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Device for the Remote Measurement of Meteorological Data Based on Arduino Platform

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Abstract: The aim of this paper is to present a realization of a device for displaying, monitoring, and recording non-electrical quantities relevant to the determination and examination of weather conditions. The main unit of this device is the Arduino platform, which controls digital sensors and the GSM module used for communication with user. To accomplish that, the GSM module responds to SMS with the current values of parameters that are being monitored. Also, it uses the GPS service, which allows an Internet connection and sends data back to the Web application. When the Web application receives these data, it processes them and saves them in a MySQL database. The device has the ability to record data on an SD card. A user application is created in C# programming language and allows reading of the recorded data from the SD card and handling of such data. All of results obtained by this device is compared with the results gathered by the Republic Hydrometeorogical Service of Serbia.

Keywords: Meteorological station, Arduino platform, GSM module, User application, Database, Remote measuring, Web application.

1 Introduction

Knowing meteorological data is very important in everyday life. Such databases are used in agriculture, the energy sector, tourism, construction and other aspects of everyday life. They are significant in different areas and fields of work for short- and long-term prediction and planning. Often meteorological data need to be collected from distant places and at inaccessible terrain under bad weather conditions. Development of science and technology allows production of small weather stations that could be placed in such places. Data of interest can be available to the user in real time, while he does not need to be at the place of the station

Regarding this problem, our idea is to develop a measurement device with the functions of measuring and collecting meteorological data in real time. Later, these data can be displayed and processed from the location of measurement.

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The device is built on the Arduino platform because it is an open source platform and uses programmable language that is simple to use. The GSM module is used for communication with user, so it allows using of device on different kind of terrains. This device can keep track of temperature, air humidity, atmospheric pressure, illumination, wind direction and speed, and detection of precipitation and rainfall. The user can obtain the data in three ways: by using SMS messaging, a user application, or a Web application. It can also analyse all data collected with the user application and Web application. This device will be explained in detail in the next chapter.

2 Description of Measurement System

The measurement system contains the Arduino platform, digital sensors, SD card, LCD display, GSM module, and computer with the user application and Web application.

The measurement system is shown in Fig. 1. Arduino is designed to collect sensor data, process it, and record it on the SD card. Also, if the user sends an appropriate SMS message to the device, the device will respond with complete sensor information.

The device will alert the user if any data reach a critical value. This critical value can be set by the application user.

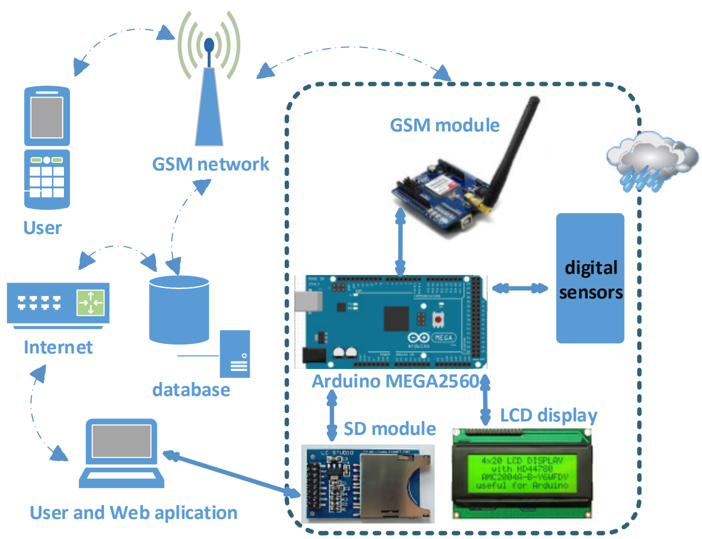


Fig. 1 – *Organization of measurement system.*

3 Measurement Device

The measurement device is shown on Fig. 2.

The most important part on this device is the Arduino platform, because it controls and communicates with all modules and sensors. This device uses Arduino MEGA2560 R3, which is based on the Atmel microcontroller Atmega2560.

