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Web Based Weather Visualization and Forecasting System For Pakistan

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Abstract

The visualization and forecasting system for northern areas of Pakistan has been developed to help users to visualize historical temporal weather data in their respective region. This system is designed with the goal to supplement the productivity of already available website of Pakistan meteorological department. The system is flexible enough to visualize current data. It also presents multiple weather scenarios to visualize weather data. The weather data which is visualized is available from 1980 to 2010 from different weather stations of Pakistan, maintained by the Pakistan Meteorological Department. Two types of weather forecasting has been implemented. Short term weather forecasting has been done to predict the daily forecast and Long term forecasting uses linear regression for predicting the weather trends from year 2011 to 2026 based on real-time data. The system is designed in such a way that it can present data in user friendly and comprehensible graphical formats and plots. The results for long term forecasting show that in next ten years rain fall will decrease effectively in the northern areas of Pakistan, whereas, an increase in the humidity has been observed after carefully reading the forecasted plots.

1. INTRODUCTION

Over the period of time numerous weather data analysis and forecasting systems have been designed and developed. Studying the change in climate is now deliberated as the major concern of many government agencies. For this purpose, many organizations are using data visualization tools to plot the evolution of inconsistent weather conditions and other environmental sensations. A technique for making pictures, outlines, or movements to impart a message is visualization. Representation through visual symbolism has been a viable approach to convey both conceptual and solid thoughts since the beginning of mankind. The term data visualization portrays any push to individuals to figure out the importance of information by describing it in a visual setting. Trends, patterns and relationships that may go unnoticed in content based information, can be shown and perceived simpler. Now a days information perception devices go past the standard diagrams. Mostly diagrams utilized as a part of Excel spreadsheets, info graphics, dials and gages, geographic maps, Spark line, warmth maps, and definite bar and pie graphs. The pictures may include intelligent aptitudes, empowering clients to direct them or drill into the information for questioning and investigation. Visualization is used in many fields including air traffic concept analysis and weather data visualizations [1] [2] [3] [4].

Most of early forecasting relied upon view of climate patterns. Logically based weather forecasting was impractical until meteorologists could gather information about current climate conditions from a generally broad arrangement of watching stations and sort out that information in an opportune manner. By the 1930s, these conditions had been met. Weather forecasting is the endeavour by meteorologists to foresee the condition of the environment at some future time and the climate conditions that may be normal. It is clear that predicting the future of the climate can be essential for people and many organizations. Exact climate conjectures can advise an agriculturist the best time to plant, an airplane

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terminal control tower what data to send to planes that are landing and taking off, and inhabitants of a beach front district when a storm may strike.

There are many tools for weather data visualization. Some of the tools are standalone and some of them are web based applications. ArcGIS and MATLAB are the softwares which provide modelling capabilities for environmental and scientific data. However, due to their high price, it is not practical for an average user to use them. A web based visualization system is proposed for the end-users to view and interpret time-varying Geographical Information Systems (GIS) data [5]. To test the technique, a Spatial Information Visualizer varying with time, based on GIS is produced [5]. The goal is to give the non-specialized client, who is not a specialist in utilizing advanced GIS programming, the capacity to opinion, translate and comprehend time-fluctuating, perplexing, spatial information utilizing an electronic strategy. A research study has addressed the challenge of inconsistent encoding of weather visualizations and the relationship of weather features [6]. Most of the visualization systems provide generic forecasts regardless of the user type. However, [7] proposed a self-configurable, user specific climate research and anticipating framework that uses Grid computing to provide scalable weather data forecasting and analysis system.

Researchers created a practicability report on fog-related crashes and concluded that weather is one of the main causes of aviation accidents [8]. According to this research paper [8] weather data of airport can be effectively used in real-time judgment of crashes which are caused by fog [8]. A large number of accidents and crashes occur due to the presence of fog. For the solution to this problem there are visibility detection systems that help to prevent the danger of limited visibility, but such systems are not wide-spread and at some place they are not at all used. The aim of this study [8] is to use information of weather at the airport in real-time risk assessment of road crash in locations where there are recurrent fog problems. Many researchers are addressing this drawback from numerous views together with designing meteorological forecasting techniques, aggregating extra weather knowledge mechanically via on-board sensors and flight modems, and rising weather knowledge dissemination and visualization techniques [7].

