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Research Article

# Web System for Visualization of Weather Data of the Hydrometeorological Network of Tungurahua, Ecuador

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## Abstract

The information provided by hydrometeorological stations can propose predictive solutions to adverse changes caused by weather in different regions. In this aspect, the publication of this type of information can help common users, farmers or populations at high risk of flooding or propose solutions to droughts. This work presents a hydrometeorological visualization system published in http://rrnn.tungurahua.gob.ec/red, including wind parameters, wind direction, precipitation, and temperature, in a graphic and documented way. The structure of the system presents the whole information required prior to the programming of the two-dimensional and three-dimensional interfaces, detailing all the tools used for the generation of graphics layers. Additionally, all the required files are presented to show the necessary graphic details, such as elevations, boundaries between cantons, roads, water bodies, and so on. Finally, a quick navigation of the bi-dimensional and three-dimensional interface is presented, where all options contained in the developed system are quickly displayed.

**Keywords:** Hydrometeorological Stations; Webpage; Map Server; Ortophotography

## Introduction

The use of meteorological stations located in the field for the collection of climatic information can propose solutions to several problems cause by different economic activities [1,2]. Problems related to droughts, excessive rainfall, frost, very high temperatures, and so on, can be partially mitigated through the information provided by the historical hydrometeorological data, allowing to find solutions to possible affections of important economies such as agriculture, livestock, aquaculture, and so forth [3]. For instance, a common case is a drought, known as a growing phenomenon which affects aspects such as food security, the environment, and the people's health. A 38-year record (1970-2007) [4] indicates that in Asia alone the drought has caused around $ 30 billion in damages, information which corroborates the impact of the drought in different regions and keeps changing under different climate change scenarios.

However, the information obtained by this kind of stations requires big data processing, reliable communication between the data collection station and the processing station, information validators, and storage methods [5]. The difficulty in access to this type of information limits the farmers to rely on empirical knowledge, which many times is misguided given the recent climatic changes. By means of the proposed web system linked to the hydrometeorological observance network, a coordinated and climate-sensitive effort in agricultural and livestock farming can be carried out [6]. Especially in developing countries, the usage of this type of information could have a positive effect on food production and investment recovery [7].

In Ecuador, hydrometeorological monitoring networks are usually composed of rain gauges, radars, and sensors, which collect meteorological and hydrometric data in order to obtain information and produce guidelines for the sustainable management of water resources and decision making processes linked to early warning systems [8]. Companies, as well as government entities, have implemented computer applications to carry out their processes effectively, safely, and quickly. In this way, several meteorological and hydrometric data monitoring networks that are regulated by the National Institute of Meteorology and Hydrology [9] (INAMHI) have been strategically located in the central region of Ecuador. These networks or monitoring stations are located in the different provinces of the country, for instance in Azuay, Chimborazo, and Carchi, many of which are difficult to access due to their strategic positioning. The information generated by the hydrometeorological networks passes a complete process of verification and control until it is stored in a database, so that the variables acquired can be easily interpreted by an end user [10,11].

This work presents the implementation of a web system with a standardized method to process hydrometeorological data, which is published in the Geoportal of the Honorable Provincial Government of Tungurahua, Ecuador. The implemented web page shows both updated and historical information on wind variables, wind direction, precipitation, and temperature. The objective of the implementation of this system is to provide hydrometeorological information to sectors of production which can take advantage of these data to foresee losses in food production, the activation of early warnings in populations close to water dams, water resource management and so on. Compared with other similar works, the system allows integrating new types of hydrometeorological stations and thus expand the data collection area without complicated and expensive configurations, providing more information for a better analysis. The process of validating data according to the World Meteorological Organization (WMO) standards is also something new in the country. This process allows the quick detection of a malfunction of a measuring instrument and, therefore, a quick replacement or calibration of the affected instrument.

## System structure

The general structure of the System is shown in figure 1 and is split into five main groups, which directly show the workflow to achieve the solution to the problems encountered. The data upload considers the methods of acquiring information from each of the meteorological stations, information that can be collected in two different ways. On the other hand, the storage methods are shown in the second block, where the pre-processing of information is considered to validate the data before saving them.

The i) data load consists of the collection of information, either manually (collected station by station and uploaded to the system in *.csv format) or automatically through a series of scripts that access via stations to TELNET and downloaded the data to a local FTP server for further processing. The data collected manually or automatically have the structure of figure 2, where the label A represents the date on which the sample was taken, B is the time at which the reading of the data corresponds, C corresponds to the type of parameter and D is the value of the hydrometeorological parameter. This received structure ii) is mapped using PHP and stored in the MongoDB database, creating an index for each group of 50000 data.

**Figure 1:** Diagram of the general structure of the implemented system.

The hydro-meteorological data stored must go through a process of iii) validation according to the models and standards indicated by the World Meteorological Organization (WMO). These models, steps and standards are detailed in the document "Guidelines on Quality Control Procedures for Data from Automatic Weather Stations" [4].