Temperature and air humidity are measured with a DHT22 sensor, manufactured by Aosong Electronics. The most important details are provided by datasheet in **Table 1**.

The DHT22 sensor is factory calibrated by default and has four pins. Two of them are used for the power supply and one for the transfer of data, while the fourth is in idle state. It consists of an air humidity capacity sensor, a thermistor, and all the electronic components for communication with the microcontroller. DHT22 uses one - wire bus interface.

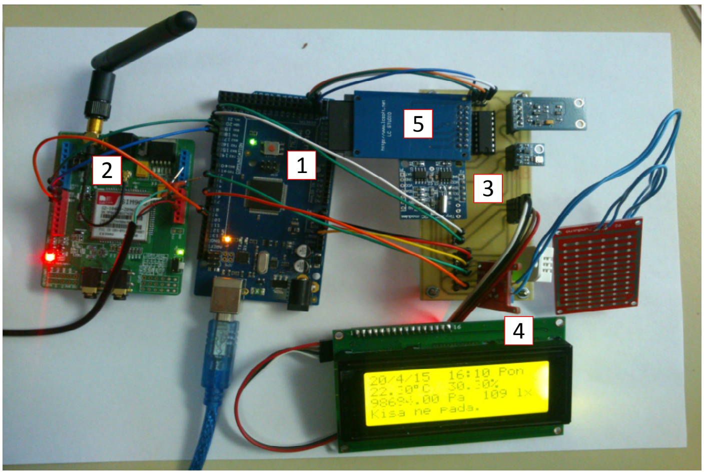


Fig. 2 – *1. Arduino Mega2560; 2. GSM module; 3. sensor board and RTC module, 4. LCD display and 5. SD card module.*

Table 1

Basic characteristic of sensor DHT22.

Power supply	3.3 – 6 V
Supply current	1 - 1.5 mA
Output signal	digital
Temperature range	-40˚C to +80˚C
Humidity range	0% – 100%
Accuracy	±2%RH ±0.5˚C
Resolution or sensitivity	±1%RH ±0.2˚C

The BMP180 is the function-compatible successor to the BMP085, a new generation of high-precision digital pressure sensors for consumer applications. The ultra-low power, low-voltage electronics of the BMP180 are optimized for use in mobile phones, PDAs, GPS navigation devices, and outdoor equipment. With a low altitude noise of merely 0.25 m at fast conversion time, the BMP180 offers superior performance. The I^2C interface allows easy system integration with a microcontroller. The BMP180 is based on piezo-resistive technology for EMC robustness, high accuracy and linearity, and long-term stability. The basic characteristics are presented in **Table 2**. It contains temperature sensor but with smaller accuracy than DHT22 sensor.

Table 2
Basic characteristic of sensor BMP180.

Power supply	1.62-3.6V
Supply current	3-32μA
Output signal	digital
Pressure range	300-1100hPa
Accuracy	-4hPa +2hPa
Resolution or sensitivity	0.01hPa

BH1750FVI sensor is being used for sunlight, which is digital sensor for I^2C bus interface. This sensor is the most suitable one to obtain the ambient light data for adjusting the LCD and keypad backlight power of a mobile phone. It is possible to detect a wide range of [1–65535lx] at high resolution. The basic characteristics are shown in **Table 3**.

Table 3
Basic characteristic of sensor BH1750FVI.

Power supply	2.4 - 3.6 V
Supply current	1 - 7 mA
Output signal	digital
Operating range	0 - 65535 lx
Accuracy	2 lx
Resolution	1 lx

Detection of precipitation uses a sensor built from an FR-04, with dimensions of 4×5 cm. It has four pins: two for the power supply, one for digital output, and one for analogue output. It uses digital output if raindrops fall on the surface of the sensor, and the digital output will be logical high (5 V). In the other case, the state of the digital output will be logical low (0V). Its sensitivity can be set by potentiometer.

