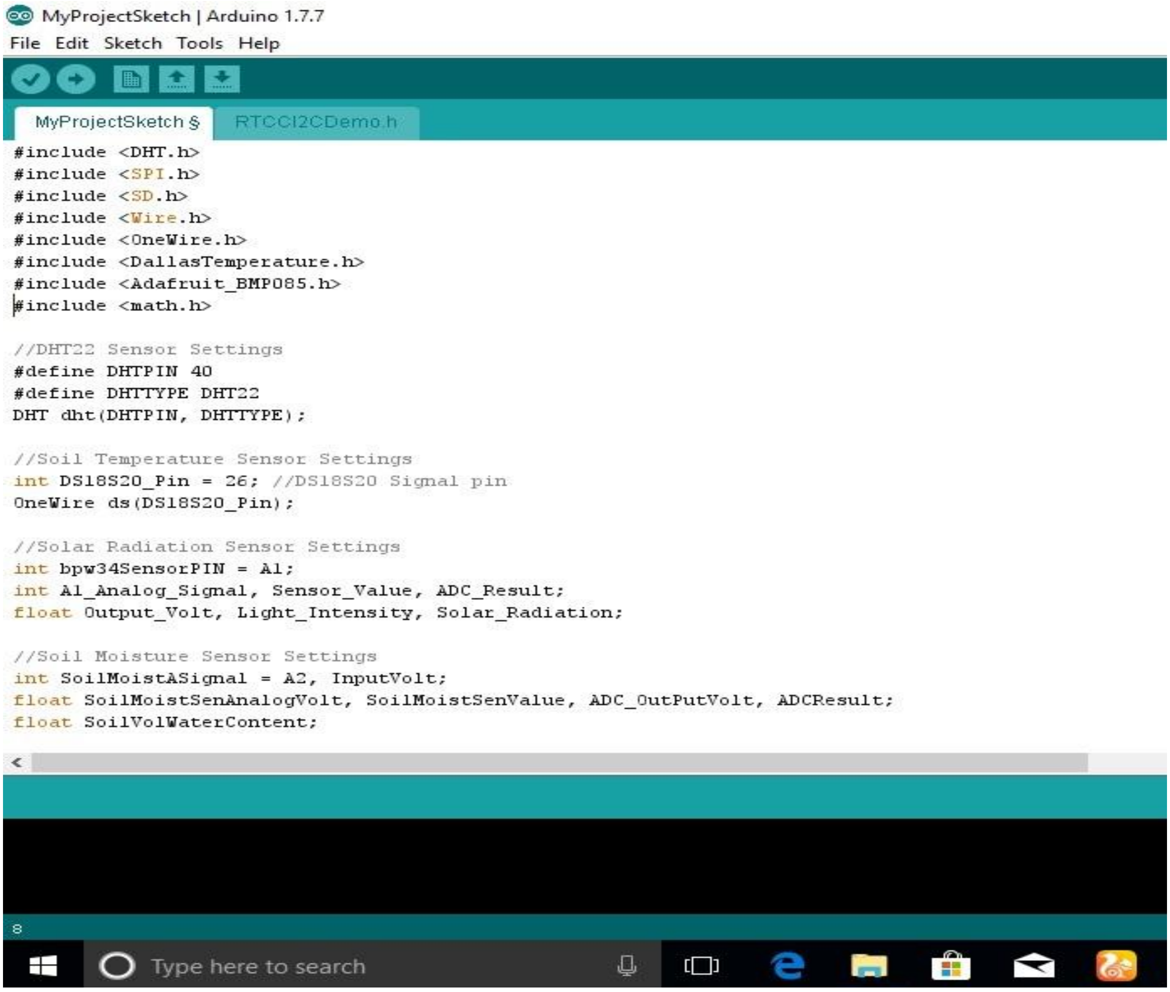


Fig. 2(b): Firmware development process.

Stage 3 – Configuring the advanced serial data logger

The advanced serial data logger (ASDL) software [19] was configured to capture the atmospheric data present at the serial port of the computer, log the data in an Excel file format to a specified folderin the computer. The advanced serial data logger was configured to log data on hourly basis – that is, at the end of each hour.Fig. 3(a) shows a flowchart on how the Advanced Serial Data Logger was configured to capture, log, and display data.Fig. 3(b) showsthe process of setting up the communication parameters. Fig. 3(c) shows the process of setting up the log rotation to log data on hourly basis. Fig. 3(d) shows the configuration process of the Excel Pro that comes with the advanced serial data logger to log atmosphericdata in an Excel file format.

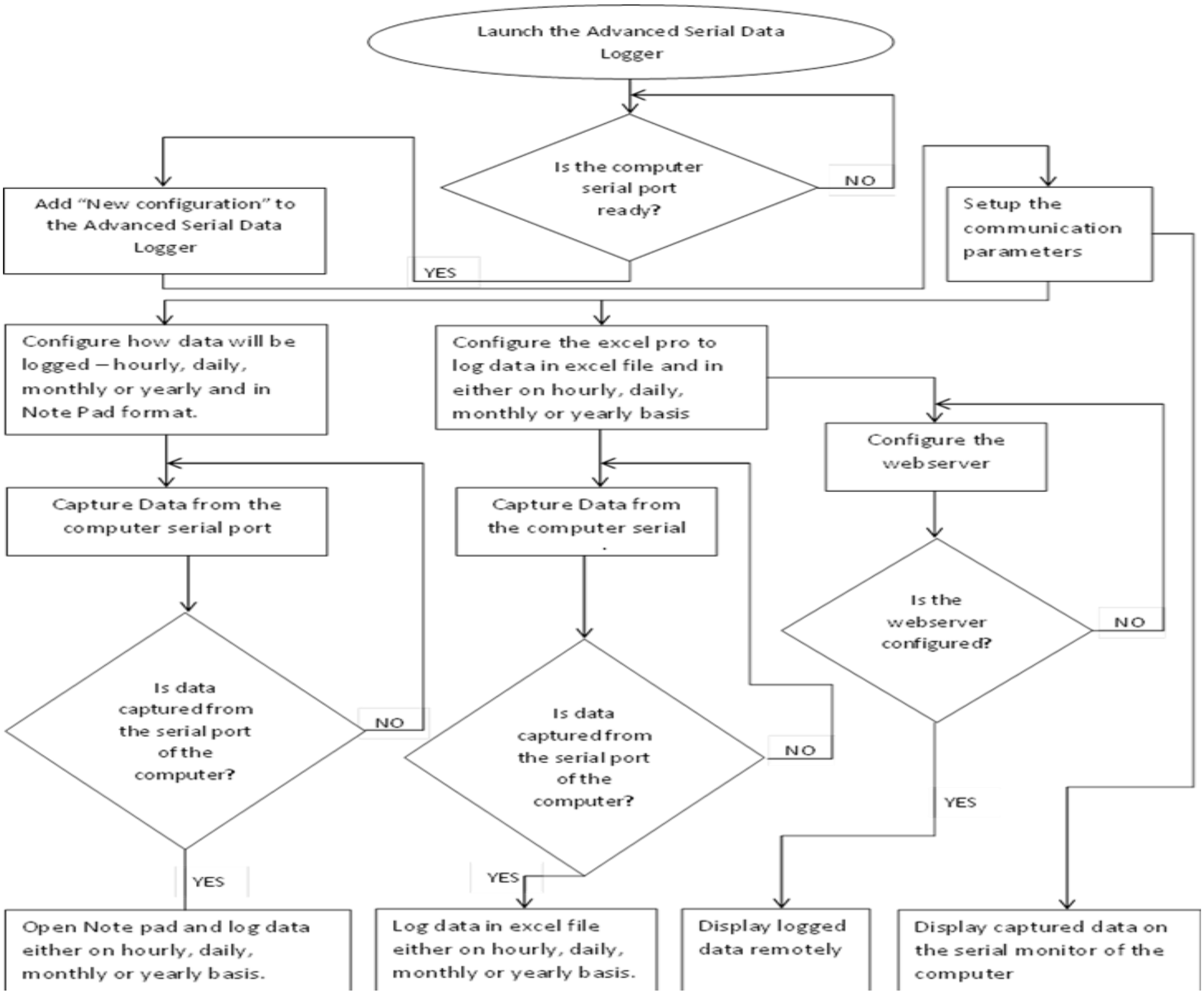


Fig. 3(a): Flowchart showing how the Advanced Serial Data Logger to capture, log, and display datawas configured