RoadVis is a web based application for communicating road weather visualizations particularly during Swedish winters [9]. The tool calculates the present and the forecasted scenarios for next 24 hours and generates alerts for the user of the risks on the roads using visualization components. The web-based visualization on the weather data can be done using large climate data sets [2]. The large data sets may help in providing clear information to perform tasks such as weather forecasting. This research mentioned that Terabytes of climate data are extracted to compact binary format summary files that are used in the application. Also to generate quick responses under a lot of load, map caching techniques are developed that quickly generate the maps, handling a large number of concurrent users.

Another study demonstrates the application of visualization of the climatic changes to generate the hypothesis related to the weather [10]. Using the large amount of data a solid hypothesis can be generated. Two datasets, namely as ECHAM5 climate model run and the ERA-40 reanalysis having the observational data, are investigated. The interactive visual exploration is used to identify the regions which are sensitive to climate change. The research work in [4] presents a web based application which includes single point observation data which is processed on the application server of the web. This research is focused on the storm tide disaster forecasting. It leads to the development of the information system of the ocean that will be used to prevent the ocean disasters.
The visualization technique is also used in wind analysis which is helpful for aviation applications [11]. Using five years old wind data, the designs for new instruments can be created keeping in mind the visualization of the wind data. It also benefits in selecting the environmental conditions for simulations.

For weather forecasting over the short time period on the basis of four parameters humidity, wind, temperature and atmospheric pressure an algorithmic realization is presented [12]. In this model base-level predictions are made through simple and individual regression function that used the historical dataset. Regression method was feasible only for the single station predictions and covariance is used for multiple stations. A Deep Belief Network (DBN) model is used for joint distribution of weather variables and Gaussian Process (GP) is used for probabilistic issues [12].

It is worth mentioning that interactive visualization techniques help in the analysis process for the experts. An interactive web-based application was developed using weather data for the analysis of road weather conditions [13]. This application help in identification of significant trends and patterns in weather data. This kind of tool may help in verifying the forecasted parameters with the actual observed parameters. A deep hybrid model for forecasting is proposed in [14]. It combines trained predictive model with a neural network. This deep neural network models the joint statistical relationships of a set of parameters. The selected parameters for this application are air pressure, dew point, temperature, and wind. Visualization for the parameters having single value does not have any uncertainty [3]. There are parameters which are represented by two values, like wind where both speed and direction are important. Visualizing this type of parameters contain uncertainties. There are different ways to visualize the uncertainty of wind forecast. This paper studies augmented reality visualization and map-based visualization approaches. It concludes that for augmented reality visualization, the user has to be in the forecasted area, whereas for map-based it is regardless of the location [3]. Wind forecasting is important because wind power is considered as renewable energy source these years. A comparative study presents the details of available forecasting techniques for wind [15].

In this paper, we will focus on visualization and forecasting of weather data in northern areas of Pakistan based on the data provided by Pakistan Meteorological Department. The system covers four weather parameters, wind speed, temperature, humidity and rainfall. The scenario based visualizations will be shown. The visualizations are provided using different figures, animations and graphs. This will help the user visualize the data recorded at the various weather stations of Pakistan Meteorological Department. Besides, short term and long term forecasting is also an integral part of our work.

The composition of the paper is as follows: Section 2 describes the methodology adopted for the system. Section 3 presents details about visualization and forecasting. Section 4 discusses the implemented system and presents forecasting plots. Section 5 concludes the paper.

2. METHODOLOGY

The proposed system is a web-based application. The ASP.NET platform is used to develop the system. SQL server is used to store and retrieve the past weather data. The programming is done in C-sharp. Visualizations are shown using images, animations, graphs etc. Data is retrieved from the database on the basis of user selection and the visualization is generated according to that data. The user will also be able to view the details. If the data is not present for a situation then the user will be shown that the record is not found.

2.1. Weather Observations

This section describes the data provided by Pakistan Meteorological department. The parameters for which observations have been provided are temperature, wind speed, rainfall and humidity. Met office Pakistan observes these parameters on different times on a daily basis.