Measurements are taken in real time, so a real-time clock is necessary. For this problem, a DS1307 module RTC (Real Time Clock) is used. This module contains 56 bytes of memory for saving data and can be used when the power goes down. In that case, the module will be powered by a 1.5V battery. That battery can power the module for at least 10 years. There is no need for readjustment of the device, because all configuration parameters will be saved. The clock can be set in 12-hour and 24-hour time format and can give an exact time until the year 2100. IC DS1307 sends data to Arduino in BCD (Binary Coded Decimal) format.

Communication between the user and Arduino is accomplished by a GSM SIM 900 module. This module forwards messages from the user to Arduino. If Arduino receives the correct messages, it will respond to the user with sensor data. The GSM link is realized with UART (Universal Asynchronous Receiver Transmitter) communication.

The collected data are recorded on an SD card which communicates with Arduino over SD module. The SD module work at 3.3V, but because the logical high on all Arduino pins is at 5V, it uses a voltage level shifter. Data are saved on the SD card in a txt file, which can be imported in the user application and processed in further analysis.

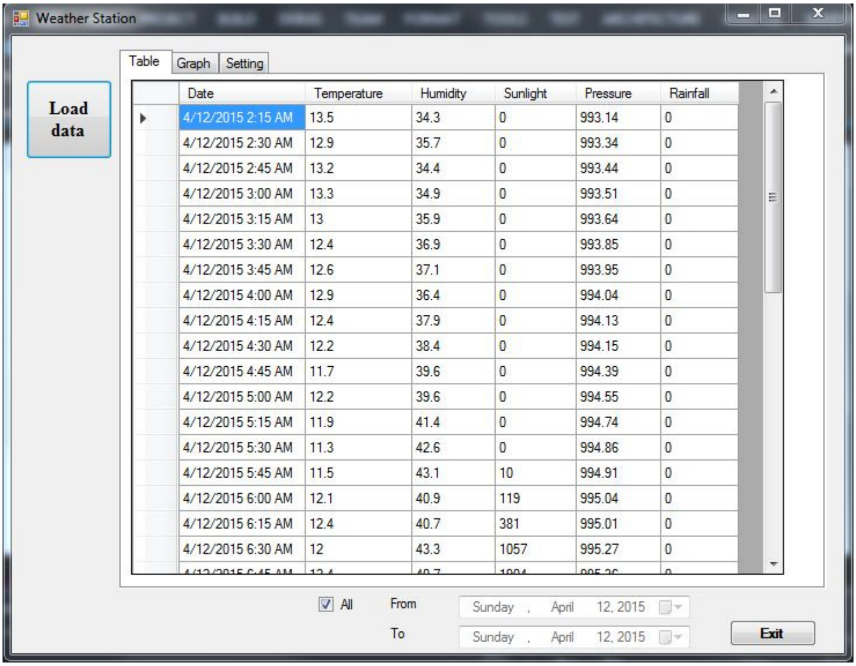
Measurement data can be displayed on an LCD display using a HD44780 microcontroller. The LCD panel has a yellow backlight and four rows per 20 characters. One character has a resolution of 5×8 pixels. Beside standard characters, the panel can display special characters that can be created by the user. Between Arduino and the LCD panel is the PCF8475T module. It has the function of cutting down the number of lines.

Every two minutes, this device sends the values of parameters measured by the mentioned sensors to the Web application. Then the Web application saves those data in a database. Using web application, users has approach to web page, where can see data from database and analyze them.

