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Weather observation and forecasting using radiosonde

Jeyaraj Jency Joseph[1], Rajasekaran Meenal[1], Francis Thomas Josh[1], Prawin Angel Michael[2], Vinoth Kumar Krishnamoorthy[3], Giriprasad Chandran[4], Selve Veerabathran[5]
[1]Department of Electrical and Electronics Engineering, Karunya Institute of Technology and Sciences, Coimbatore, 641 114, Tamil Nadu, India
[2]Department of Aerospace Engineering, Karunya Institute of Technology and Sciences, Coimbatore, 641 114, Tamil Nadu, India
[3]Department of Electrical and Electronics Engineering, New Horizon College of Engineering, Bengaluru, 560 103, Karnataka, India
[4]Department of Civil Engineering, New Horizon College of Engineering, Bengaluru, 560 103, Karnataka, India
[5]Department of Electrical and Electronics Engineering, Velammal Engineering College, Chennai, 600 066, Tamil Nadu, India

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ABSTRACT

Weather balloons are high-altitude meteorological balloons particularly used for carrying scientific payloads into the upper atmosphere. These data are obtained by using an instrument called as radiosonde which is attached to the helium filled weather balloon to measure the meteorological data as it ascends up into the atmosphere. For more than 100 years, weather balloons have given valuable information for climate and meteorological research. In this paper, the radiosonde module is designed with negligible risk of failure and cost effectiveness. The instruments to be fixed along with the weather balloon are logging camera, temperature sensor, pressure sensor, humidity sensor, global positioning system (GPS) module and a power source. This module is used to measure and log the basic weather parameters such as pressure, temperature, humidity and this also captures the picture of a particular locality with the help of a microcontroller. This proposed work is useful for observing high altitude weather data which is essential for predicting natural disasters. Further more, it is helpful to analyze the climatological and weather details of a particular region it also plays an important role in estimating agricultural models.

Corresponding Author:

Vinoth Kumar Krishnamoorthy
Department of Electrical and Electronics Engineering, New Horizon College of Engineering
Bengaluru, 560 103, Karnataka, India
Email: kvinoth_kumar84@yahoo.in

1. INTRODUCTION

For a country like India with a tropical climate system with quite strong seasonal variation, climate forecasting is important for future planning and adaptation to climate change. Various publications anticipate the need for climate forecasting, as current weather and climate play an important role in the daily functioning of society [1], [2]. According to business today report, India recorded around 32 extreme weather events in the recent years [3]. Heavy rainfall, drought, wildfire, landslides, extreme temperatures, flood, fog and storm are some of the extreme events which results in high mortality. Computer based weather prediction models are used for predicting the weather parameters and the extreme events [4]-[6]. Weather balloons are the main source of the upper air data above the ground surface. They can carry loads up to 40,000 m at 130,000 feet. About 800 weather balloons are released around the world every day [7]. This gives a "snapshot" of the upper atmosphere of the earth two times a day. A radiosonde is an instrument attached to the weather balloon to measure weather data like pressure, temperature and relative humidity as it ascends up into the atmosphere [8], [9]. The valuable data provided by the weather balloons are used by the computer forecast models to predict the climate pattern [10]-[12]. These data are very essential for meteorologists to make accurate forecasts and to predict extreme events like storms, heavy rainfall, cold wave and hot wave.

Weather balloon data are the upper air data from the atmosphere, starting at three meters above the earth's ground surface. These upper air data received from radiosondes are transmitted back to a receiver unit on the ground. Radiosonde instruments are used to measure meteorological variables like atmospheric pressure, temperature, humidity, wind speed and direction, and geopotential height. Various literatures foretell that the climate trends can be estimated accurately with the upper-air data set [13]. Radiosondes have been used as the basic method for collecting the upper air data from the ground to altitudes in surplus of 35 km, which includes both the troposphere and a major section of the stratosphere. The basic climate variables measured by radiosonde are affected by external sources. Especially the temperature measured by the radiosonde is affected by heataing effect other than air. So a correction is necessary on each radiosonde instrument. The most widely used radiosondes have been evaluated relating to climate studies. Based on the analysis of this current paper, it is observed that all of the radiosonde instruments have small errors and can be prepared appropriate for climate studies and analysis if the suitable temperature correction models are used to correct the data [14]-[16]. Thus the data obtained by radiosondes is not only a chief input to numerical weather prediction, but also used for the model validation, research investigations on climate studies. A small error in radiosonde observations can lead to higher forecast errors [17]. The uncertainties on the initial conditions in climate modeling are taken care of by using ensemble simulations [18].