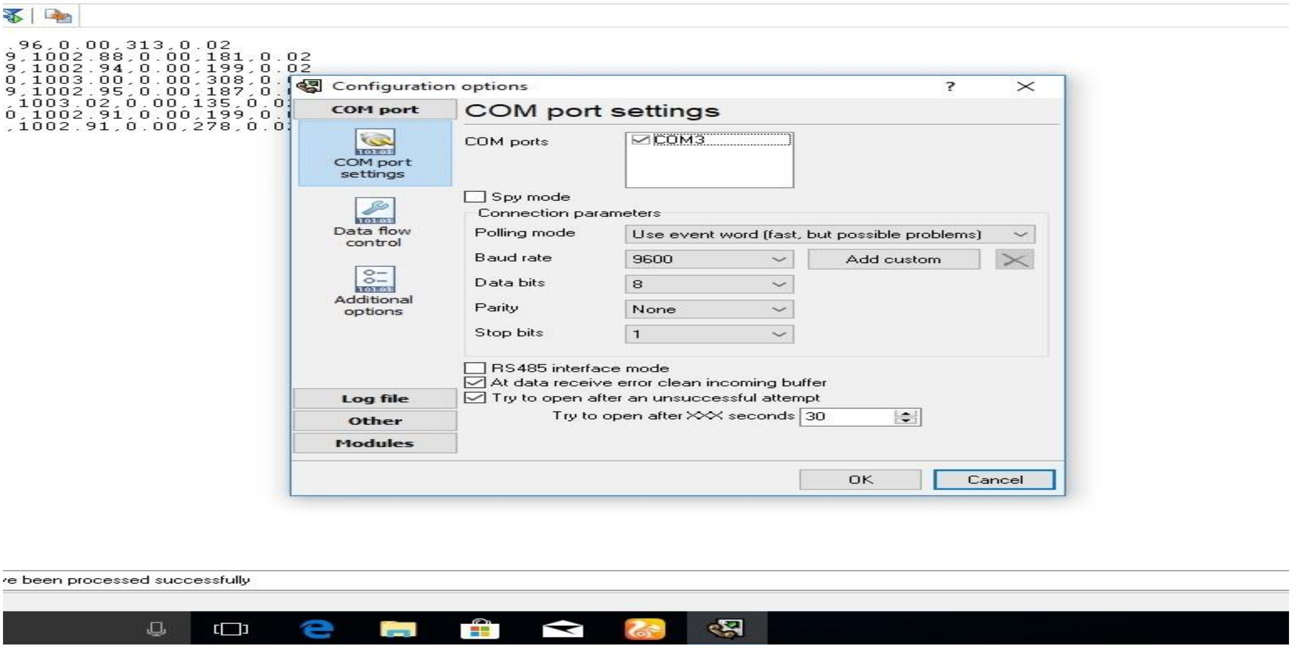


Fig. 3(b): Setting up of the communication parameters

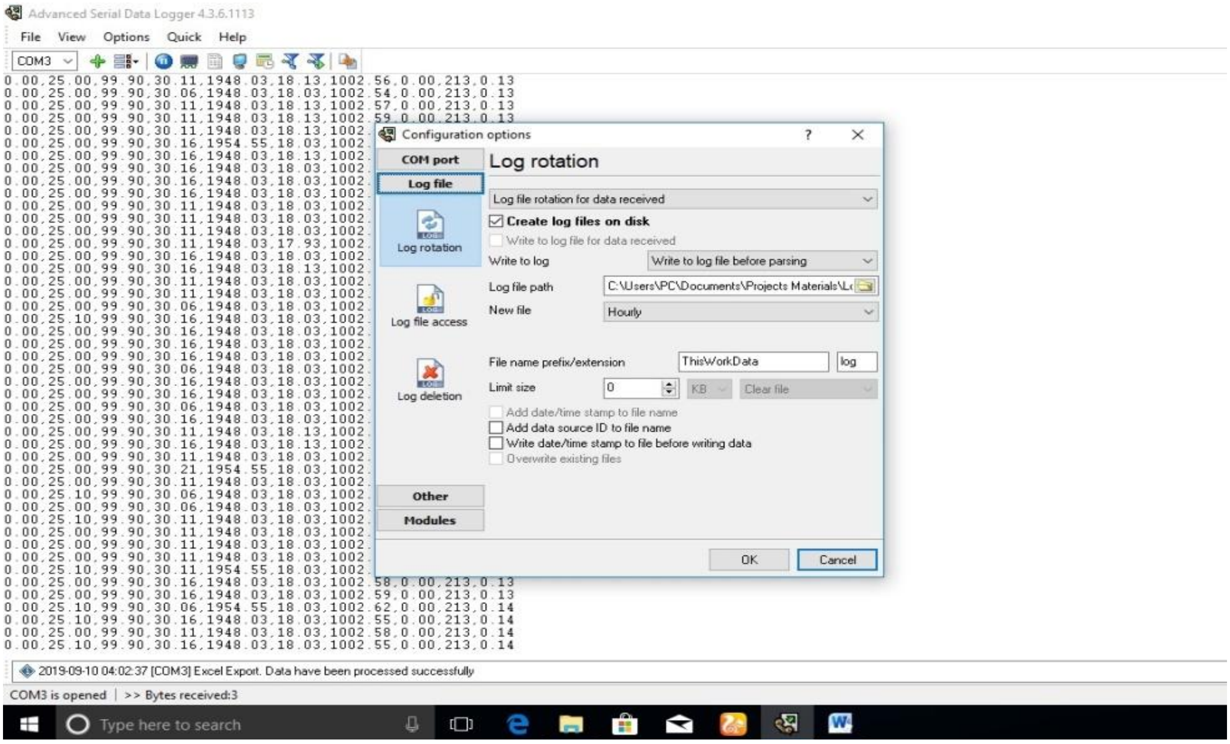


Fig. 3(c): Setting up of the log rotation to log data on hourly basis.

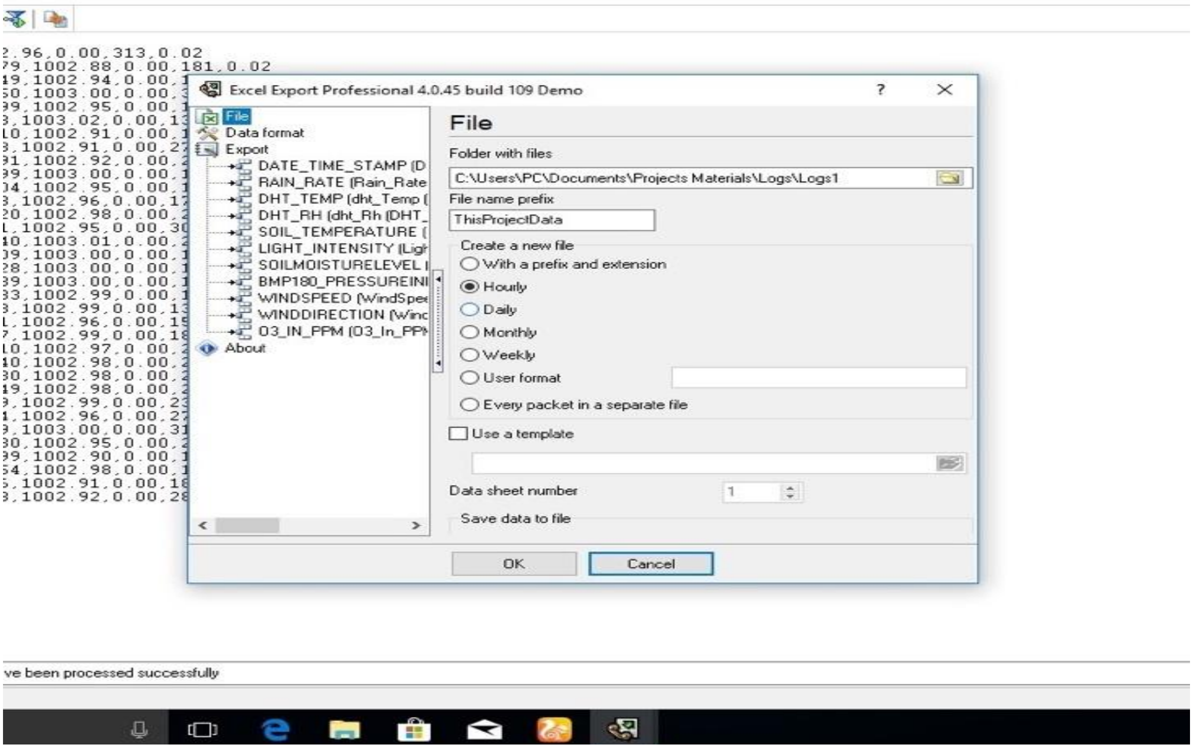


Fig. 3(d). The configuration process of the web server.

Next, the web server was configured to enable users to monitor and access the data remotely. Fig.4 shows configuration process of the web server plug-in that comes with the advanced serial data logger.

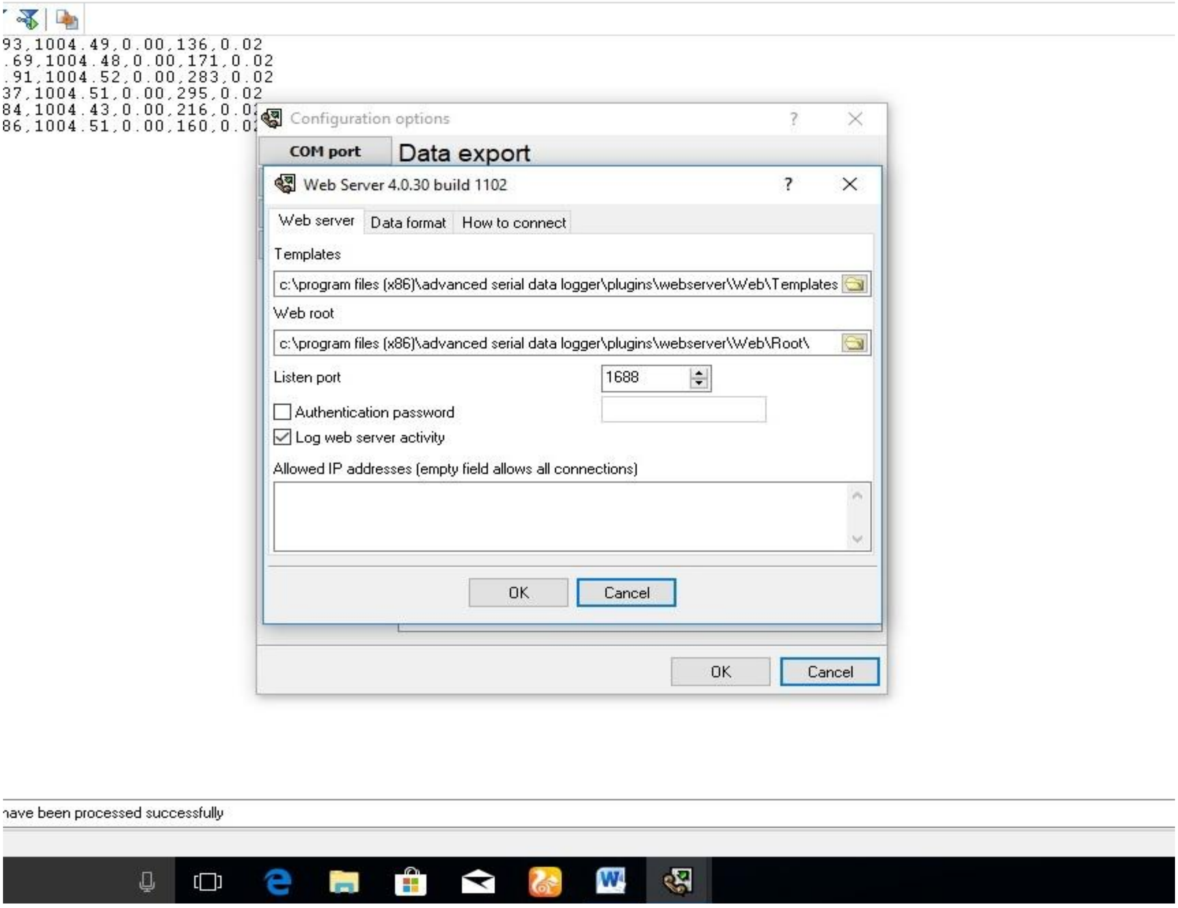


Fig. 4. Configuration process of the web server

Stage 4 – Designing a simple webpage

A simple webpage was designed using notepad and html5. A link to the folder containing the logged files was created and from the web server, a link was created to the webpage so that when the web server is launched, users monitoring the atmospheric data remotely can also access and download data remotely through the link.

