A Cloud Computing Based Framework for Storage and Processing of Meteorological Data

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Abstract. This document shows an analysis of emerging technology for the recovery of meteorological data and its cost-benefit using GPRS (General Packet Radio Service) data transfer in automatic meteorological stations to improve the monitoring and the prediction of the atmosphere and inland water behavior in Ecuador. In different areas of study comparisons between data or generated registers coming from Automatic Weather Station (AWS) and Conventional Weather Station (CWS) have been made. Therefore, here the authors mainly underline the importance of storing meteorological information using cloud computing. Among the benefits of cloud computing there are high data availability access and high efficiency in technical/scientific studies at lower cost due to the decrease of local investment in technological infrastructure, upgrades, maintenance of equipment and applications.

Keywords: Cloud computing · GPRS · Meteorology · Weather Station

1 Introduction

In the last few years decision makers and general public have recognized the importance to have a meteorological station network in-situ that provides accurate information to be used for both surveillance and forecast of weather, hydrological surveillance, agrometeorological prediction or to reduce climate risk [1]. In this way the WMO –World Meteorological Organization –established the creation of the Global Framework for Climate Services (GFCS), to promote the best access and use of the climate information for the users [2]. Moreover regional efforts have been done, for example the "Latin American Observatory for Climate Events" [3] which through a database (http://datoteca.ole2.org/) gives access to different resources for hydro-meteorological data as well as climate forecast that could be directly query by the users in an interactive manner. In

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the same line, the CIFEN (Centro Internacional para la Investigación del Fenómeno de El Niño) participates in The International Climate Assessment & Dataset (ICA&D), which integrates meteorological, hydrological and climate information for the Andean region and supports decision makers. There is also a running regional program called PRASDES [4], which recovers and keeps meteorological, hydrological and climate information to have access to accurate and up-to-date information.

The National Institute of Meteorology and Hydrology (INAMHI) is the Ecuadorian meteorological and hydrological national service which is the responsible for delivering information related to the weather, climate and hydrological resources. INAMHI has been a key factor in the development of new projects related to weather services for the whole country, among which we can find those related to public health (for example [5, 6]) as well as agriculture. These projects have been made possible due to the automatic and conventional INAMHI weather station infrastructure, which provides the necessary data to carry out climate studies and to create new products for climate-related activities [7].

In the present study the technology that is currently used to process and keep data is analyzed in order to propose a model for the management of meteorological information through cloud computing. For example, [8] underlines the importance of the cloud for storage and information processing. Additionally, studies were done for this service application under different perspectives. Cloud storage gives the opportunity to have high availability over the historical and updated real time meteorological data to help to scientific and technical communities to access to information so that different studies can be carried out. Research also mentions [9] that in Ecuador there exists some inconvenient to data acquisition due to the fact that this job is still done manually. Consequently, in the first place we will show a short description of the model that is currently used for the manual register of data in the Conventional Weather Stations (CWS); in the second place, we talk about the transfer model through Automatic Weather Stations (AWS); and finally, we show the proposed model which consists of using cloud computing to manage meteorological data, and of which main goal is to offer access to storage data in real time using actual technologies.

2 Station Types Used in Ecuador

According to research done by different institutions dedicated to meteorological data observation in Ecuador [10], there is 2 main station types: conventional and automatic meteorological stations.

2.1 Conventional Weather Station (CWS)

A CWS is a mechanic equipment that is used to collect values of meteorological variables based on the instruments located on site to do these measures. According to related literature[10] there are three types of stations: the main station, which does five daily observations with a minimum of nine variables; the secondary station doing three daily observations with a minimum of three variables; and the precipitation measure, which does one observation per day. For this article it is considered a secondary station as reference for future comparison.

The secondary weather station does three daily observations of three variables minimum [10]; among the meteorological instrumentation we consider the following:

- Meteorological shelter: it is a box designed to protect the instruments that measure the temperature; it is usually white painted.
- Thermal hygrograph: it is an instrument used to measure temperature and relative humidity.
- Heliograph: it is used to register sunlight intensity.
- Rain gauge: it is used to measure the amount of precipitation that occurred in a specific period of time, with the help of a test tube. It is installed with WMO specifications.
- Weather-vane: it helps to generate wind data.
- Anemometer: it helps to register wind speed observations.
- Barometer: it helps the user to register atmospheric pressure.