2. RADIOSONDE IN WEATHER FORECASTING

Many researchers used radiosonde data for evaluating their forecasing models [19]-[22]. A radiosonde invented in 1920 to measure the basic meteorological variables in the troposphere and stratosphere [23]. In the olden days such observations were costlier and quite intermittent. Recently, these upper air data from radiosonde serve as a valuable input source for various weather forecasting models. Aeolus winds were assessed using operationally collated radio wave data from the global observation system (GOS) [24]. Integrated Global Radiosonde Archive (IGRA), a National Climate Data Center (NCDC) radio wave dataset, containing measurements from radiosonde instruments and balloons at 2700 stations worldwide [25]. Radiosonde observations are used as main source of input data for weather forecasting models, predition of extreme events like local severe storm and fire weather forecasting, temperature forecasting, investigations on air pollution, research investigations on weather and climate change, aviation, marine forecasts and defense applications and so on.

2.1. Artificial intelligence and machine learning based forecasting with radiosonde

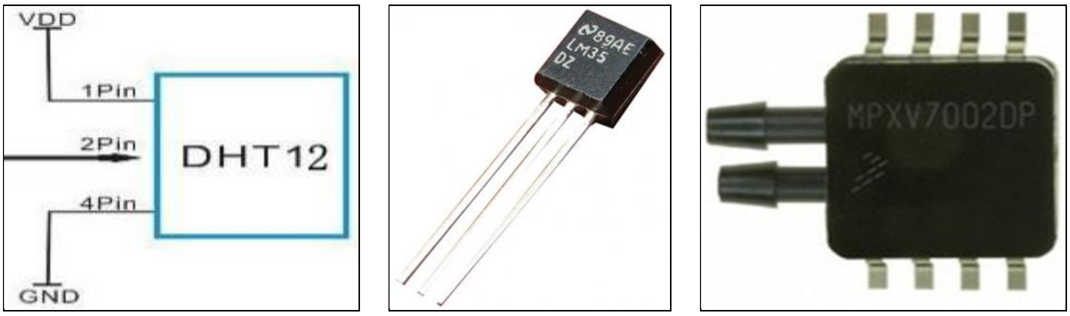
The extreme events like drought, flood, fog and storm results in high mortality. Also many states in India have recorded the highest deaths during last floods in the recent years. The conventional complex numerical weather prediction models create a great challenge for our Indian scientists in climate studies such as weather forecasting and extreme event prediction for tropical system [26]. As a result, there is a need for emerging techniques such as artificial intelligence, machine learning, and deep learning methods in weather forecasting and climate research. Artificial intelligence based cumulonimbus prediction result proved that the neural network gives better accuracy after principal component analysis for early warning system with radiosonde indeces [27], [28]. Machine learning algorithms are commonly used in image and speech recognition, medical diagnosis, stock market trading and various prediction and classification applications [29]-[33]. Recently machine learning techniques are used in weather forecasting especially in extreme event prediction using these upper air data [34]. Numerical weather prediction models cannot consistently estimate the extreme events such as the deadly heat waves. It is dificult to understand the physics behind the weather pattern which causes the extreme events. Deep learning techniques like accumulative neural networks and long-term memory are commonly used in many applications such as load forecasting, radiation and wind velocity forecasting, image processing, and more. [35]. Deep learning neural network generates realistic 14-day weather forecasts independent of atmospheric physical data [36].