For the hydrometeorological stations of the province, the following steps were identified to validate the instantaneous data:

**Figure 2:** The structure of data collected from each station.

apply threshold control, establish and apply control of minimum and maximum temporal consistency and finally, apply internal consistency control. The goal of threshold control is to check if the instantaneous values fluctuate within a range of acceptable limits. The WMO proposes absolute limits for each of the climatic parameters as indicated in the following table.

| Parameter | Value |
|---|---|
| Air temperature | -80°C - +60°C |
| Soil temperature | -50°C - +50°C |
| RH | 0 - 100 % |
| Wind direction | 0 - 360° |
| Wind speed | 0 - 75 m/s (media de 2min o 10min) |
| Precipitation | 0 - 40 mm/min |

**Table 1:** Absolute threshold values.

For its part, the Minimum and Maximum Temporal Consistency Control allows to verify the rate of change of instantaneous data of the stations. The main objective of this step is to detect unrealistic spontaneous changes of values or repetitions by sensors which are blocked. In this aspect, for the control of the maximum variability allowed in the instantaneous data, the value should not differ too much from the previous value. The limits of maximum variability can be the following:

To check the maximum variability, the instantaneous value must be compared with the previous and following ones, and if the data exceeds the established limits, it is marked as incorrect:

$$|Vi - Vi\text{-}1| + |Vi - Vi\text{+}1| \leq 4 \cdot \sigma V \qquad (1)$$

| Parameter | Value |
|---|---|
| Air temperature | 3°C |
| RH | 10 % |
| Atmospheric pressure | 0,5 hPa |
| Wind speed | 20 m/s |
| Solar radiation | 1000 W/m$^2$ |

**Table 2:** Limits of maximum variability imposed by WMO.

Vi: Instantaneous value of the climate parameter,

Vi-1: Previous instantaneous value of the climate parameter, Vi+1: Next instantaneous value of the climate parameter, σV: Standard deviation of the climatic parameter calculated from the last 60 min.

**Remark 1:** In the event that the previous or next value does not exist, the corresponding part of the formula is omitted, and the comparative term is 2·σV.

Furthermore, a control of minimum variability is required to consider the cases in which the instantaneous value of one minute does not change for more than a specific limit during one hour, being marked as doubtful the group of values acquired. The possible limits of minimum variability required for a period of 60 minutes are:

| Parameter | Value |
|---|---|
| Air temperature | 0,1°C |
| RH | 1 % |
| Atmospheric pressure | 0,1 hPa |
| Wind speed | 0,5 m/s |
| Wind direction | 10° |

**Table 3:** Limits of minimum variability imposed by WMO.

Finally, the control of the internal consistency of data is made based on the relationship between two climatic parameters, that is, if the wind speed is 0, the wind direction must also be 0. According to the WMO, the parameters have to comply with the following conditions to approve the internal consistency control:

- o Wind speed = 00 and wind direction= 00
- o Wind speed ≠ 00 and wind direction ≠ 00

Likewise, the iv) Generation of Averages calculates values that represent a period of time that summarizes the capture of information to simplify the interpretation of acquired values. This measure is applied in order to offer a more of hydrometeorological data, which can be downloaded in the Geoportal of the HGPT. It was observed that data with intervals of less than one hour are usually not requested by users of the Geoportal. In addition, the reduction of information is necessary to facilitate the sending of data to INAMHI, which is responsible for a second phase of validation. Finally, the v) publication results phase details the methods used to generate the interface with which the end user interacts. In this study, two visualization methods are considered: 2D and 3D. These measures are meant to improve the interaction between system and user, providing a downloading option of historical climate data, the location of each station in map that includes surfaces and altitudes, boundaries between cantons and useful information with respect to the maintenance of the station.

## Web system construction

The construction of the web system requires basic information to reach the level of detail of the maps, as well as the adequate presentation of the data received by the primary stations. Figure 3 presents all the information necessary to achieve the proposed interface, detailing the format in which the data is imported. In this way, the geospatial information of the Tungurahua province is stored in Raster and vector files. The i) raster files generated for the web system are the georeferenced aerial shots of the province, where isotherms and isohyets maps, digital terrain models, and orthophotos are included.

**Figure 3:** Web System Construction.

The most representative raster files are the orthophotos of the whole province, purchased from the Geophysical Institute of Ecuador by the HGPT. The Raster (* .tiff) files for the orthophoto has a size of approximately 260 GB; in these satellite images the terrain is displayed with a relatively low percentage of cloudiness. The information obtained by the HGPT is captured in vector files (Shapefiles), which are formed by points, lines or polygons and are used to represent locations of places or objects, relevant areas, towns, routes, rivers, boundaries and other elements which can be represented through geometric figures. The vector files are generated manually using the software QGIS, based on consultancies or surveys of the authors of this work.