3.1 User application

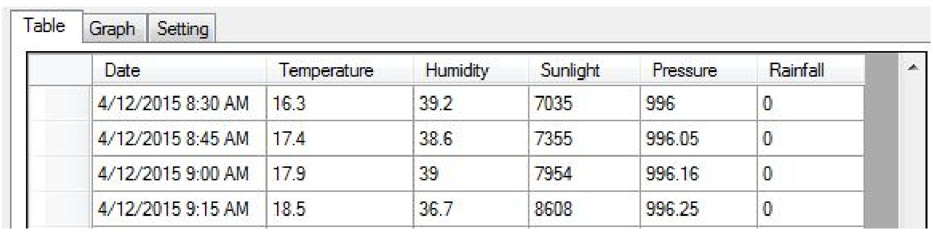
The application is created in C#, which is a .NET framework. Fig. 3 shows a startup panel with data from the SD card. On the left side is a button for importing all data from the SD card that were saved on Arduino.

The application is divided into three tabs, of which two are used to display imported data. In the first tab, named “Table”, data are separated into columns, where data can be sorted by date and time. An example of the tab “Table” is shown in Fig. 4.



Date	Temperature	Humidity	Sunlight	Pressure	Rainfall
4/12/2015 2:15 AM	13.5	34.3	0	993.14	0
4/12/2015 2:30 AM	12.9	35.7	0	993.34	0
4/12/2015 2:45 AM	13.2	34.4	0	993.44	0
4/12/2015 3:00 AM	13.3	34.9	0	993.51	0
4/12/2015 3:15 AM	13	35.9	0	993.64	0
4/12/2015 3:30 AM	12.4	36.9	0	993.85	0
4/12/2015 3:45 AM	12.6	37.1	0	993.95	0
4/12/2015 4:00 AM	12.9	36.4	0	994.04	0
4/12/2015 4:15 AM	12.4	37.9	0	994.13	0
4/12/2015 4:30 AM	12.2	38.4	0	994.15	0
4/12/2015 4:45 AM	11.7	39.6	0	994.39	0
4/12/2015 5:00 AM	12.2	39.6	0	994.55	0
4/12/2015 5:15 AM	11.9	41.4	0	994.74	0
4/12/2015 5:30 AM	11.3	42.6	0	994.86	0
4/12/2015 5:45 AM	11.5	43.1	10	994.91	0
4/12/2015 6:00 AM	12.1	40.9	119	995.04	0
4/12/2015 6:15 AM	12.4	40.7	381	995.01	0
4/12/2015 6:30 AM	12	43.3	1057	995.27	0

Fig. 3 – *Start screen of user application.*



Date	Temperature	Humidity	Sunlight	Pressure	Rainfall
4/12/2015 8:30 AM	16.3	39.2	7035	996	0
4/12/2015 8:45 AM	17.4	38.6	7355	996.05	0
4/12/2015 9:00 AM	17.9	39	7954	996.16	0
4/12/2015 9:15 AM	18.5	36.7	8608	996.25	0

Fig. 4 – *View of „Table" tab.*

The second tab is called "Graph". This tab contains graphical data from measurements. The user can check the data and select those needed for further processing. Different graphic types can be chosen from the combo box in the upper left corner. This is presented in Fig. 5. Calendar adjustment for the needed period is shown in Fig. 6.

In the third tab, parameters can be modified so that the user is alerted when they become higher or lower than set values. These set values were saved on the SD card. When Arduino starts up, it reads these values and compares them with measured ones, every time on interval saving. In this tab, the user can set the interval for saving data.