3. RESEARCH METHOD

In this proposed paper, a cost effective radiosonde module is designed. The helium test balloon containing the parachute and the payload which experiences a strong lift reaching a height of approximately 90,000-110,000 feet in the atmosphere. During this flight, the sensors observe the various parameters like the temperature, pressure, humidity and capture the photograph of a particular locality and records the data obtained into a memory storage device with the help of an Arduino microcontroller and Raspberry Pi. As the altitude increases, the pressure outside the balloon (atmospheric pressure) decreases and so this caused the balloon to explode also the payload along with the parachute descends down rapidly. After a particular altitude, the parachute opens and this helps in the safe landing of the payload. A global positioning system

(GPS) unit along with a global system for mobile (GSM) module helped to detect the co-ordinates of the landing location of the payload. Later, the payload is detected and the memory storage element is retrieved and the recorded data is obtained. In addition, a lithium ion battery is used as a power source.

The radiosonde module is used to measure and record the metrological data like the pressure, temperature, humidity, altitude and capture a picture of a particular locality. In this study, LM35 temperature sensor is used to measure the temperature. The LM35 series is a precision integrated circuit temperature sensor. The output voltage of this sensor is linearly proportional to the temperature in degrees Celsius (degrees Celsius). The LM35 is designed to operate in the range of −55° to +150 °C. Monolithic silicon pressure sensors MPXV7002 and digital humidity and temperature (DHT11) humidity sensors are used to measure the pressure and humidity. The MPXV7002 is designed for many applications, but mainly those that use microcontrollers or microprocessors with analog-to-digital (A/D) inputs. Figure 1(a), Figure 1(b) and Figure 1(c) shows the various sensors and the block diagram of the entire module is shown in Figure 2. In general these high altitude weather data is very essential for predicting natural disasters and climate based research studies. Thus this work plays a major role in determining the agricultural pattern also. Moreover by knowing the wind speed and its flow of direction, the implementation of renewable energy resources like the wind mills can be successfully done at the right areas. The complete design details of the test balloon are summarized in the Figure 3. The design details include the size, weight, radius, height and number of balloons. Also it includes the floating time, duration and the location. Figure 4 shows the path of the test balloon. The overall hardware implementation of this module is shown in Figure 5. Figure 6 shows the flowchart for the whole process for data collection and forecasting.



(a) (b) (c)

Figure 1. Sensors used in the radiosonde for (a) DHT11 humidity sensor, (b) temperature sensor LM35D, and (c) pressure sensor MPXV7002

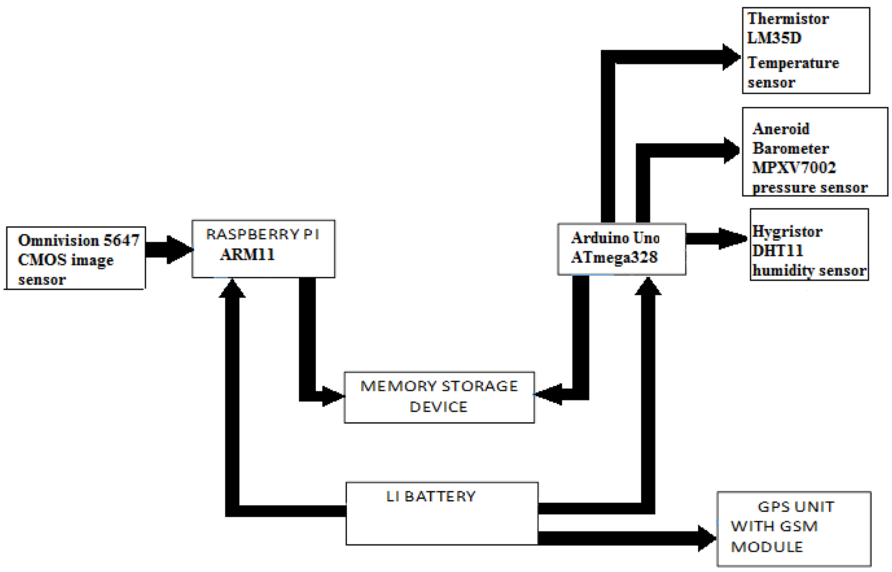


Figure 2. Functional block diagram

- Location : Karunya University
- Coordinates of the location : 10°56'14.8N 76°44'34.0E
- Date of flying : 3 March 2016
- Time : 7am
- Colour : White
- Size :1.64m in diameter
- Weight : 1200gm balloon, 140-160gm parachute, 500 gm equipment
- Radius : 0.8m
- Height : 115,000ft
- Number of balloon : 1
- Floating time : 30 minutes
- Floating area : 70km radius