Stage 5 – Setting up a network system

To monitor, access, and download data from the weather station, network is needed.Though, the weather station can also be accessed through the internet if the website is hosted using its own internet protocol (IP) address (which is quite expensive to acquire). In this work, a wireless local area networkwas set up using a phone hotspot to access the weather station. For a user to monitor, access, and download data, such user must be connected to the network which the server is connected to. During the field test, all the users that were connected to the network which the server also used, were able to monitor, access, and download data to their devices.

III. The Developed Low Cost Server-based Automatic Weather Station Board.

Figure 5(a) shows the developed low cost server-based automatic weather station. Fig. 5(b) shows the constructed low cost server-based automatic weather station with sensors connected and placed inside the case.

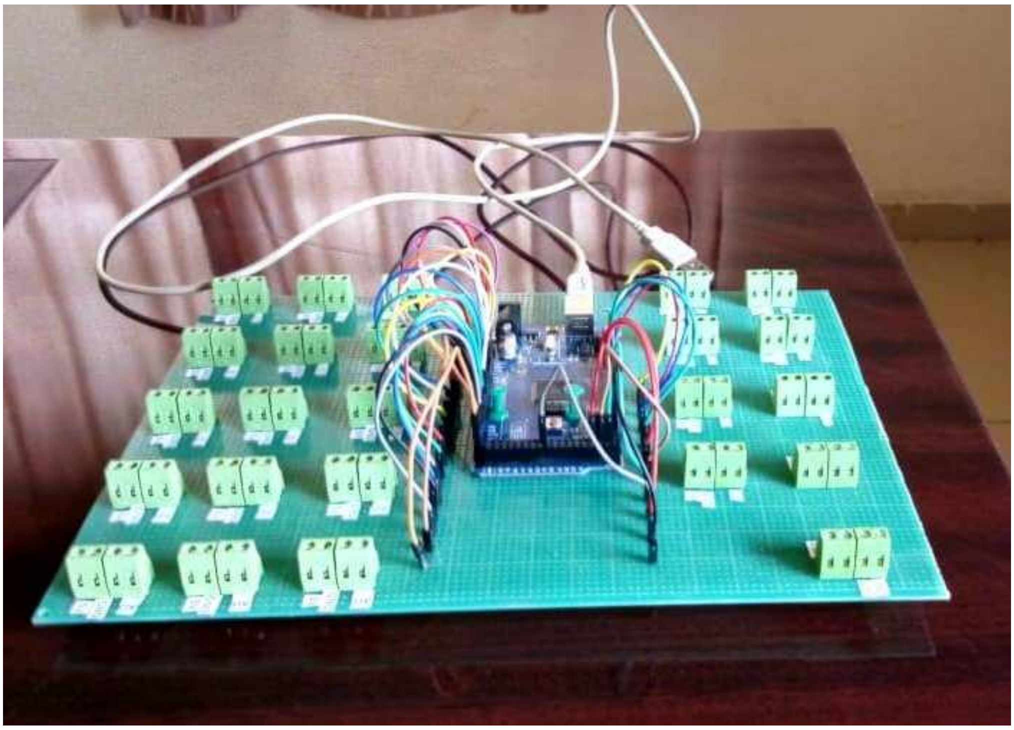


Fig. 5(a): The constructed low cost server-based automatic weather station

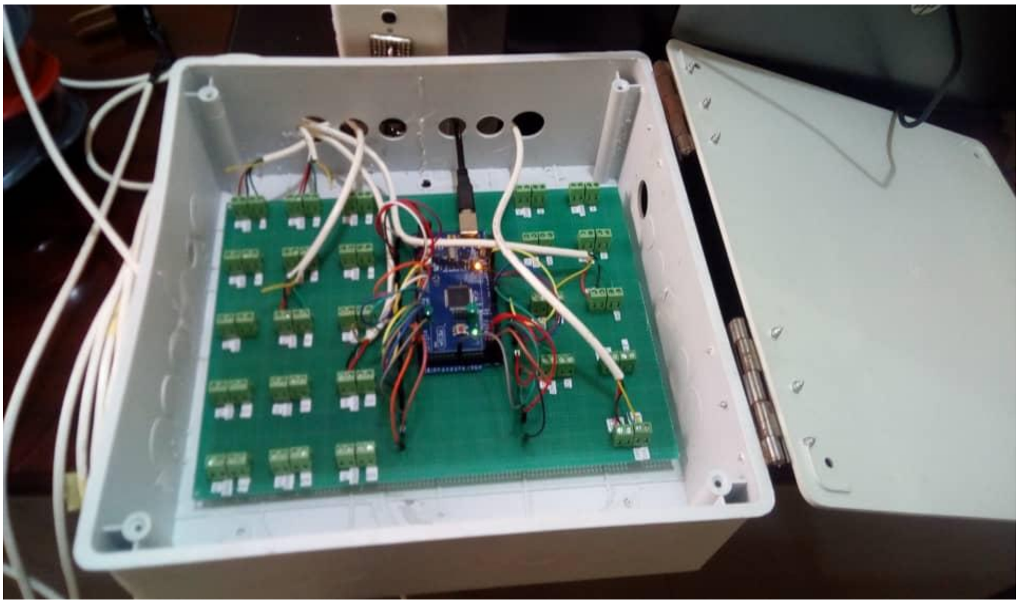


Fig. 5(b): The constructed low cost server-based automatic weather station with sensors connected

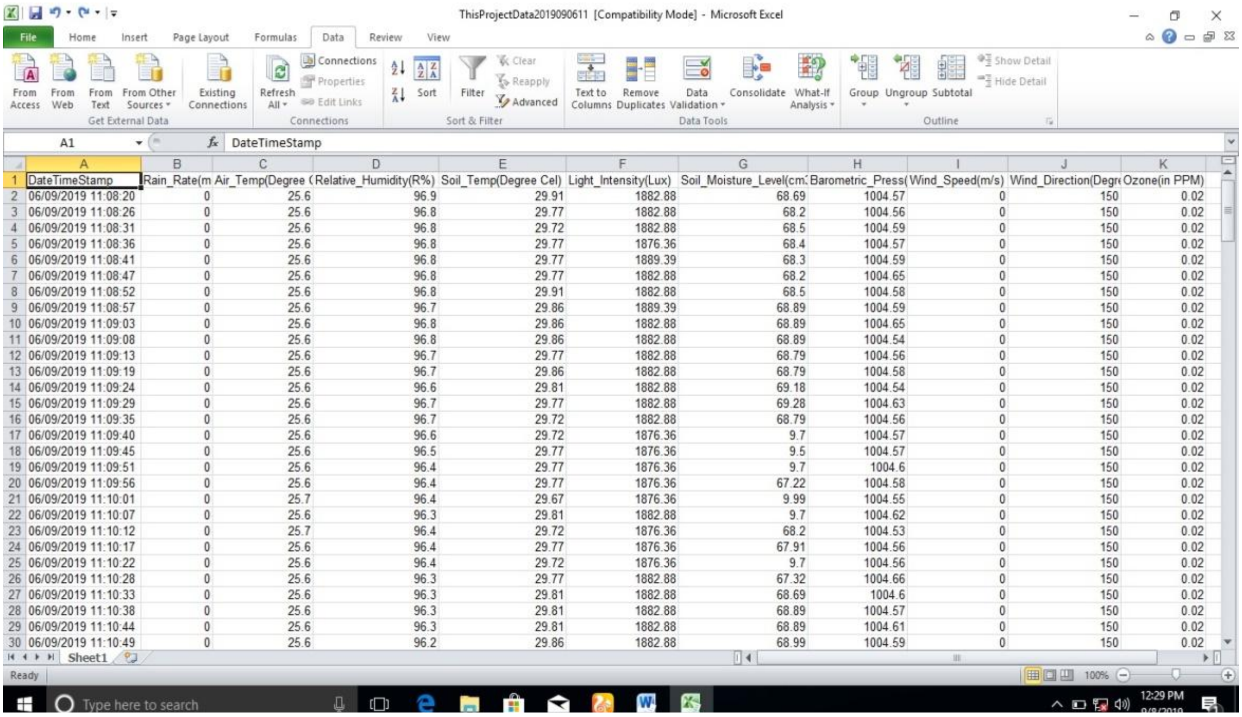
Testing the Weather Station

After the various sensor modules were connected to the Arduino board and the Arduino board was programmed with the firmware, the low cost, server-based automatic weather station was put to test. Fig. 6shows the setup for the testing of the weather station.

Fig. 6: Testing the weather station.

IV. Results

After the testing of the automatic weather station, data were logged in both notepad and Excel file formats as shown in Fig. 7(a) and Fig. 7(b)respectively.