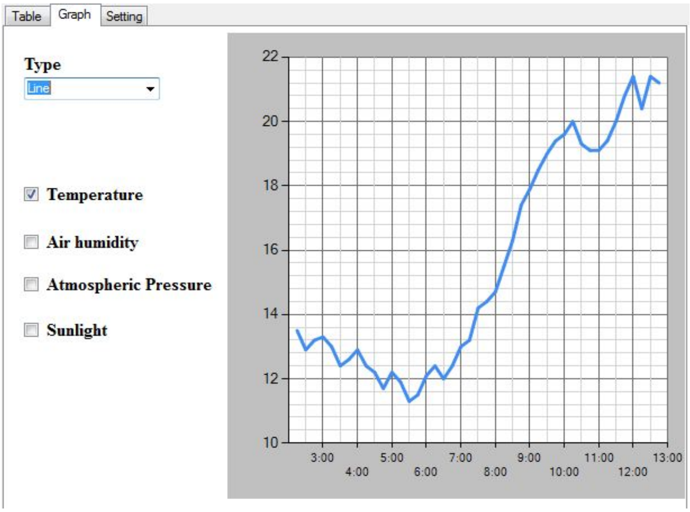


Fig. 5 – *View of „Graph" tab.*

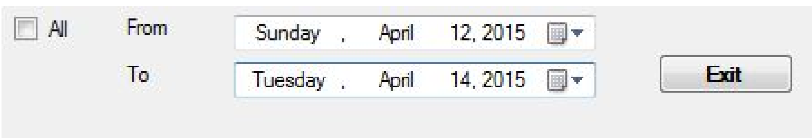


Fig. 6 – *Calendar for choose period.*

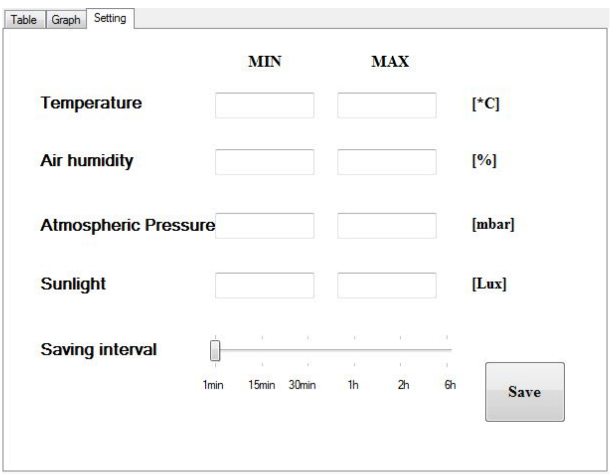


Fig. 7 – *View of „Setting" tab.*

3.2 Web application

The Web application is used to display the measurement data and later for processing them.

The application is designed to have public and restricted data. Public data can be seen by everyone on the Internet and the last measurements from one or more nodes are displayed (Fig. 8). To see the restricted data, the client must be registered on our system. There are two types of users: simple users and admin. Simple user can only see and export data, but admin user has full rights. After logging in to the application, the client is sent to the admin page (Fig. 9). The admin page has two sections: a left menu bar and content. In the left menu bar, the logged-in user can choose which data to display, depending on what is of interest, and in the content section the selected data will be displayed. An additional option is to export the selected data to a picture or pdf file.

Fig. 8 – *Displaying last measurements from one node.*

Fig. 9 – *Displaying all measurements from one node – admin page.*

The data that we present are collected from nodes (measurement stations). The node communicates with the application using an http request, which is represented by the GET method with parameters. These parameters are actually measurement data from the node and some parameters are used for basic authentication of the node. If the node is contacting the Web application for the first time, with proper parameters in the GET request, it will be registered. Every future communication will only verify and write the measurement data in the database.

The plan for the future is to integrate the following features:

- Better and secured communication between node and application;
- Build of Web API (other users can use our data for researches);
- Additional new options (newsletter, more management options on measurements data and nodes, email notifications…);
- Support for all devices and web browsers;

The Web application consists of an MVC model. The Web technologies used are as follows:

- Server side: php, MySQL [9];
- Client side: html, css, Angular JS, jQuery, Ajax;

4 Communication and Communication Protocols

The device uses four communication protocols. Via the I^2C protocol, Arduino communicates with the real-time clock, atmospheric pressure sensor, ambient light sensor, and LCD display. With temperature and humidity sensor he communicates via 1 wire link. The SPI protocol implements communication with the SD card module and communication with the GSM module is realized with serial UART communication. A diagram of all communication is shown in Fig. 10.