Figure 3. Design details of the test balloon and launch

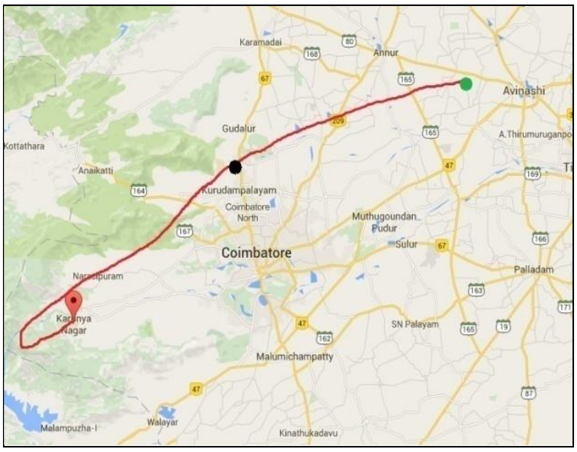


Figure 4. Path of the test balloon

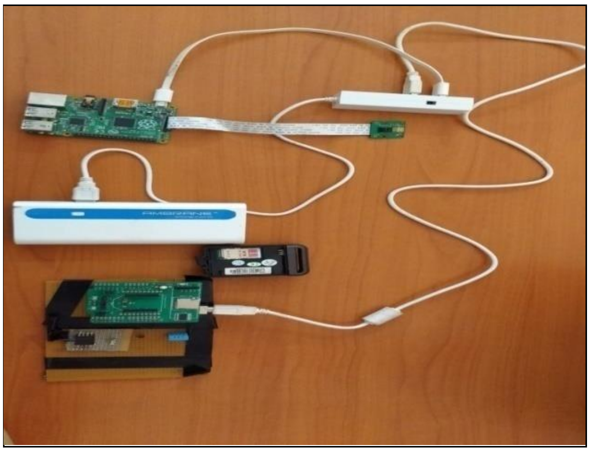


Figure 5. Hardware implementation

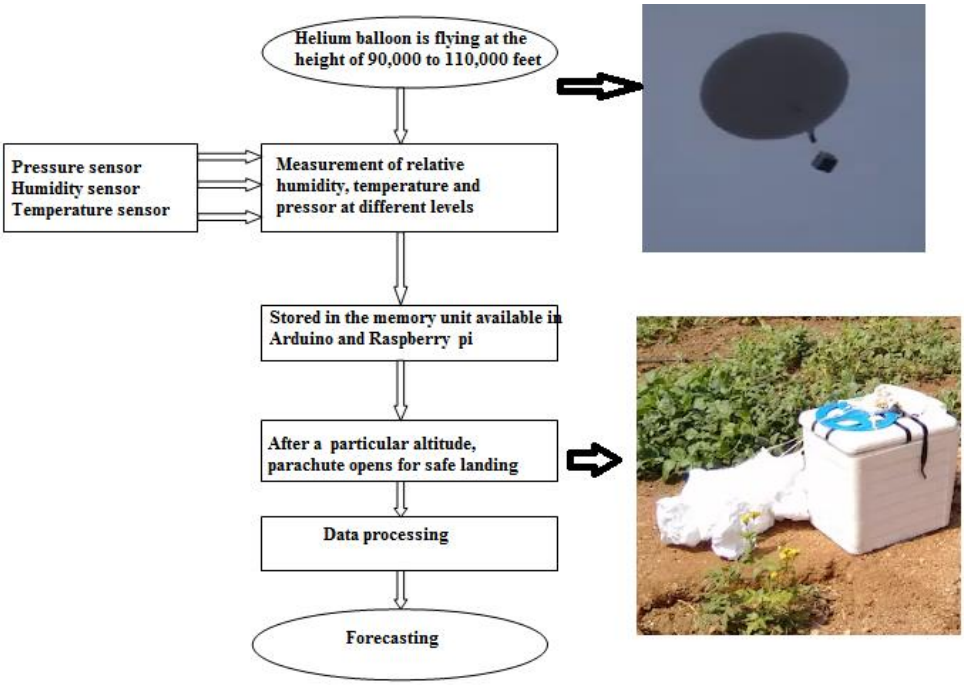


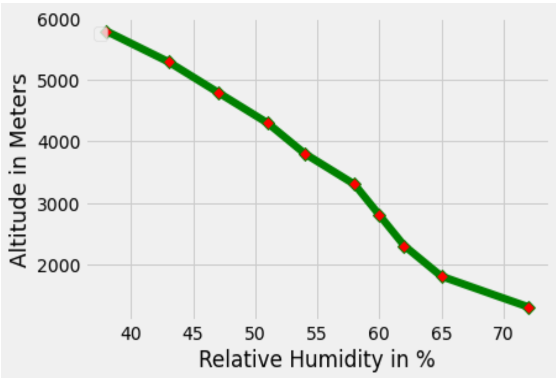
Figure.6. Flowchart for the process of test weather balloon

4. RESULTS AND DISCUSSION

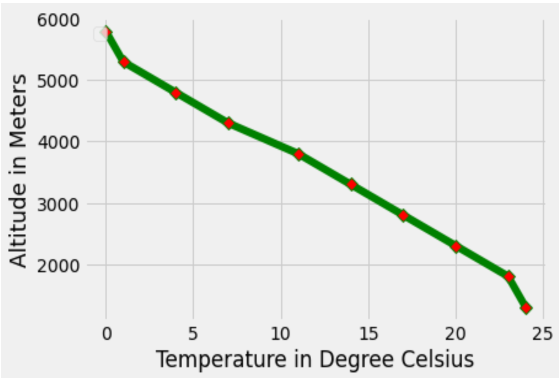
A helium weather balloon equipped with radiosonde is used to measure the basic atmospheric variables like temperature, pressure and humidity with the sensors LM35D, MPXV7002 and DHT11 respectively. This balloon is tested to provide the weather information. A transmitter available in the radiosonde sends the data back to the receiver equipment on the ground. The meteorological data namely the percentage relative humidity and temperature in degree celcius at various altitudes in meters are tabulated in Table 1. During this flight, the photograph of