	DateTimeStamp	Rain_Rate(m	Air_Temp(Degree (	Relative_Humidity(R%)	Soil_Temp(Degree Cel)	Light_Intensity(Lux)	Soil_Moisture_Level(cm:	Barometric_Press(	Wind_Speed(m/s)	Wind_Direction(Degr	Ozone(in PPM)
2	06/09/2019 11:08:20	0	25.6	96.9	29.91	1882.88	68.69	1004.57	0	150	0.02
3	06/09/2019 11:08:26	0	25.6	96.8	29.77	1882.88	68.2	1004.56	0	150	0.02
4	06/09/2019 11:08:31	0	25.6	96.8	29.72	1882.88	68.5	1004.59	0	150	0.02
5	06/09/2019 11:08:36	0	25.6	96.8	29.77	1876.36	68.4	1004.57	0	150	0.02
6	06/09/2019 11:08:41	0	25.6	96.8	29.77	1889.39	68.3	1004.59	0	150	0.02
7	06/09/2019 11:08:47	0	25.6	96.8	29.77	1882.88	68.2	1004.65	0	150	0.02
8	06/09/2019 11:08:52	0	25.6	96.8	29.91	1882.88	68.5	1004.58	0	150	0.02
9	06/09/2019 11:08:57	0	25.6	96.7	29.86	1889.39	68.89	1004.59	0	150	0.02
10	06/09/2019 11:09:03	0	25.6	96.8	29.86	1882.88	68.89	1004.65	0	150	0.02
11	06/09/2019 11:09:08	0	25.6	96.8	29.86	1882.88	68.89	1004.54	0	150	0.02
12	06/09/2019 11:09:13	0	25.6	96.7	29.77	1882.88	68.79	1004.56	0	150	0.02
13	06/09/2019 11:09:19	0	25.6	96.7	29.86	1882.88	68.79	1004.58	0	150	0.02
14	06/09/2019 11:09:24	0	25.6	96.6	29.81	1882.88	69.18	1004.54	0	150	0.02
15	06/09/2019 11:09:29	0	25.6	96.7	29.77	1882.88	69.28	1004.63	0	150	0.02
16	06/09/2019 11:09:35	0	25.6	96.7	29.72	1882.88	68.79	1004.56	0	150	0.02
17	06/09/2019 11:09:40	0	25.6	96.6	29.72	1876.36	9.7	1004.57	0	150	0.02
18	06/09/2019 11:09:45	0	25.6	96.5	29.77	1876.36	9.5	1004.57	0	150	0.02
19	06/09/2019 11:09:51	0	25.6	96.4	29.77	1876.36	9.7	1004.6	0	150	0.02
20	06/09/2019 11:09:56	0	25.6	96.4	29.77	1876.36	67.22	1004.58	0	150	0.02
21	06/09/2019 11:10:01	0	25.7	96.4	29.67	1876.36	9.99	1004.55	0	150	0.02
22	06/09/2019 11:10:07	0	25.6	96.3	29.81	1882.88	9.7	1004.62	0	150	0.02
23	06/09/2019 11:10:12	0	25.7	96.4	29.72	1876.36	68.2	1004.53	0	150	0.02
24	06/09/2019 11:10:17	0	25.6	96.4	29.77	1876.36	67.91	1004.56	0	150	0.02
25	06/09/2019 11:10:22	0	25.6	96.4	29.72	1876.36	9.7	1004.56	0	150	0.02
26	06/09/2019 11:10:28	0	25.6	96.3	29.77	1882.88	67.32	1004.66	0	150	0.02
27	06/09/2019 11:10:33	0	25.6	96.3	29.81	1882.88	68.69	1004.6	0	150	0.02
28	06/09/2019 11:10:38	0	25.6	96.3	29.81	1882.88	68.89	1004.57	0	150	0.02
29	06/09/2019 11:10:44	0	25.6	96.3	29.81	1882.88	68.89	1004.61	0	150	0.02
30	06/09/2019 11:10:49	0	25.6	96.2	29.86	1882.88	68.99	1004.59	0	150	0.02

Fig. 7(a): Data logged in Excel file

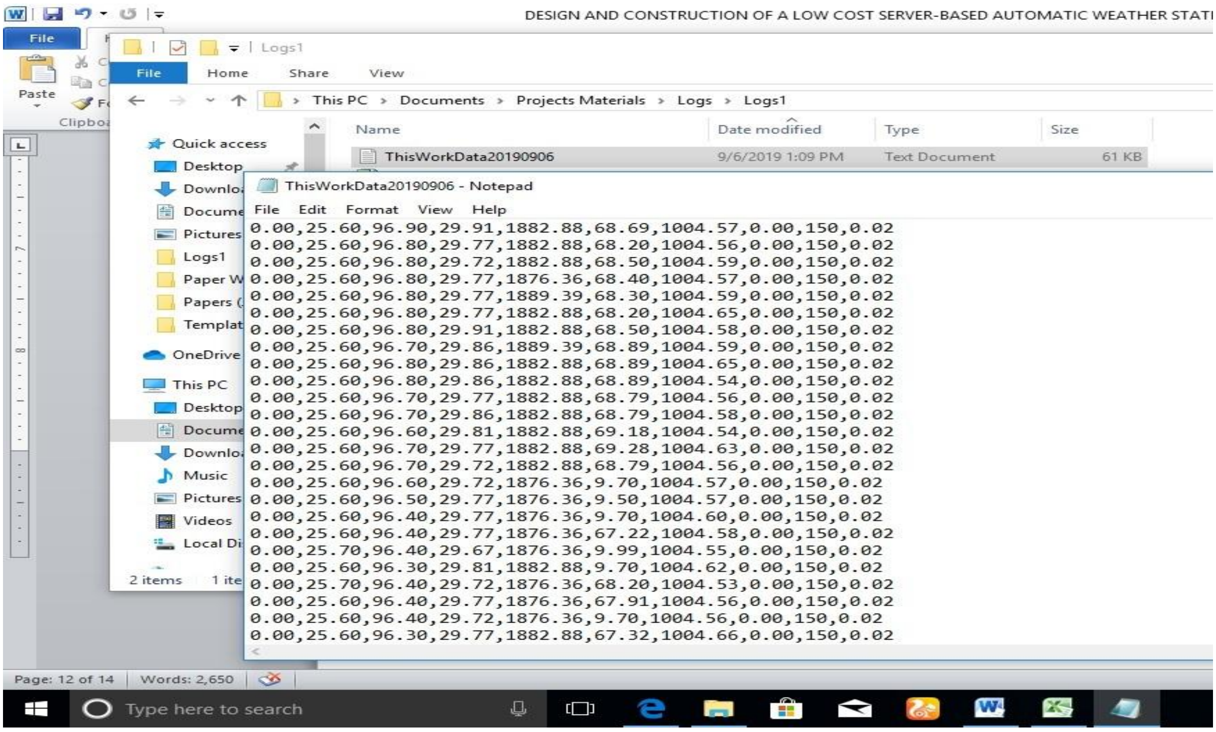


Fig. 7(b): Data logged in note Pad file.

Data were logged on hourly basis as shown in Fig. 8.

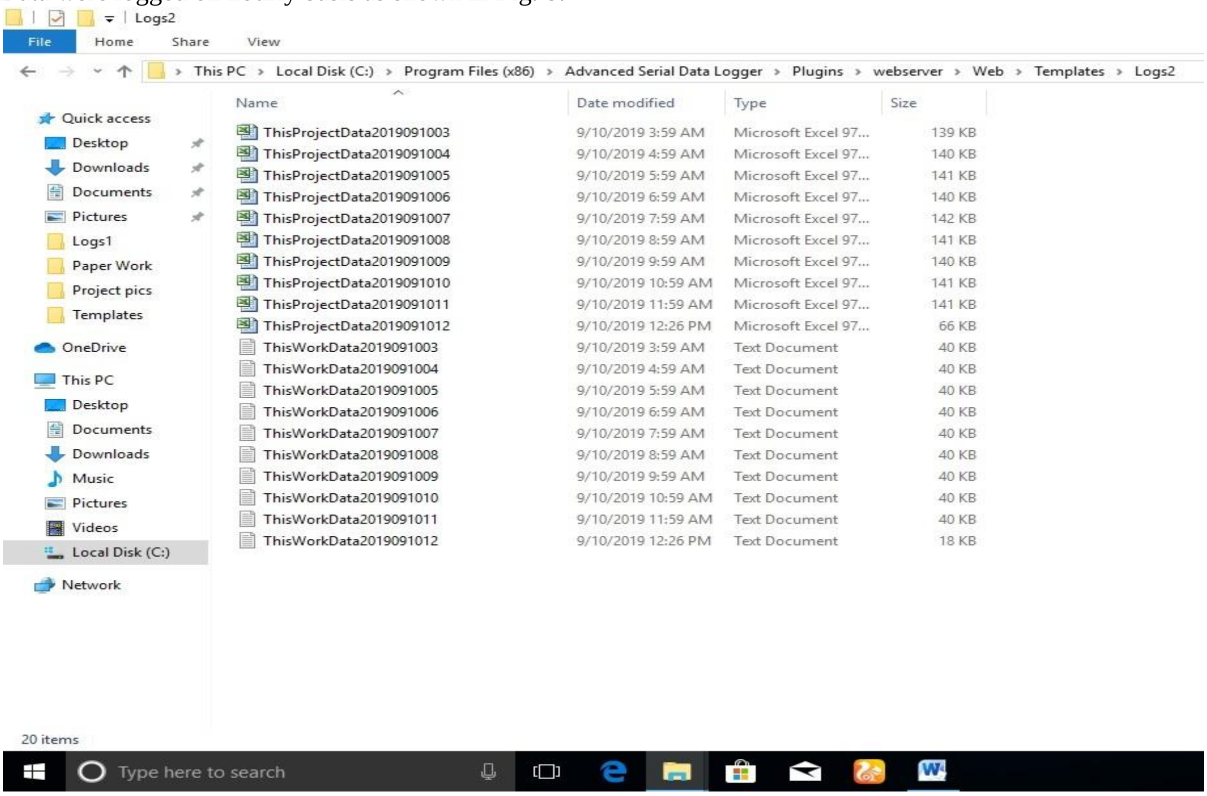


Fig. 8: Data logged on hourly basis.

Users were able to access, monitor, and download the data logged by the weather station remotely. Fig. 9 shows the remote monitoring of the weather station. The users (two users) while using their phones were connected to the wireless local area network that was setup. The users were able to view and monitor the data logged by this weather station remotely.