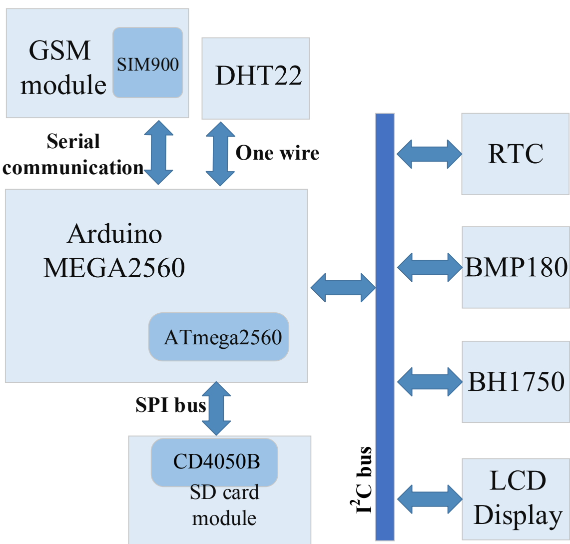


Fig. 10 – *Communication scheme of the system.*

5 Measurement Data

On 11 April 2015 during the period from 11:00 to 15:00 hours, the device measured the parameters. It was located 184.64 m above sea level near to the meteorological station of the Republic Hydrometeorological Service of Serbia (RHMZ), due to minimal variations in measurement, and compare with data from web site RHMZ [6], that is shown on Figs. 11, 12 and 13. T_o, P_o, RH_o is parameters values taken from RHMZ and T, P, RH parameters present values from measuring device in Kragujevac on 11 April 2015.