the particular locality is captured with the help of a camera attached in the module and record the data obtained into a memory storage device with the help of an Arduino microcontroller and Raspberry Pi. Figure 7 shows the graph of altitude versus temperature, humidity and pressure. From the Figure 7(a), Figure 7(b), and Figure 7(c) it is observed that as the altitude increases, magnitude of the weather parameter is decreased. By using these radiosonde based weather observation, accurate weather forecasting can be done. Also these data can be used as the main source of input data for climate studies and for predicting the agriculture pattern.

Table 1. Temperature and percentage relative humidity obtained using radiosonde

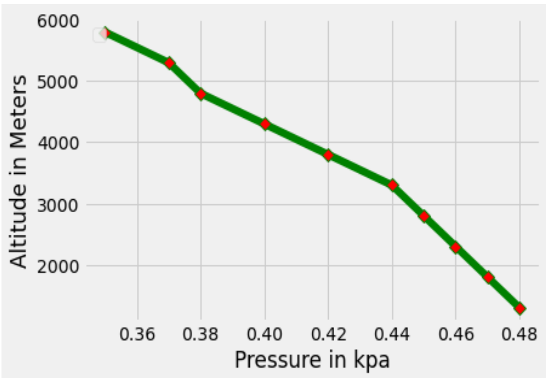
Sl. No	Altitude (meters)	% Relative humidity	Temperature (degree Celsius)
1	1300	72	24
2	1800	65	23
3	2300	62	20
4	2800	60	17
5	3300	58	14
6	3800	54	11
7	4300	51	7
8	4800	47	4
9	5300	43	1
10	5800	38	0