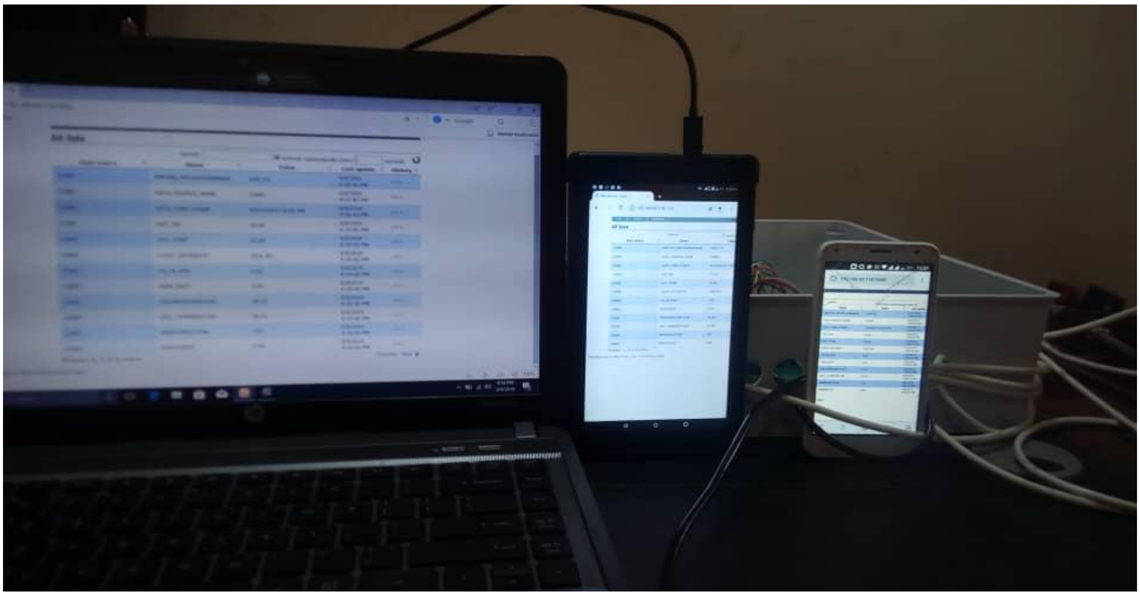
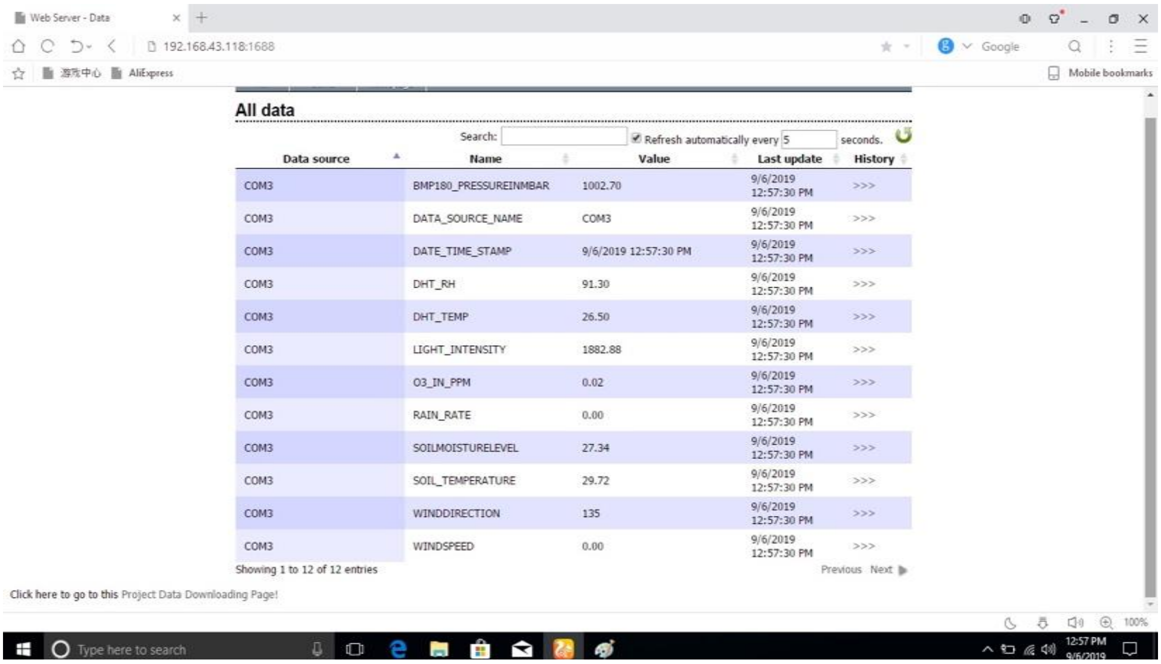


Fig. 9: Two users viewing and monitoring the low cost server-based automatic weather station remotely

The process required to download data from the weather station is as presented in Fig. 10(a) to Fig. 10(e). Fig. 10(a) shows the remote display of the data with data download link at the bottom left of the screen. Clicking on this link will take you to Fig. 10(b)



Data source	Name	Value	Last update	History
COM3	BMP180_PRESSUREINMBAR	1002.70	9/6/2019 12:57:30 PM	>>>
COM3	DATA_SOURCE_NAME	COM3	9/6/2019 12:57:30 PM	>>>
COM3	DATE_TIME_STAMP	9/6/2019 12:57:30 PM	9/6/2019 12:57:30 PM	>>>
COM3	DHT_RH	91.30	9/6/2019 12:57:30 PM	>>>
COM3	DHT_TEMP	26.50	9/6/2019 12:57:30 PM	>>>
COM3	LIGHT_INTENSITY	1882.88	9/6/2019 12:57:30 PM	>>>
COM3	O3_IN_PPM	0.02	9/6/2019 12:57:30 PM	>>>
COM3	RAIN_RATE	0.00	9/6/2019 12:57:30 PM	>>>
COM3	SOILMOISTURELEVEL	27.34	9/6/2019 12:57:30 PM	>>>
COM3	SOIL_TEMPERATURE	29.72	9/6/2019 12:57:30 PM	>>>
COM3	WINDDIRECTION	135	9/6/2019 12:57:30 PM	>>>
COM3	WINDSPEED	0.00	9/6/2019 12:57:30 PM	>>>

Fig. 10(a): Remote display of the data with data download link at the bottom left of the screen

Fig. 10(b) also shows a download link. Clicking on this link will take you to the page where the logged files are listed (see Fig. 10(c)).

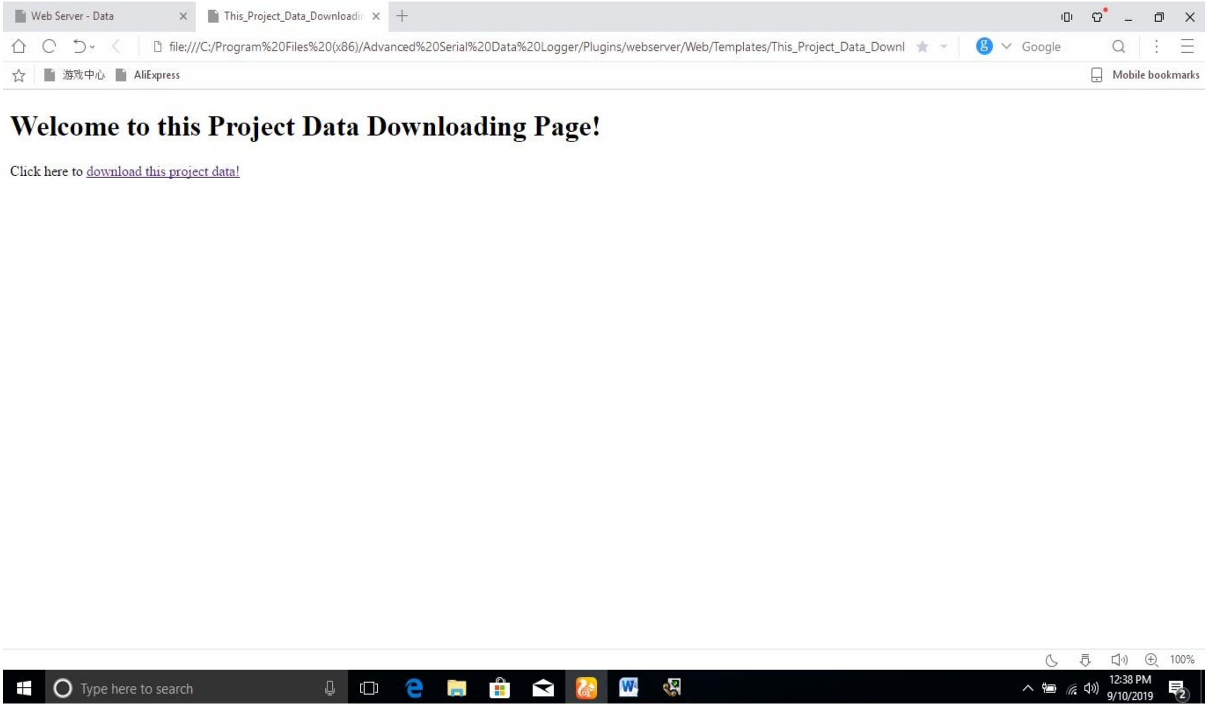


Fig. 10(b): The data downloading page

In order to download the data in the third (from top to bottom) file, the file was double clicked on. After which, a new page as presented in Fig 10(d) was displayed.

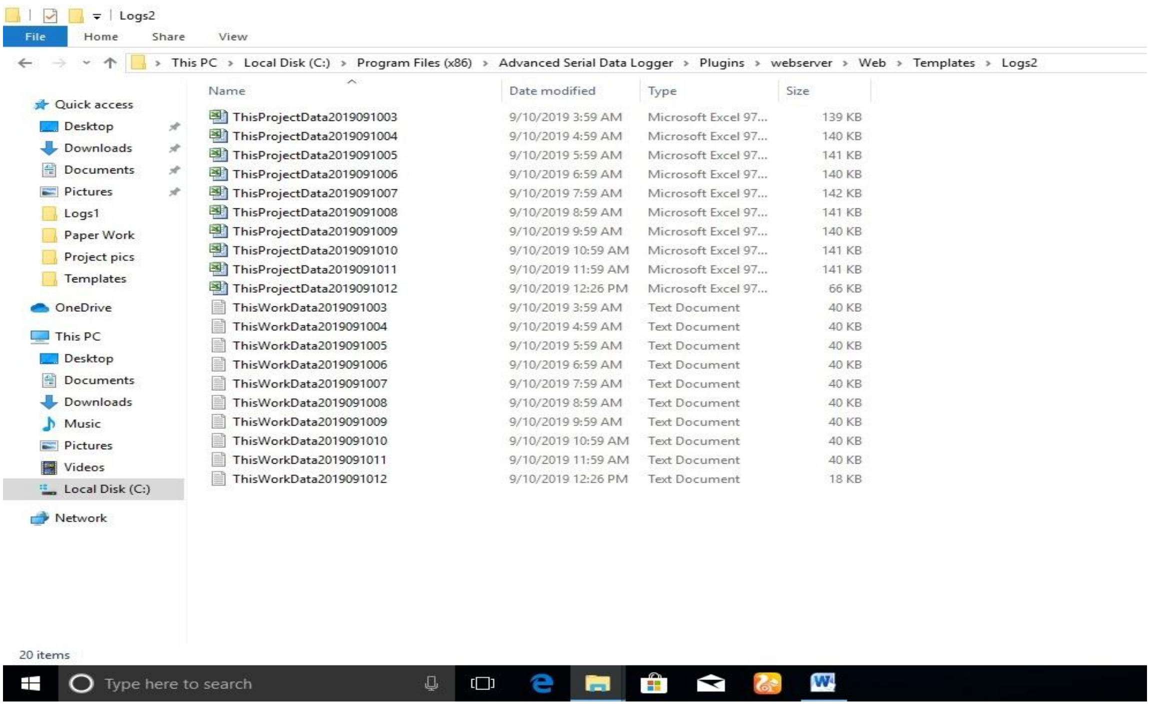


Fig. 10(c): Logged data files

From the download dialogue box that popped up (see Fig. 10(d)), the “Download” button was clicked and the data was downloaded. The downloaded data is shown in Fig. 10(e).