2.1.1 Manual Data Transmission for the CWS

According to the web page of Ecuador meteorological service data from conventional station exist from 1990 in Ecuador [11].

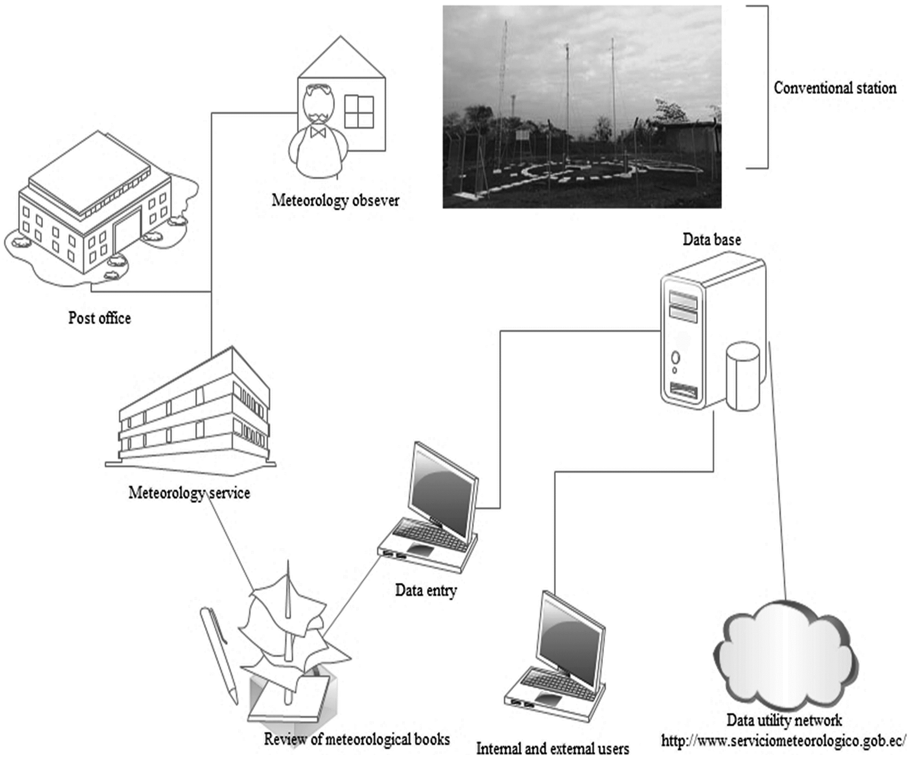

Fig. 1. Representation of how information is sent from conventional stations to the meteorological service.

Figure 1 shows the manual data transmission for CWS. As can be seen, the weather data is collected for a technical officer called Observer, who registers the weather observations in meteorological notebooks; once it is completed, the observer brings the information to the closest local office. It is important to mention that these documents frequently get lost due to some inconvenient in the transport or postal service.

Once the data is saved in the database, technicians make a data quality control of the data, following the normalized standards suggested by the WMO to accomplish with the worldwide required standards.

2.2 Automatic Meteorological Station

For this study we have developed a functioning analysis for a basic automatic meteorological station that measures speed and direction of the wind, humidity, temperature, sunlight intensity and atmospheric pressure. The station has two ways to collect information. Figure 2 shows that meteorological observation registered by the sensors initially is stored in the internal memory of a datalogger to be transmitted by GPRS to a specific storage site. There is another option to download data from the datalogger directly to a computer through software called Lizard [12]. Daily data from the Data logger could be downloaded through RS 232 [12] and RS485 [12] serial protocols for further analysis.