Figure 1 presents the activity diagram of the web based system we have developed for weather visualization. The process starts with the user having choice of selecting single station or multiple stations. Next step involves selection of single date or a range of dates. Now the parameter selection for which the user wants to see the visuals, such as temperature, wind, rainfall or humidity. He will be shown the visualization based on the input he has given. For storing the past data SQL server has been used. We have performed arithmetic operations on the data for use in specific situations like calculating the average temperature. Visualizations are shown using images, animations, graphs etc. Data will be retrieved from the database and the visualization will be generated according to that data. The user will also be able to view the details. If the data is not present for a situation then the user will be shown that the record is not found. Figure 1 presents the activity diagram of the system. Graphs will be generated for long term forecasting. In this system Google Map API is used to show the location of the weather station(s).

2.2 System Architecture

This section describes the architecture of the system. The infrastructure of the whole application is defined that how the application will move ahead and will reach its goal i.e. the resulting scenario. Architecture of the system for weather visualization will be three layered. Dividing the system into three layers is more beneficial and attractive. It will be easier to design, use and modify data in the system with the mentioned architecture.

The three layers of the system are as follows:

2.2.1 Presentation Layer:

This is the top layer; functions like taking input from user or from any database are performed here. It will send the data to the next layer for more operations. Basic purpose of this layer is to make the interaction successful between user and system.

2.2.2 Business Logic Layer:

This is the middle layer, it accepts data from the top layer and applies basic operation on data and calculate the results of processing operations. It also move data among both (top and bottom) layers.

2.2.3 Data Access Layer:

Processed information is stored to the database. Data is stored or accessed to or from data base and processed information is kept to the database for user to get results.

3. VISUALIZATION AND FORECASTING

We have different weather parametric data. The available data covers four main domains related to weather: Humidity, Temperature, Wind Speed and Rainfall. Then further we will forecast the future trends of weather on the basis of past meteorological data.

Data can be viewed against four different kinds of scenarios. The scenarios are as follows:

1. Single place single point in time weather visualization
2. Multiple places single points in time weather visualization
3. Single place multi points in time weather visualization
4. Multi places multi points in time weather visualization

3.1 Weather Data Forecasting

3.1.1 Short Term Forecasting:

We have used Weather API for performing short term forecasting. It provides the daily weather forecast for any entered region, depicting the maximum and minimum temperature of day and night.

The 2 or 3 days for the sites within the areas of a number of purpose of short-range prediction today is to supply numerous users with data on the anticipated weather over forthcoming million sq. kilometers to take necessary precautions beforehand and thus to cut back the harm of adverse weather.

3.1.2 Long Term Forecasting:

For long term forecasting we have used linear regression. Linear regression is a mathematical technique that is used for finding the straight line that best-fits the values of a function that is linear. It is plotted on scatter graph as different data points. When 'best fit' line of the relation is found, it is used as the basis for estimating the future values of the function. We do so by extending it without disturbing its slope. It always uses two variables to observe the data. One variable is considered to be independent variable and the other is dependent variable. Independent variable is also known as explanatory variable and effects the values of dependent variable. To use the linear regression it is necessary to first see the relationship between different parameters.

In long term forecasting we have predicted the weather trend of next 10 years on the basis of previous 30 years data. For weather trends we have used the 24 values for each year minimum value for each parameter in every month and maximum value for each parameter in every month. Our parameters are the same as discussed before, i.e. humidity, wind, rainfall and temperature. Each parameter has three values within 24 hours at 12pm at 03pm and at 12am. For regression we need to have an independent and a dependent variable and these parameters will have some relationship.
Relationship among different parameters which is used in forecasting is as follows: Humidity depends on rainfall. Temperature depends on average humidity. Rainfall depends on average temperature. Wind speed depends on average temperature. To use linear regression equation, first step is to determine if there is a relationship between the two variables. The equation has the form as follows:

$$Y = aX + b$$

X represents the independent variable and Y is the dependent variable. If X is plotted on X-axis and Y is plotted on Y-axis then b is slope of the line and a is the y-intercept. To calculate a and b following equations are used:

$$a = \frac{(\sum Y)(\sum X^2) - (\sum X)(\sum XY)}{n(\sum X^2) - (\sum X)^2}$$

$$b = \frac{n(\sum XY) - (\sum X)(\sum Y)}{n(\sum X^2) - (\sum X)^2}$$

Table 1 describes the relationships of the weather parameters which have been used in long-term forecasting.