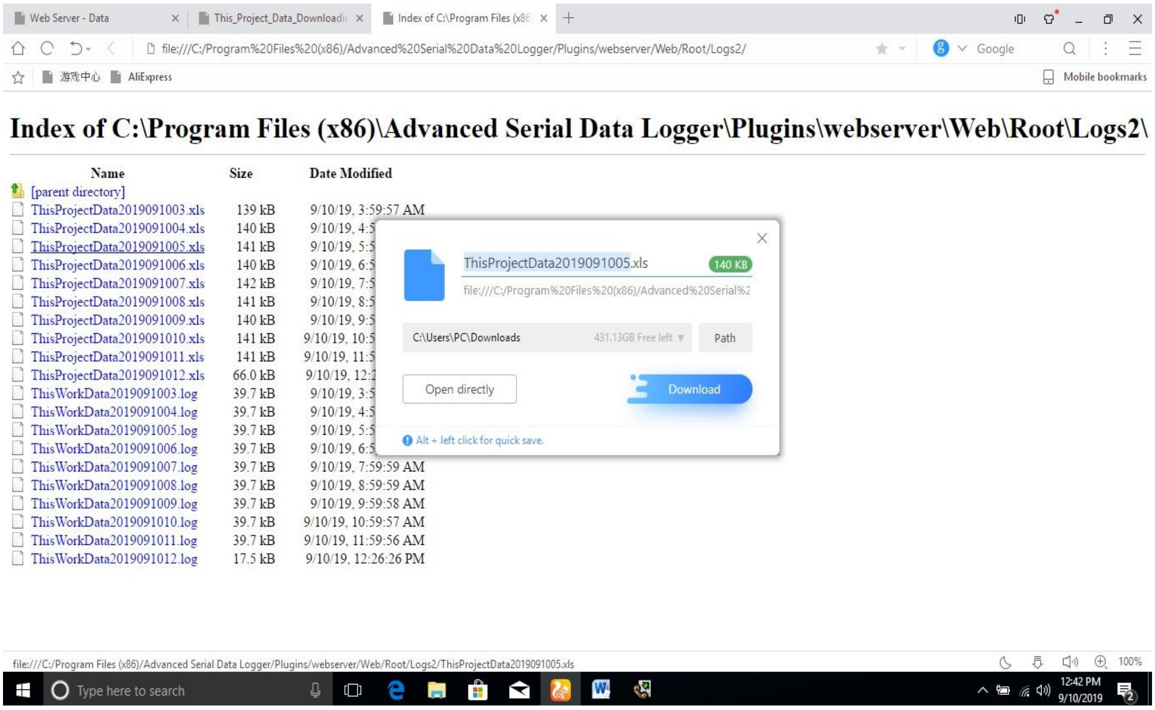


Fig. 10(d): Data downloading page.

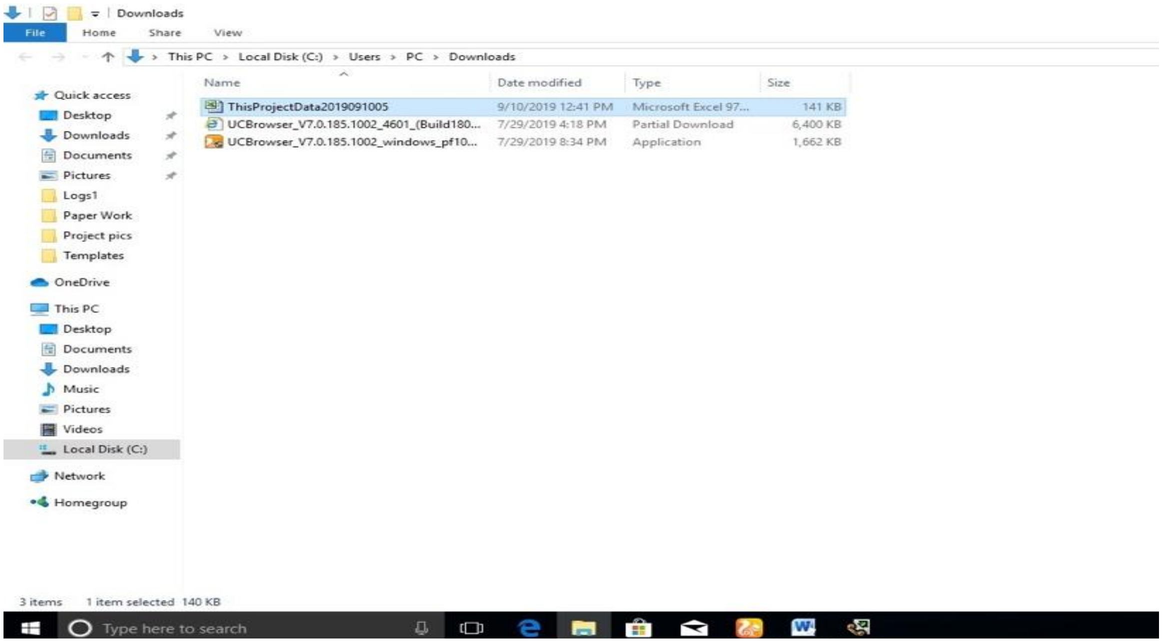


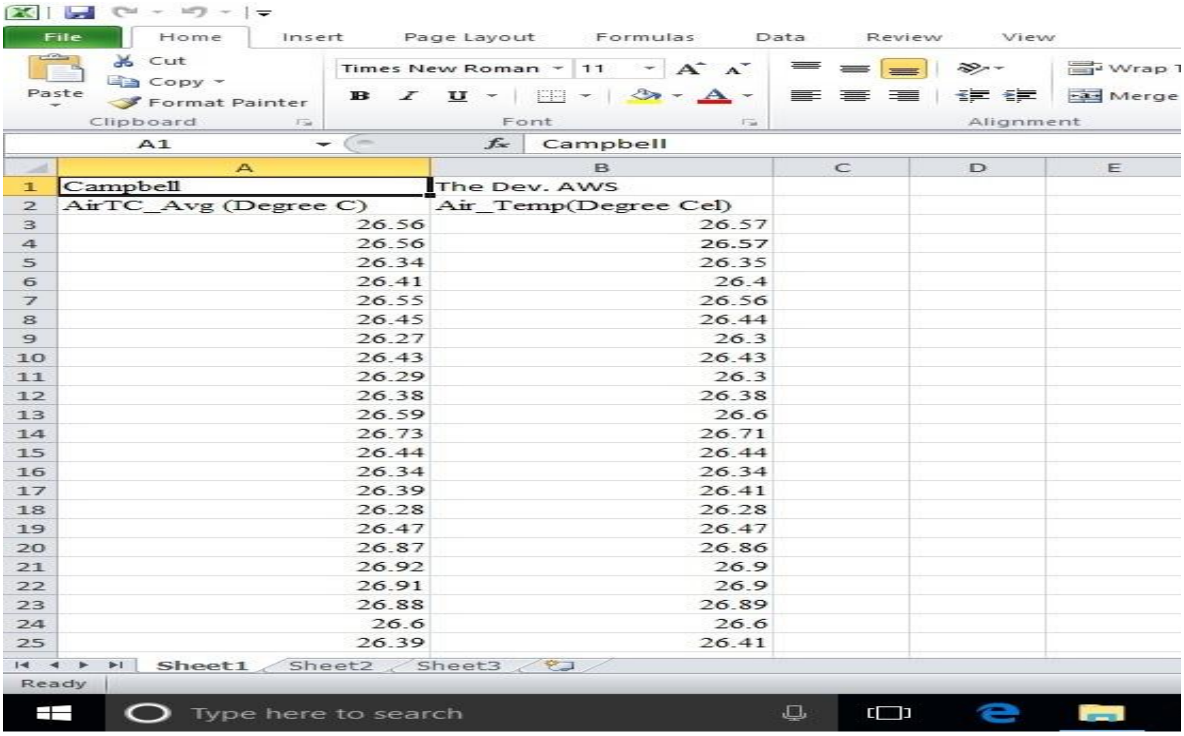
Fig. 10(e): Downloaded data.

V. Comparison of Some of the Data Obtained from this Weather Station with Corresponding Data Obtained from Campbell Weather Station

The developed weather station was placed outdoor for 12 hours to record atmospheric data. At the end of 12 hours, some of the data obtained from this our weather station was compared with some of the data obtained from Campbell weather station at the same time interval.

Comparison of Air Temperature Data

Figure 11(a) shows air temperature data obtained from the two weather stations, while Fig. 11(b) shows the graph of air temperature data from the two weather stations.