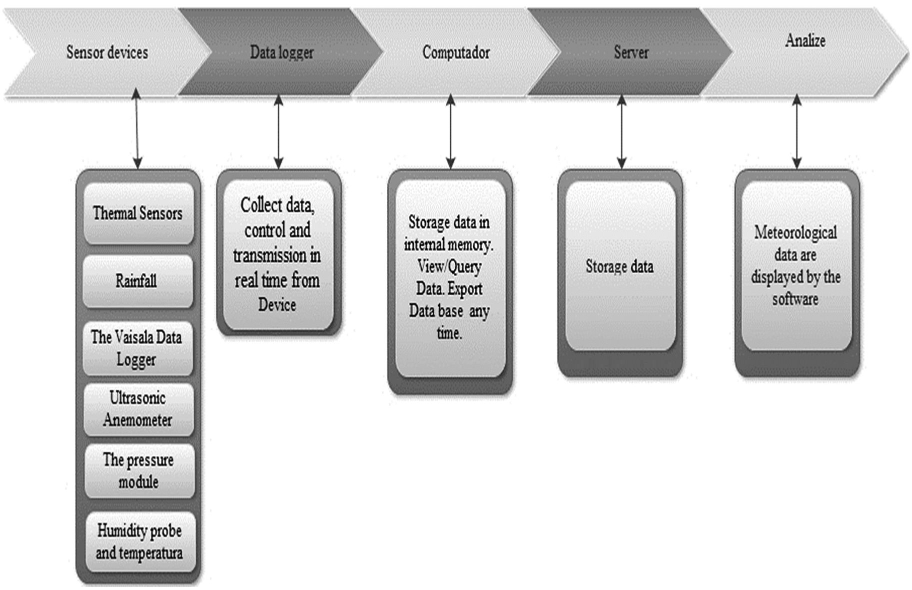

Fig. 2. The Treasure Data Cloud Computing depicts transmission flow for data based in the analysis done in this article; the information after collection is kept in a server so it must be extracted for further analysis.

In order to detail the sensors, Table 1 shows a description of the devices that are part of an automatic meteorological station. These sensors must be calibrated with special instruments at least every two years to confirm if the observations are done correctly. For this type of stations there is also installation standards based on WMO recommendations. The stations are generally installed in a place separated from buildings or tree shadow in a 6 * 6 m^2 room.

Table 1. Sensor description and automatic meteorological specifications analyzed in this article

Devices	Descriptions
Thermal sensors	It is a solar radiation sensor that is applied in most common solar radiation observations
Rainfall	It is a freestanding receptacle for measuring precipitation
Data logger QML201C	It incorporates Vaisala's proven sensor technology
Ultrasonic Anemometer	It is a wind tunnel fully tested and calibrated to provide reliable and accurate wind measurement
The pressure module BAROCAP	It has excellent accuracy, repeatability and long term stability in a wide range of operating temperatures
Humidity probe and temperature	It provides reliable measurement of humidity and temperature

2.2.1 Automatic Weather Station Transmission, According to Present Situation

This section refers to the communication types used to send meteorological data from each AWS; in Sect. 2.1.1 we detail the procedure to send the data collected in situ in the CWS, where people are in charge to do observations. In this section the transmission scheme using GPRS service is explained.

The automatic weather station has two ways to transmit data, see Fig. 3; first data are sent by GPRS [13] using a mobile operator; this path is used to transfer information from remote site; the second option is a 1.6 MB internal memory that keeps data in case

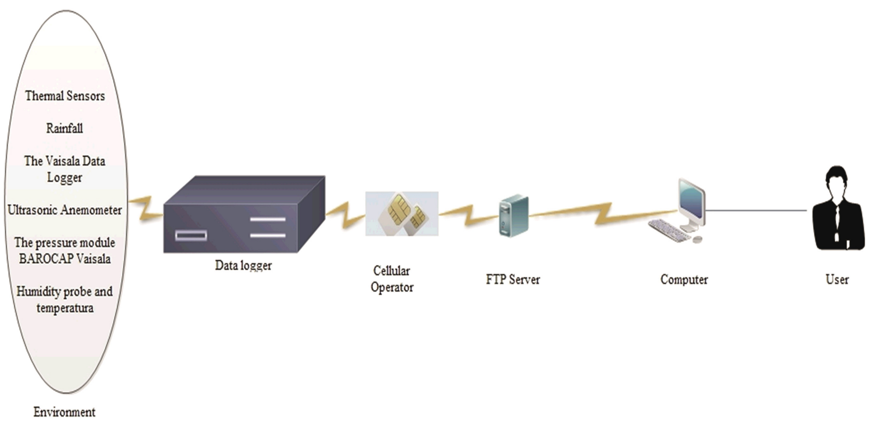

Fig. 3. Current infrastructure of the AWS.

the GPRS transceiver is not working. If this happened the data are queued to be transmitted as soon as the GPRS signal is available.