Table 1: *Dependency of the weather parameters used for forecasting*

X (Independent Variable)	Y (Dependent Variable)
Rainfall	Humidity
Average Humidity	Temperature
Average Temperature	Rainfall
Average Temperature	Wind speed

4. RESULTS AND DISCUSSION

4.1. Visualization System

Figure 2 shows the Home page of the designed web-based visualization system. It also shows the main codes/symbols which are used for weather visualization. The main weather parameters under consideration are displayed on the Homepage.

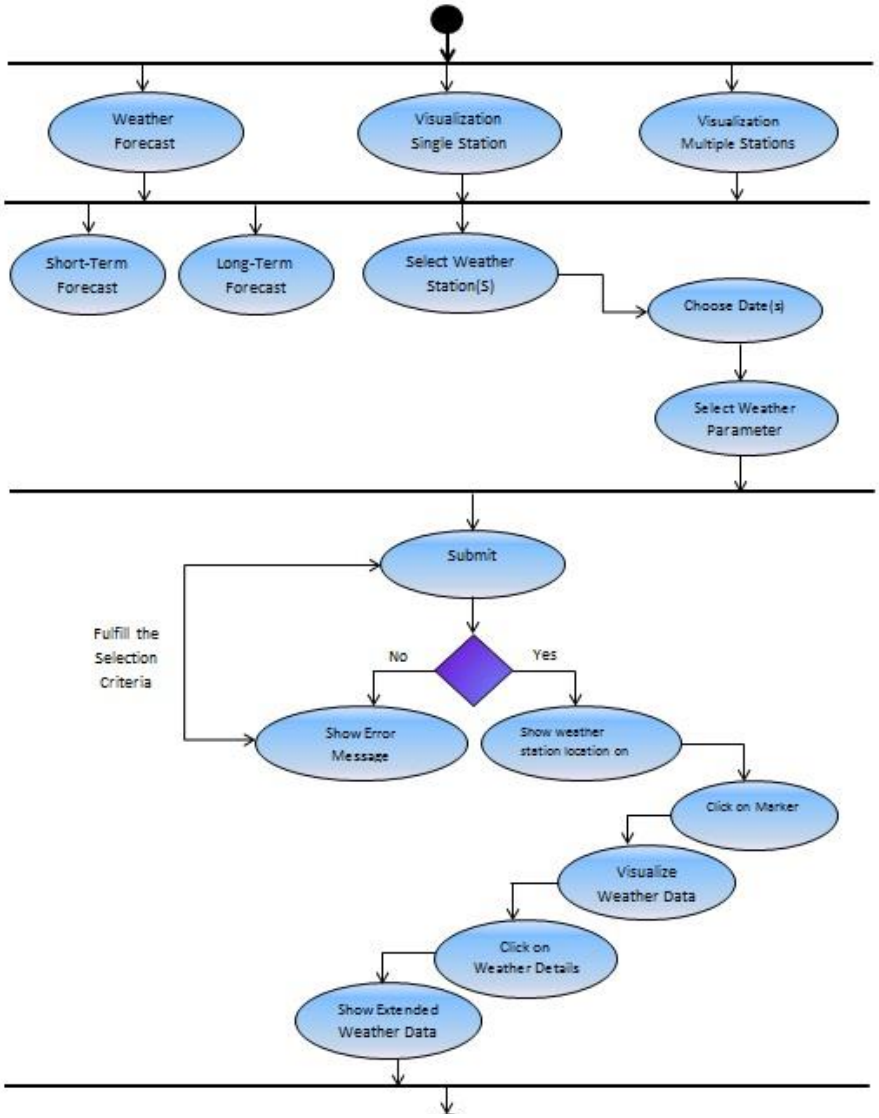

Figure 1: *Activity Diagram*

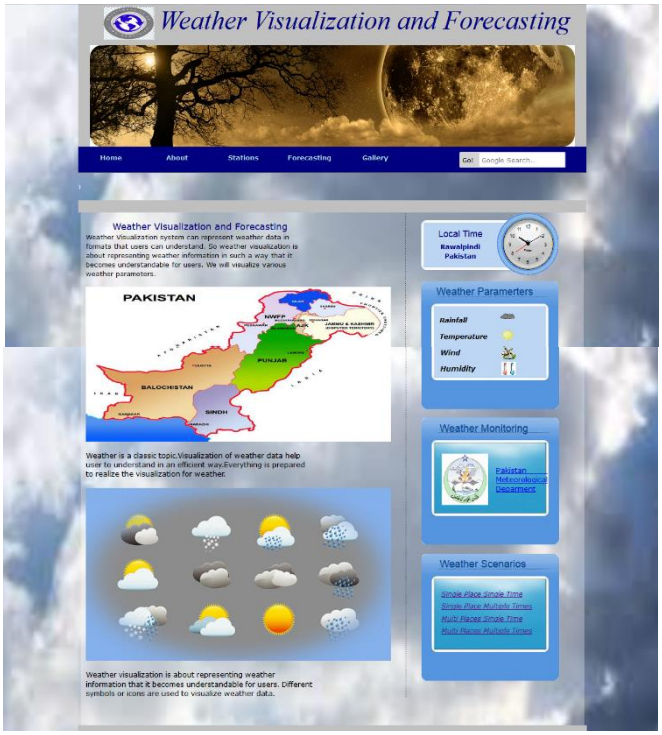

Figure 2*: Home page*