	A	B
1	Campbell	The Dev. AWS
2	AirTC_Avg (Degree C)	Air_Temp(Degree Cel)
3	26.56	26.57
4	26.56	26.57
5	26.34	26.35
6	26.41	26.4
7	26.55	26.56
8	26.45	26.44
9	26.27	26.3
10	26.43	26.43
11	26.29	26.3
12	26.38	26.38
13	26.59	26.6
14	26.73	26.71
15	26.44	26.44
16	26.34	26.34
17	26.39	26.41
18	26.28	26.28
19	26.47	26.47
20	26.87	26.86
21	26.92	26.9
22	26.91	26.9
23	26.88	26.89
24	26.6	26.6
25	26.39	26.41

Fig. 11(a): Air temperature data obtained from the two weather stations

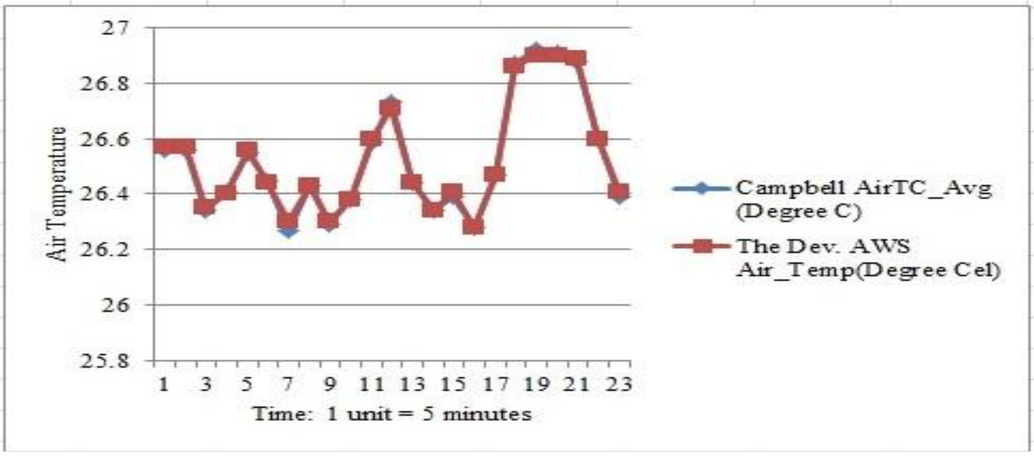
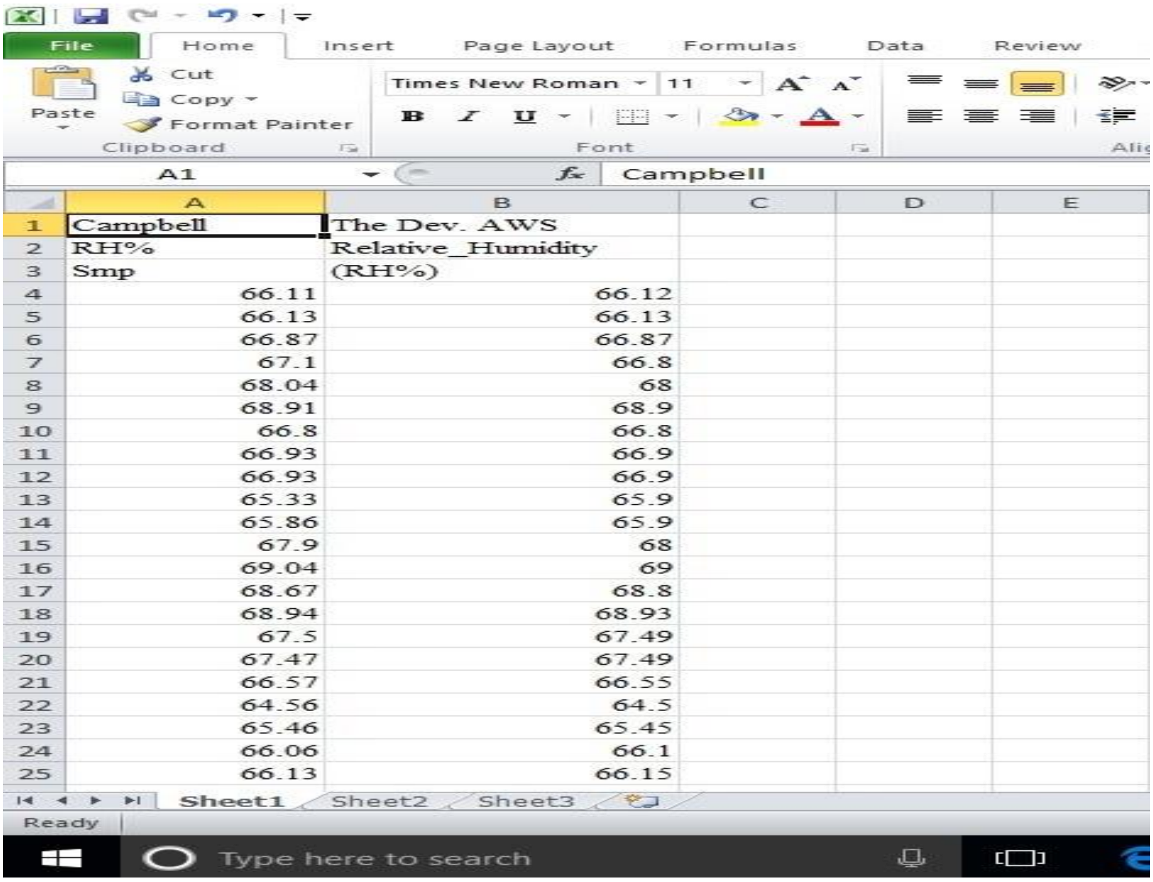


Fig 11(b): Graph of the air temperature data obtained from thetwo weather stations.

Comparison of Relative Humidity Data

Figure 12(a) shows relative humidity data obtained from the two weather stations, while Fig. 12(b) shows the graph of relative humidity data obtained from the two weather stations.



	A	B
1	Campbell	The Dev. AWS
2	RH%	Relative_Humidity
3	Smp	(RH%)
4	66.11	66.12
5	66.13	66.13
6	66.87	66.87
7	67.1	66.8
8	68.04	68
9	68.91	68.9
10	66.8	66.8
11	66.93	66.9
12	66.93	66.9
13	65.33	65.9
14	65.86	65.9
15	67.9	68
16	69.04	69
17	68.67	68.8
18	68.94	68.93
19	67.5	67.49
20	67.47	67.49
21	66.57	66.55
22	64.56	64.5
23	65.46	65.45
24	66.06	66.1
25	66.13	66.15

Fig 12 (a): Relative humidity data obtained from the two weather stations

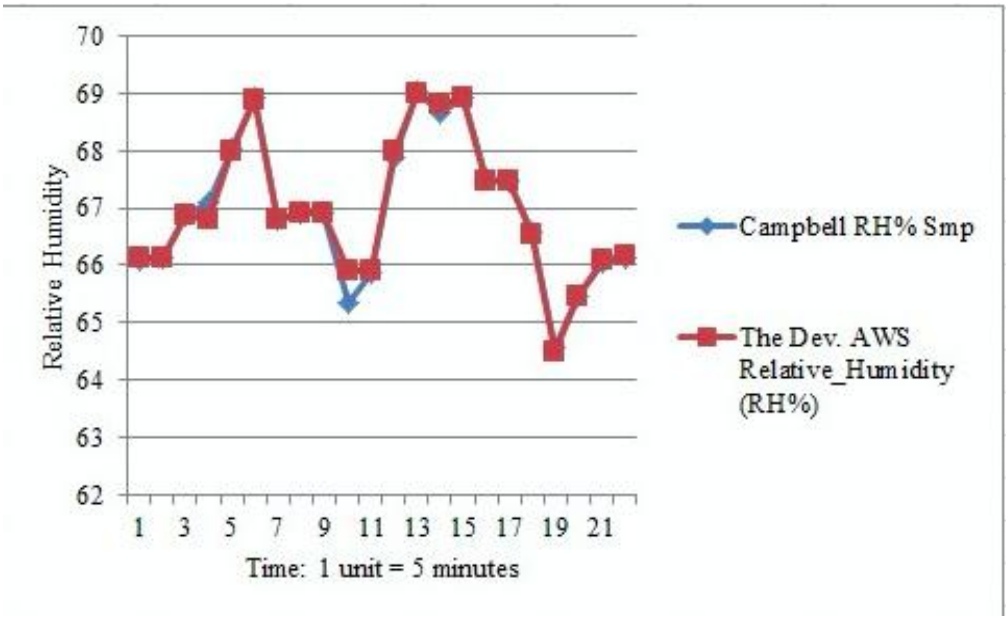
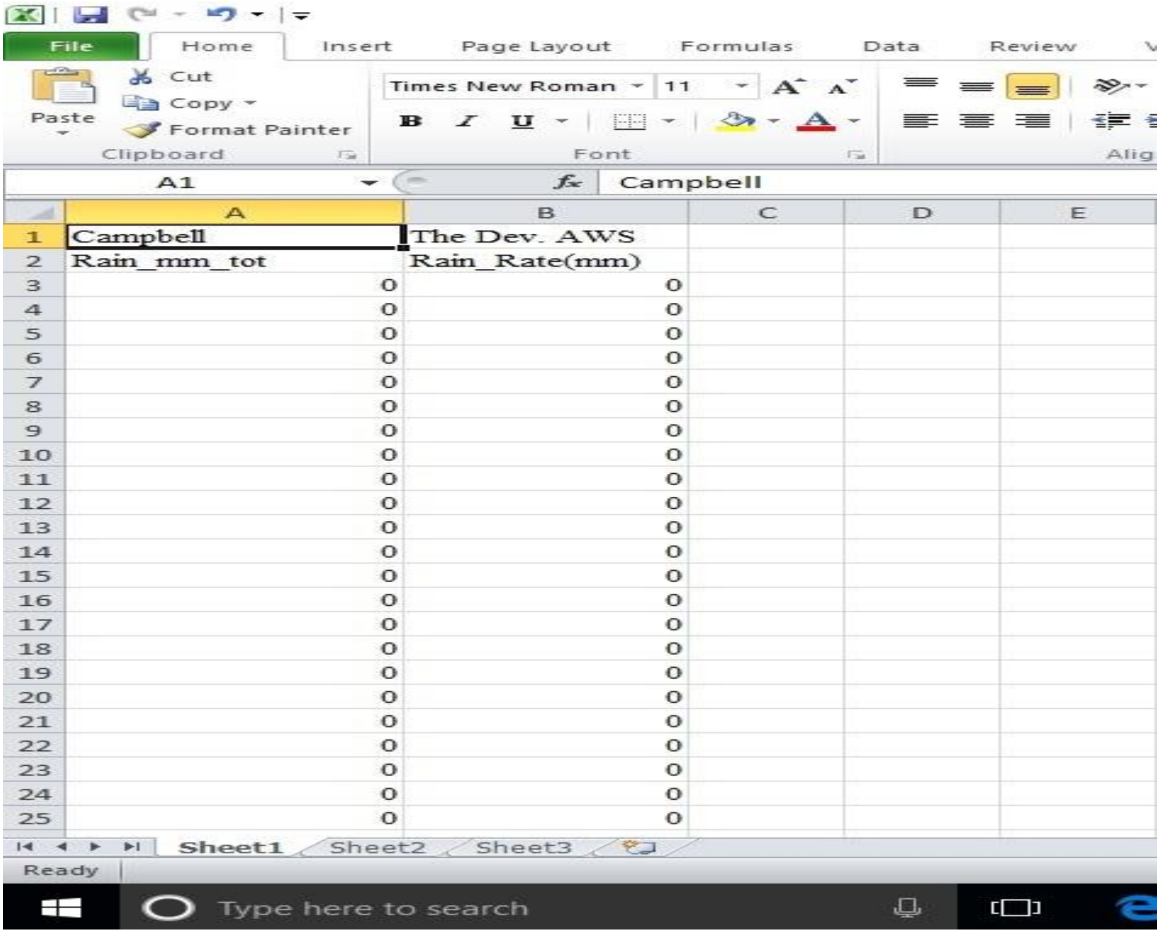


Fig 12(b): Graph of the relative humiditydata obtained from the twoweather stations.