Additionally, the station has a third option which consists in a 2 GB external memory that keeps all the data registered by the sensors; this is useful because at the moment to do a maintenance in the AWS, the data could be downloaded to a local computer by a proprietary software of the equipment provider to manage the configuration of equipment and to download data in a direct way. It should be mentioned that the time interval when the data are collected is configurable by the technician that manages the AWS.

3 Transmission Model, Storage and Processing Through Cloud Computing

As regards cloud computing, this study suggests the storage and information processing in the cloud. We resort to previous studies [14] in which the use of the cloud is emphasized to control different processes. One of these processes consists of delivering computer efficiency products in order to improve the monitoring of different atmospheric variables, meteorological forecast, and climate analysis national wide. Integrated management of the cloud resources [15] automatizes and reduces process execution time. Taking into consideration other similar studies [16], for the implementation of this proposal cloud services will be used namely virtual servers and storage.

We have also analyzed that cloud computing can play an important role integrating environmental information, offering processing and storage possibilities on demand. Example [17] -which is based on urban management- helps to identify a generic set of technical skills in information intelligence, and it proposes a SIAA layer architecture by using different cloud-based scenarios. Figure 4 shows the data transfer process of inclusion.

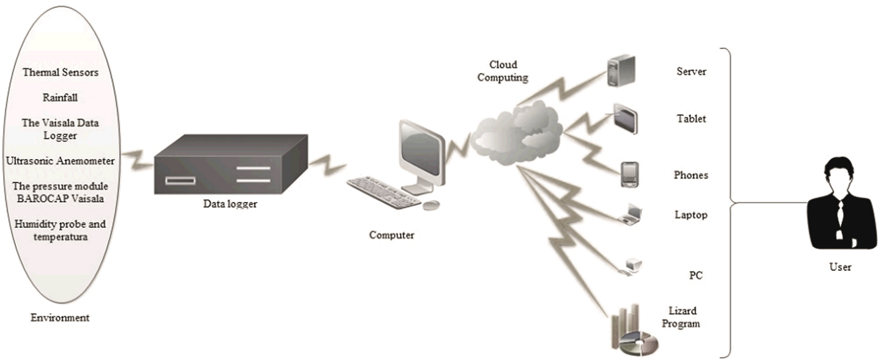

Fig. 4. Automatic Weather Station Infrastructure. It represents the data transfer process from automatic station by data logger toward a server in the cloud that will be used to keep and process whole data; once information is processed the products could be observed and analyzed from different types of devices by external or internal users.

Research on cloud [14] for the meteorological information integration shows that this technology allows better surveillance of the environment to decrease environmental issues such as climate change. On the other hand, we have analyzed how cloud computing can be the key to attain the integration of environment information, delivering processing and storage on demand. Example [17] is based on urban management and helps to identify a generic set of technical capacities for information intelligence. It also proposes a SIAA layer architecture by using different application cloud- based scenarios. Figure 4 shows the cloud inclusion within data transmission.

It was taken as reference the research done in "Cloud-based Remote Environmental Monitoring System with Distributed WSN Weather Stations" to affirm that a server in the cloud allows users to access to geo referenced data in real time [18]. It clearly shows how the information coming from the stations, in this cloud server, can use a public or private cloud according with the available resources in an institution. Nevertheless research affirms that a private cloud should be used [19].

The advantage of consolidating a solid and web access database for the analysis of meteorological patterns has been previously analyzed [20]. Thus, once meteorological information is available, different types of products can be implemented, namely maps, season statistics of variables, as well as climate observation and social conditions [21]. The direct benefits of the cloud model are detailed in Sect. 5.