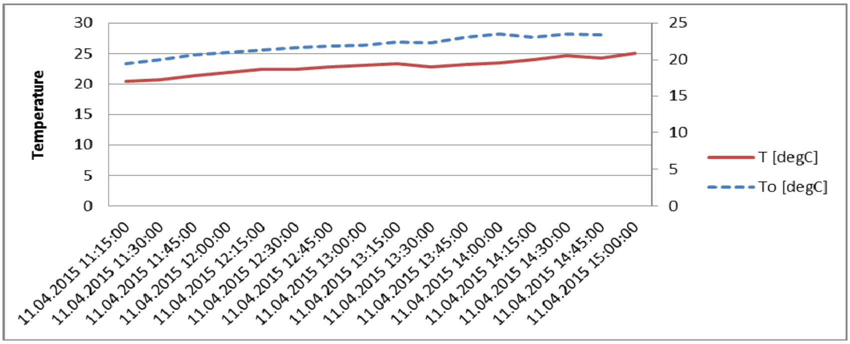


Fig. 11 – *Comparison of temperature results.*

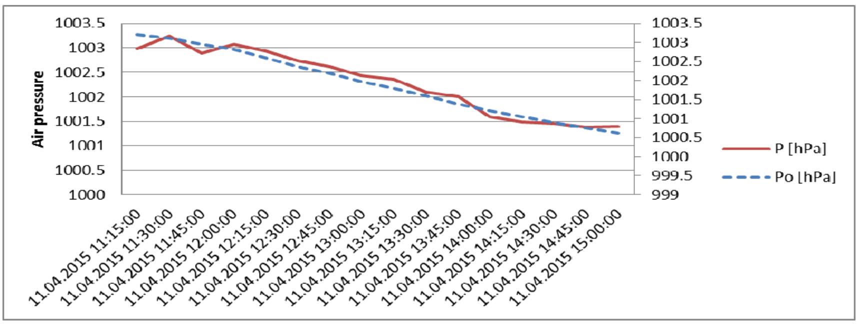


Fig. 12 – *Comparison of atmospheric pressure results.*

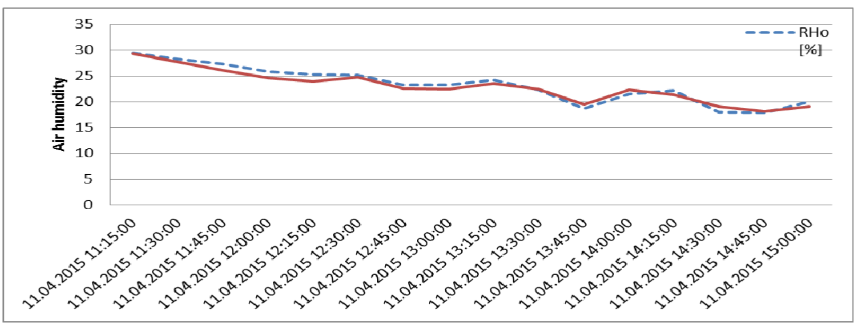


Fig. 13 – *Comparison of air humidity results.*

In Figs. 11, 12 and 13 the dashed line represents the parameters of our device and the solid line represents the parameters of the meteorological station RHMZ. A very good agreement between the results obtained can be observed. Some deviation of the results can be found in temperature measurement. Reason for that is because device did not have appropriate standard box and it is not placed 2 meters from ground, which is standard procedure [7, 8].

Table 4

The relative deviation of the measured values.

Time	Relative deviations of the measurement results		
	$\frac{T-T_0}{T_0}100$	$\frac{P-P_0}{T_0}100$	$\frac{RH-RH_0}{RH_0}100$
11:15	5.670%	-0.022%	-0.678%
11:30	6.154%	0.013%	-1.773%
11:45	7.000%	-0.006%	-4.396%
12:00	5.797%	0.027%	-4.651%
12:15	6.667%	0.034%	-5.534%
12:30	5.634%	0.038%	-1.587%
12:45	5.556%	0.044%	-2.586%
13:00	5.479%	0.047%	-3.448%
13:15	5.909%	0.056%	-2.893%
13:30	2.232%	0.050%	0.448%
13:45	4.036%	0.061%	4.278%
14:00	1.732%	0.040%	3.721%
14:15	2.128%	0.043%	-4.054%
14:30	6.926%	0.055%	6.111%
14:45	3.404%	0.063%	1.685%
15:00	6.838%	0.078%	-4.500%

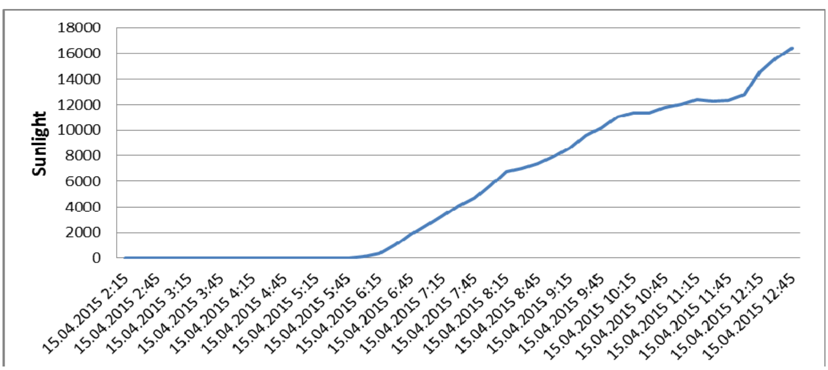


Fig. 14 – *View of Sunlight results.*

5 Conclusion

This article describes the realization of a device for displaying, monitoring, and recording several meteorological parameters based on the Arduino platform. There are similar devices based on the Arduino platform, but they can be used as either Real-time or Off-line automatic meteorological stations. This means that the user can have access to data in real time or data can be stored in the database for later use. This device has both functionalities, which is its biggest advantage.

Communication with users is accomplished through the GSM network and module, so this device can be placed on inaccessible terrain, which provides efficiency, speed, and ease of use.

The application that allows data manipulation and storage in the database is created as well. Among other things, the application allows the setting of parameters and automatic notification of the user.

The device can be improved by introducing additional sensors, for example sensors for wind speed and wind direction, which will give a wide range of usage. Provided improvements will be subject of further research.

6 References

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