Comparison of Rain Fall Data

Figure 13(a) shows rain fall data obtained from the two weather stations, while Fig. 13(b) shows the graph of rain fall data obtained from the two weather stations.



	A	B
1	Campbell	The Dev. AWS
2	Rain_mm_tot	Rain_Rate(mm)
3	0	0
4	0	0
5	0	0
6	0	0
7	0	0
8	0	0
9	0	0
10	0	0
11	0	0
12	0	0
13	0	0
14	0	0
15	0	0
16	0	0
17	0	0
18	0	0
19	0	0
20	0	0
21	0	0
22	0	0
23	0	0
24	0	0
25	0	0

Fig 13(a): Rain fall data obtained from the two weather stations

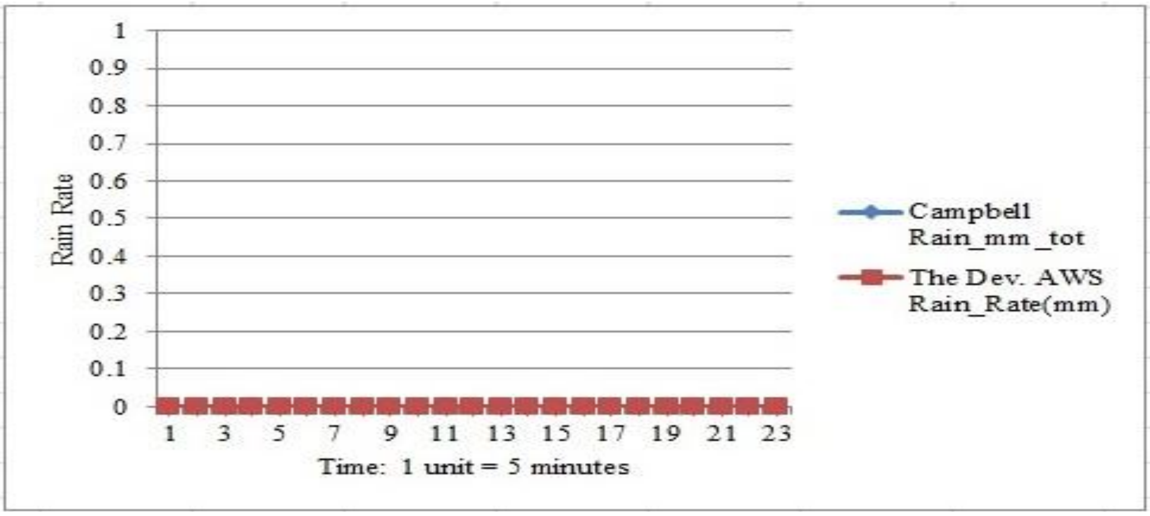
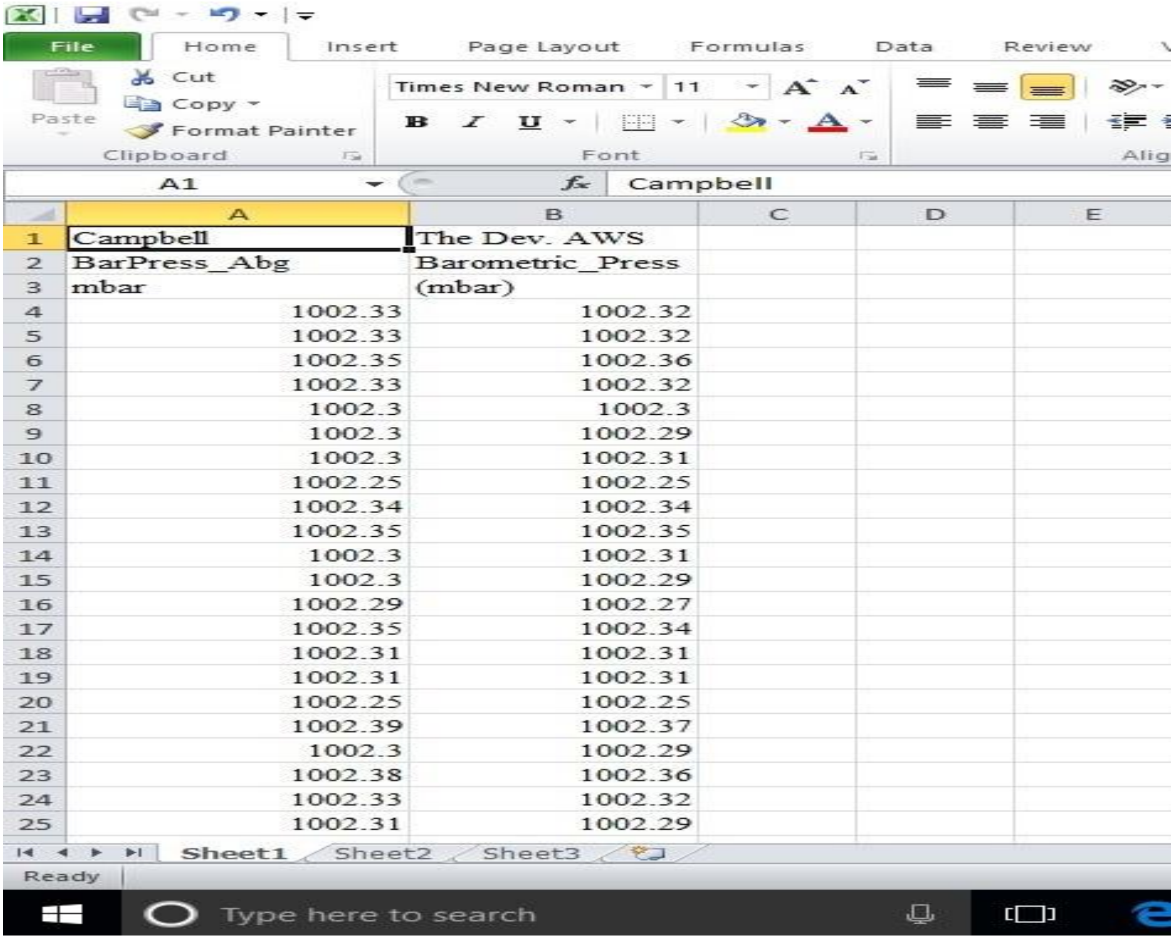


Fig 13(b): Graph of the rain fall data obtained from the two weather stations.

Comparison of Barometric Pressure Data

Figure 14(a) shows barometric pressure data obtained from the two weather stations, while Fig. 14(b) shows the graph of barometric pressure data from the two weather stations.



	A	B
1	Campbell	The Dev. AWS
2	BarPress_Abg	Barometric_Press
3	mbar	(mbar)
4	1002.33	1002.32
5	1002.33	1002.32
6	1002.35	1002.36
7	1002.33	1002.32
8	1002.3	1002.3
9	1002.3	1002.29
10	1002.3	1002.31
11	1002.25	1002.25
12	1002.34	1002.34
13	1002.35	1002.35
14	1002.3	1002.31
15	1002.3	1002.29
16	1002.29	1002.27
17	1002.35	1002.34
18	1002.31	1002.31
19	1002.31	1002.31
20	1002.25	1002.25
21	1002.39	1002.37
22	1002.3	1002.29
23	1002.38	1002.36
24	1002.33	1002.32
25	1002.31	1002.29

Fig. 14(a): Barometric pressure data obtained from the two weather stations

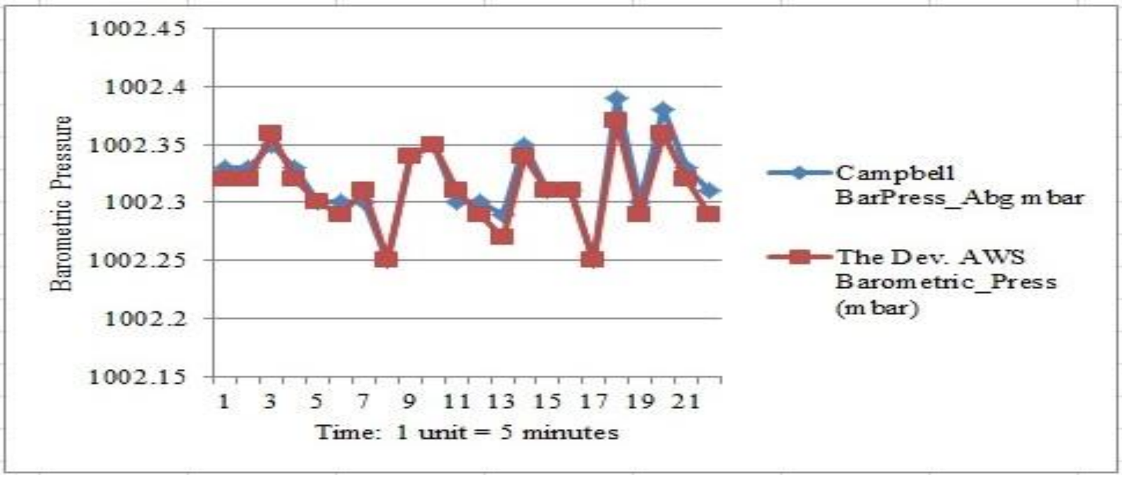


Fig 14 (b): Graph of the barometric pressure obtained from the two weather stations

Looking at the data we compared closely, you will see that the data obtained from this work's weather station are very close to that obtained from the Campbell weather station (see Fig. 11 to Fig. 14). Thus, there is a good agreement between the values obtained using the two weather stations.

VI. Conclusion

In this work, the development of a low cost server-based automatic weather station which logs data on hourly basis and with remote data download capability is presented. With the existing technology today, this weather station can be built locally and installed at remote locations to log atmospheric data at regular intervals. The accuracy of the data was compared with data obtained from Campbell weather station, and it was found that the data obtained from this system (low cost server-based automatic weather station) are in good agreement with that obtained from the Campbell weather station. The data obtained using this developed system can be used in environment and energy applications where there is need for metrological data.

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