(a)



(b)



(c)

Figure 7. Graph shows: (a) altitude vs relative humidity, (b) altitude vs temperature, and (c) altitude vs pressure

5. CONCLUSION

In the current scenario, awareness on climatology and weather predictions play an important role in the day to day running of society and for future planning. Also to reduce the mortality rate, extreme event predictions models are necessary to implement early health warning system. Radiosonde observations like temperature, pressure and humidity are the primary source of input data for various computer based weather prediction models. In this proposed work, a cost effective radiosonde is designed to measure the basic atmospheric variables. Weather parameters like pressure, temperature, humidity at various altitudes above the ground surface are measured with the help of necessary sensors interfaced with Arduino microcontroller and a picture of a particular locality is captured with the help of a camera interfaced with Raspberry Pi. Hence these presented results will be useful for observing high altitude weather data. Also the radiosonde observations are used to understand and analyze the climatological and weather details of a particular region thereby it plays a most important role in determining the agricultural pattern.

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BIOGRAPHIES OF AUTHORS

Jeyaraj Jency Joseph working as an Assistant Professor in Department of Electrical and Electronics Engineering at Karunya Institute of Technology and Sciences, Coimbatore. She received her Ph.D Degree in Electrical & Electronics Engineering from Anna University, Chennai. She is having 12 years of teaching as well as research experience and her research area includes soft computing techniques in power electronics applications and renewable energy. She can be contacted at email: jenjeffy@gmail.com.

Rajasekaran Meenal working as an Assistant Professor in Department of Electrical and Electronics Engineering at Karunya Institute of Technology and Sciences, Coimbatore. She received her Ph.D Degree in Electrical and Electronics Engineering from Karunya Institute of Technology and Sciences, Coimbatore. She can be contacted at email: meenasekar5@gmail.com.

Francis Thomas Josh working as an Assistant Professor in Department of Electrical and Electronics Engineering at Karunya Institute of Technology and Sciences, Coimbatore. He received his Ph.D Degree in Electrical & Electronics Engineering from Anna University, Chennai.He is having 18 years of teaching as well as research experience and her research area includes soft computing techniques in power electronics applications. He can be contacted at email: frandajosh@gmail.com.

Prawin Angel Michael working as an Associate Professor in Department Aerospace Engineering at Karunya Institute of Technology and Sciences, Coimbatore. She received her Ph.D Degree in Electrical and Electronics Engineering from Anna University, Coimbatore and research area includes hydel energy, nano materials, and solar and wind energy forecasting models. She can be contacted at email: legnaprawin@gmail.com.

Vinoth Kumar Krishnamoorthy working as an Associate Professor in Department of Electrical and Electronics Engineering at New Horizon College of Engineering, Bengaluru. He received his Ph.D Degree from Karunya Institute of Technology and Sciences University, Coimbatore in 2017. He is having 14 years of teaching as well as research experience and his research area includes neuro-fuzzy computing and renewable energy. He can be contacted at email: kvinoth_kumar84@yahoo.in.

Giriprasad Chandran working as an Associate Professor in Department of Civil Engineering at New Horizon College of Engineering, Bengaluru. He received his Ph.D Degree from Sri Satya Sai University of Technology and Medical Sciences, Sehore. He is having 13 years of teaching as well as research experience and her research area includes soil stabilization, GIS and remote sensing application for mapping, application of geosynthetics, natural waste investigation-application in soil. He can be contacted at email: profgiriprasad2015@gmail.com.

Selve Veerabathran working as an Assistant Professor in Department of Electrical and Electronics Engineering at Velammal Engineering College, Chennai. She is having 20 years of teaching as well as research experience and her research area includes restructured power systems, artificial intelligence techniques and its applications in power systems. She can be contacted at email: selveveerabathran@gmail.com.