Figure 3, 4, 5 and 6 show the screenshots of the visualizations according to different scenarios proposed in Section 3.

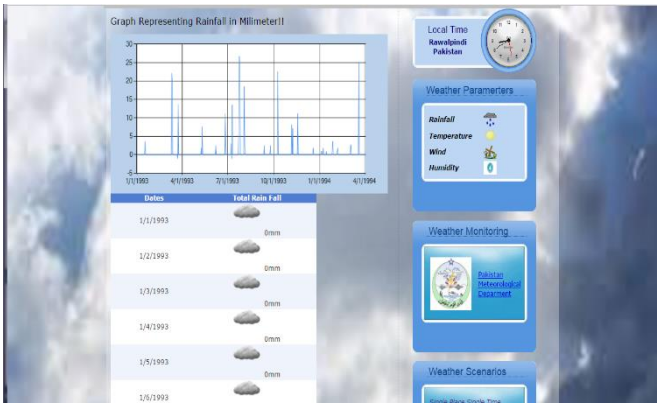

***Figure 3**: Multiple Stations data visualization for rainfall*

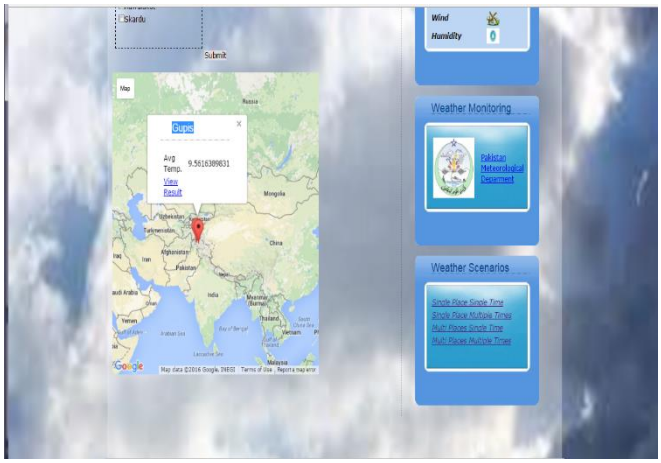

***Figure 4:** Multiple Stations data visualization*

***Figure 5**: Multiple Stations data visualization for temperature*

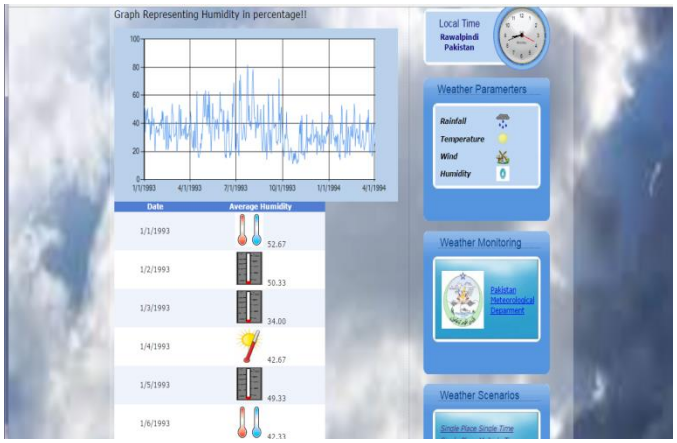

Figure 6: *Multiple Stations data visualization for humidity*

4.2 Short and Long Term Forecasting

Forecasting on Humidity parameter: The figures of humidity illustrate the maximum, minimum and average humidity forecast graphs at time 00, 03 and 12 taking dates on X-axis and unit values on Y-axis.