4 Comparative Cost Benefits Analysis of the Proposed Model

The following analysis allows us to compare the implementation costs of a meteorological station in the proposed modalities, as well as the cost to get final data to use them for prediction in different fields previously specified.

Table 2 shows the purchase and installation costs of a meteorological station, where data equipment and registers are compared according to what has been explained in Sect. 2. Details such as workforce use for installation make a radical difference in costs among alternatives, concluding that the cost of a CWS and the costs of an AWS included in the cloud are equal, but in the latter (Automatic and cloud) we would have uncountable benefits in computer infrastructure reduction, among other advantages that are explained in Sect. 5.

Table 2. Operative costs comparison for a Conventional Weather Stations (CWS), Automatic Weather Stations (AWS), and the automate process in the cloud.

Detail	CWS	AWS	Automatic and cloud
Equipment	23,013.63	10,437.00	10,437.00
Cost of installation	6,759.89	600.00	600.00
Total equipment cost	29,773.52	11,037.00	11,037.00

Table 3 compares monthly costs associated with tabulated and processed data and processing, which are useful to final users from different sectors related to the weather.

Table 3. Comparison of storage and data processing costs for a CWS, AWS, and automated processing in cloud.

Detail	CWS	AWS	Automatic and cloud
Computational infrastructure	$543.38	$543.38	$1,437.00
Storage and data processing	$2,384.33	$1,935.59	$515.76
Total cost	$2,927.71	$2,478.97	$1,952.76

For the conventional model it has been considered that each station must have a person to take daily data, who must live nearby the station. Considering this, data are consolidated in a monthly report that is sent through post office to the regulatory office for further analysis and publishing by a specialized technician in the area, which is explained in detail in Sect. 2.1. In this process special computer equipment is used in order to get useful information of which cost is observed in Table 3. This model has the disadvantage of not allowing the users to obtain up-to-date information in real time (see Sect. 2.1.

As explained in Sect. 2.2 the Automatic model is based on a technical scheme that has GPRS data transmission to get up-to-date information. However, the disadvantage is that historical or real time information cannot be seen by final users; it depends on the processing made by specialists with special software tools.

The benefit of using this transmission, storage and information processing model through Cloud Computing detailed in Sect. 3 is not just economic (as shown in Fig. 5) but also favorable in the way reliable information is handled within a web environment

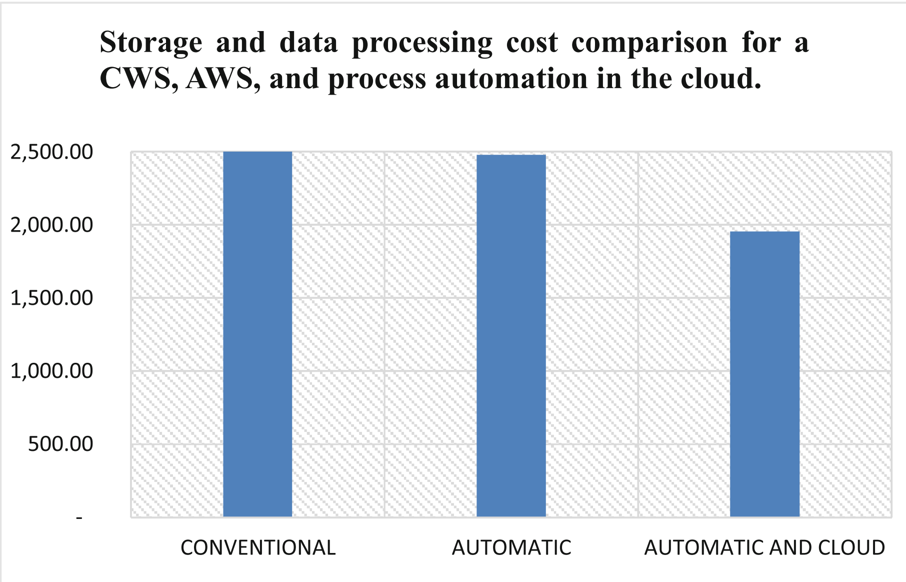

Fig. 5. Cost (dollars) of obtaining meteorological data, including storage and processing with a cloud server. Costs are represented monthly comparing the three models of transfer explained in this study.

without restrictions, allowing any user to get useful forecasts for their economic activities. The costs mentioned in this study for the cloud service are borne by the NewAccess Enterprise in Ecuador [22].