In order for geospatial information to be presented in a web environment, it is necessary to publish it through a Web Map Service (WMS), being MapServer and GeoServer the most used open source map servers. The proposed structure uses Mapserver, since most of the system is programmed over PHP and the support presented for this programming language is adequate, unlike GeoServer, which has greater support for systems developed in Java. MapServer allows to generate web services of maps (WMSs) from vector or raster information, where a WMS represents a map that can be made up of several layers, each layer corresponding to a single shapefile or *.tiff file. To generate the WMS to publish the orthophoto it is necessary to make an image arrangement and process them so that the 260 GB of images are reduced to 90% using tools from the GDAL library. Figure 4 presents a working diagram of MapServer, showing the files and services that are required inputs and the result of internal processing.

The construction of the web system interface uses HTML and CSS, which allow presenting the information in a structured and stylized way in a web page javascript, on the other hand, allows to include the interaction and the animation which is displayed on the web. Javascript has several libraries to present maps using the WMSs, of which Leaflet and CesiumJS are used. With Leaflet it is possible to present maps in 2D (using WMSs), add markers and popups to the map so that the user can interact with the interface

**Figure 4:** Map Server Operation Diagram.

by increasing or decreasing the zoom, dragging it or clicking on the maps to obtain information of a specific point or consulting the historical of each month, day or year.

**Remark 2:** The exclusive use of open source programs provides an excellent opportunity for the dissemination of the process and thus the system can be replicated elsewhere.

The 2D viewer made with leaflet includes the base layer of OpenStreetMaps (Figure 5) used as a background on which are added the cantonal division layers and the markers which indicate the position of each hydrometeorological station within the province.

**Figure 5:** Base layer provided by open street maps.

The climatological information that is shown when interacting with the map and opening the file of each hydrometeorological station is obtained from the non-relational MongoDB database in JSON format. The database contains the average, minimum and maximum values of the hydrometeorological parameters that were manually or automatically loaded and that later passed the validation and averaging process to be included in the 2D or 3D viewer.

Furthermore, the 3D viewer made with CesiumJS includes the WMSs with the most relevant layers to be displayed in a three-dimensional way. In this case, the layers with hydrometeorological stations, the base layers of orthophotos, height, relief and cantons of Tungurahua are included to have a broader perspective of the location of the stations or the acquired measurements, including roads, rivers, water bodies, provincial and parish divisions, cities and isothermal maps.

**Figure 6:** Display showing the base layers of orthophotos and height.

## Results

The results presented in this section show the 2D and 3D displays implemented with Leaflet and CesiumJS respectively, which obtain the maps from MapServer through the pre-configured WMS and the weather information validated and averaged from MongoDB. The results are completely interactive, with data and measured parameters entered intuitively, as shown in the figures presented in this section.

### 2D Display

The main window (Figure 7) shows the interface of the 2D viewer that allows to see the location of the meteorological and hydrometric stations distributed in the 8 cantons of the province of Tungurahua. When interacting with the map the client can filter the stations by region, type of station or measured parameters. Additionally, the user can access the climatic information of each station or region and see the historical data available, by clicking on the area that he wishes to consult (Figure 8).

**Figure 7:** A. 2D Viewer of the Tungurahua's Hydrometeorological network.

**Figure 8:** Historical climate information of a hydrometeorological station.

The result shown allows access to a detailed view of each station, which consists of its geographical location, basic data (Figure 9), a section with the climatic history of each hydrometeorological parameter and a section to download the hydrometeorological data in csv or excel format.

### Visor 3D

The 3D viewer consists of 3 main sections. The first contains a list of the layers loaded through the WMS of the Weather Stations and base layers of Tungurahua. These layers have the characteristic of modification of opacity and allow to be added on the second section containing the 3D map and the markers of the climatic stations (Figure 10).

**Figure 9:** Complete display of hydro meteorological station and geographical location.

**Figure 10:** 3D display of hydrometeorological network and base layers available.

The third section of the 3D display shows a table with information about the selected station and allows you to position and orient the map to obtain a panoramic view of the area where each station is located. Additionally, you can set the heading, pitch and roll values of the camera to change the orientation of the viewfinder manually (Figure 11).

**Figure 11:** Location of weather station on 3D map and base information.

## Conclusions

A system for presenting data collected from hydrometeorological stations is easy to interpret and use when they are processed and displayed graphically. In this context, the implemented system collects manual or automatic information for the plotting of climate parameters, such as wind speed, wind direction, precipitation, and temperature, in order to show summarized information. Through this system, a common user can have access to graphical information of the received data, as well as the historical information of each of the stations. By means of the user-friendly and interactive webpage, the acquired, processed and stored information can be used, for instance, in agricultural and livestock planning, water resource management, and disaster prevention. This facility of interaction is achieved through the representation of two-dimensional and three-dimensional maps, which show the location of each of the stations on a map including altitudes, populations, water bodies, flora and fauna, and so on.

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