According to the forecasting graphs of humidity at time 03:00 the maximum of humidity will decrease in the years to come as well as the minimum of the humidity will decrease in the years to come. The decrease in the maximum of humidity will be more as compared to the decrease in the minimum of the humidity at the time 03:00 in the next ten years as shown in Fig. 7.

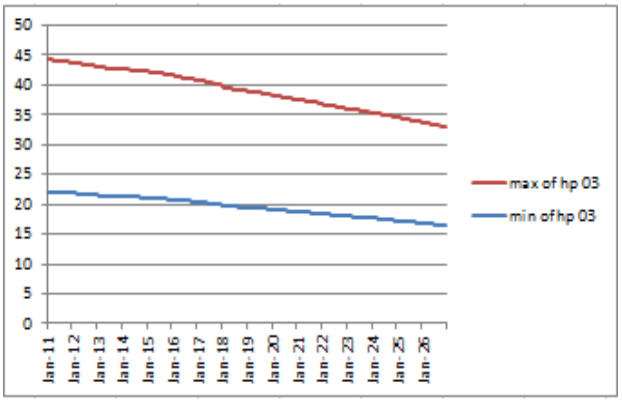

Figure 7: *Forecasting of Humidity at time 03:00*

Forecasting on Rain parameter: According to the forecasting graph of rainfall in Fig. 8, it may be predicted that the minimum of rainfall as well as maximum of rainfall will decrease over the years. The decrease in the minimum of rainfall will be more as compared to the decrease in the maximum of the rainfall. This indicates that overall the rainfall will decrease in the years to come.

Forecasting on temperature parameter: According to the forecasting graph of average temperature in Fig. 9, the minimum of average temperature as well as maximum of average temperature are increasing. The increase in the maximum of average temperature is more as compared to the increase in the minimum of average temperature. This indicates that overall the average temperature will increase in the years to come.

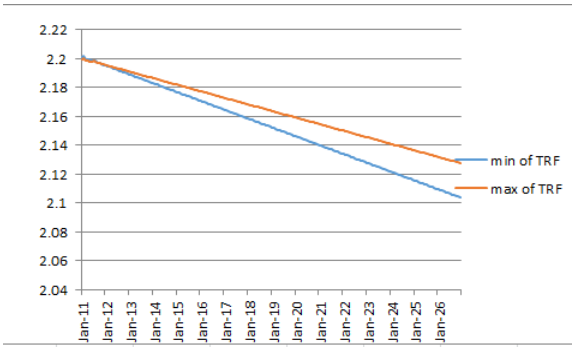

Figure 8: *Forecasting of rainfall parameter*

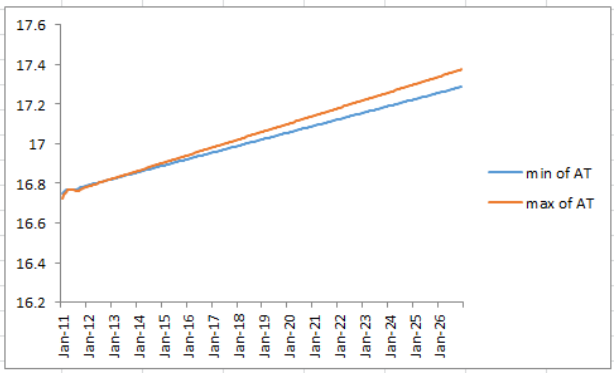

Figure 9: *Forecasting of temperature*

5. CONCLUSIONS

This paper describes a web-based interactive application for visualization and forecasting of northern areas of Pakistan. All the stages of development of the system were discussed. The data set was taken from Pakistan Meteorological Department which contained four parameters, wind speed, temperature, humidity and rain fall. After a detailed background study and work on the project, it became clear that weather visualization is a challenging and sensitive problem. Making clear and understandable visualizations needs careful contemplation and analysis. The interactive visualization system may assist experts and researchers in the process of finding patterns and relationships in weather data. The system contains a module of short term forecasting and long term forecasting as well. The results of long term forecasting for humidity, rainfall and temperature are presented for next 10 years.

CONFLICTS OF INTEREST

No conflict of interest was declared by the authors.

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