5 Transmission Model Benefits

Cloud computing tendency has shaken up the concepts of information storage, processing and monitoring [23]. It is gaining interest especially among big and medium-size companies. It represents an alternative for the traditional installed software model, considerably reducing the costs as there is no need of purchase, installation, maintenance or upgrade for hardware or software [24].

There are three service categories to which the users can access from its devices: Software as service (SaaS), platform as service [15, 16] (PaaS), and infrastructure as service (IaaS) [25]. PaaS and SaaS include applications, data, functioning time, middleware, operating system, virtualization, servers, storage, and network. These resources are managed by the provider. As for IaaS, the data, functioning time, middleware, and operating system are managed by the user, whereas virtualization, servers, storage and network are managed by the provider.

Cloud computing offers three implementation models:

- Private cloud: Resources are specifically used by the organization and there exists fast provisioning in business services. The property, management, and functioning is in charge of the Enterprise or a third party.
- Public cloud: It is focused on the public use, and its property, management and functioning is covered by the university, the company or the government.
- Hybrid cloud: It combines both models.

Among the advantages of Cloud Computing [26] we can have:

- Speed: Working under this scheme allows getting new applications without a risk of implementation for business, deceasing answer time and increasing flexibility.
- Scalability: Computer resources, network, and storage room can be created in just a few minutes, providing the organization with better control, security and flexibility
- Saving: The organization doesn't have expenses in startup capital, which helps to reduce operational costs because the time of use for equipment is eliminated. There is the option of acquiring storage room per hours according to the demand.

Nowadays, medium-size organizations don't need many technological resources to access platforms or infrastructure such as a DataCenter. In the past these types of resources were only accessible for multinational companies. Now, this kind of organizations does not need to make big technological investments to access and get the advantages that offers this type of platform. Therefore, and due to lower investment, they can be more competitive. This type of service have become more and more popular in the last years, and it is currently used in many private and public organizations around the world; the National Telecommunications Corporation (Public enterprise) in Ecuador is also offering the data storage and disaster recovery service with which they can show its customers that this kind of technology could be applicable to different sectors.

In different studies some methodologies have been analyzed for the management of big volumes of data in the cloud and its performance [27]. It is demonstrated that this kind of technology perfectly works in different areas and it is easily oriented to meteorology. [18], if we take into consideration previous research [28] that shows cost reduction due to a reduction in infrastructure and staff.

6 Conclusions and Further Research

We can conclude that it is much economic and sustainable to maintain an AWS and to get its data than a CWS, due to the fact that the hired staff has to take daily observations, causing high costs as well as different types of the employer's obligations. At the same time, the benefits of the use of cloud computing in the management and storage of information are remarked in Sect. 5.

Additionally, it makes it easy the access and it also improves the process to get meteorological information that exists at present, avoiding issues such as those mentioned in the study [9] "Meteorological data acquisition in Ecuador, South America: problems and solutions". Therefore, problems as unwillingness to communicate the data to the public as well as the lack of interest in the daily task to collect data will disappear; thereby users will be able to obtain complete access to the information, complying with the "Organic Law of Transparency and Access to Public Information" [29], established in Ecuador.

In the future it is possible to carry out a research project that includes the development of a web platform to manage meteorological data, taking as a reference the web platform developed by The International Research Institute for Climate and Society [22], which gives relevant and processed information using meteorological data. This platform can offer relevant products simulating different meteorological scenarios based on the information stored in the cloud service.

Nowadays, the concept "intelligent city" is gaining momentum. We adopt this concept as a reference [30] to indicate that the information processed and saved in the cloud storage will be available to citizens. Thus, they could access to data in real time, that is, to weather information, forecasts and climate indices. It will directly benefit to different economic sectors, for instance, tourism, transport or agricultural industry. The model here exposed will bring economic benefits to the government and private institutions. That is why future projects are necessary to evaluate in detail its implementation, functioning and scope.

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