Improving Weather Information Systems for Climate Change Assessment in Nigeria: The Role of Automatic Weather Stations (AWSs)

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Abstract
Climate change is happening on a global scale, but the ecological impacts are often local and vary from place to place. The pertinent question is how can a country like Nigeria empirically assess, formulate mitigation measures or adapt to the enormous negative impact of climate change on livelihood of people living in rural and remote places in the country without systematic, reliable and consistent weather information. Detailed weather observations on local and regional levels are essential to a range of needs from forecasting to making decisions that affect energy security, public health and safety, transportation, agriculture and all of our economic interests. Reliable weather information allows farmers to maximize their productivity and governments to implement preventative disaster management and effective public health measures. The paper highlighted benefits of the use and implementation of Automatic weather stations (AWS) in gradual replacement of conventional weather stations in Nigeria.

Keywords: Early warning, Manual weather station, Weather Information systems and Weather forecast

Introduction
The world's climate is changing, and it will continue to change throughout the 21st century and beyond. Rising temperatures, new precipitation patterns, and other changes are already affecting many aspects of human society and the natural world. Climate change is transforming ecosystems on an extraordinary scale, at an extraordinary pace. As each species responds to its changing environment, its interactions with the physical world and the organisms around it change too. This triggers a cascade of impacts throughout the entire ecosystem. These impacts can include expansion of species into new areas, intermingling of formerly non-overlapping species, and even species extinctions. Climate change is happening on a global scale, but the ecological impacts are often local and vary from place to place.

A study conducted by Mendelsohn and Williams (2004) indicated that damages from climate change may be the highest for low latitude countries. Low latitude countries such as Nigeria are expected to have higher damages because they are already very hot, they have a greater fraction of their economy in climate sensitive sectors especially agriculture, and they have less resources and technology for adaptation. Unfortunately, low latitude countries are difficult to study because of the absence of complete
information about them. One of the major problems facing global warming policy is that the regions most sensitive to climate change may be the most poorly studied. Developing empirically-based estimates of the impact of climate change in low latitude regions is consequently a critical issue for policymakers. Several climate change authors in Nigeria acknowledged inadequacy of reliable weather information (Nnoli et al, 2006; Eludoyin et al., 2009) The pertinent question is how can a country like Nigeria empirically convinced the global audience of the enormous negative impact of climate change on livelihood of people living in rural and remote places in the country without systematic, reliable and consistent weather data. Detailed weather observations on local and regional levels are essential to a range of needs from forecasting to making decisions that affect energy security, public health and safety, transportation, agriculture and all of our economic interests. The ability to get detailed observations of weather at the "mesoscale"--ranging in size from a city to a state requires networks of local weather observing systems called "mesonets." For the developing nations like Nigeria to survive the effects of climate change, there is the need to establish better-equipped weather stations as against the scanty and ill-equipped ones we currently have in Nigeria. With these, accurate weather forecast and predictions will be possible and this will help to prevent weather-related disasters through early warning and effective response system. 

Automatic weather stations (AWS) have become the worldwide standard for meteorological monitoring. AWSs are known for their precision, rugged reliability, wide operating temperature range, and low power consumption. Automatic weather stations offer the flexibility to easily change sensor configurations, data processing, and data storage and retrieval options. The aim of this paper is to highlight the benefits, installation and uses of AWS in climate change study as well as proffers recommendations for gradual transition from manual weather station. 

**Definition**

The anatomy of a typical AWS is presented in Figure 1. An automatic weather station is defined as a “meteorological station at which observations are made and transmitted automatically” (WMO,1992a). At an AWS, the instrument measurements are read out or received by a central data-acquisition unit. The collected data from the autonomous measuring devices can be processed locally at the AWS or elsewhere, for example, at the central processor of the network (WMO, 1989a). Automatic weather stations may be designed as an integrated concept of various measuring devices in combination with the data-acquisition and processing units. Such a combined system of instruments, interfaces and processing and transmission units is usually called an automated weather observing system (AWOS) or automated surface observing system (ASOS).
Figure 1: Anatomy of a typical Automatic Weather Station (AWS)
It has become common practice to refer to such a system as an AWS, although it is not a “station” fully in line with the stated definition.

**Benefits of AWS**

The key benefits of automated measurements include:

1. All current weather readings can be seen from indoors, at a glance and at any time;
2. Routine daily maintenance chores (eg emptying the rain gauge) are done automatically;
3. AWS stations can automatically record maximum and minimum values for a range of weather parameters through each day and keep track of total monthly and yearly rainfall;
4. Readings can be easily taken direct from the console display;
5. A data logger and PC can be readily linked to the station so that all weather data is automatically logged. This means that;
6. Automated systems can run for weeks and months without attention whilst continuously recording all details of the weather;
7. Much greater within-day detail is available eg the complete pattern of wind speed & direction through the day can be logged;
8. Comprehensive statistics can be automatically calculated and analysed;
9. collecting, processing and displaying meteorological data;
10. performing automated generation and transmission of meteorological reports;
11. being configured to support a wide range of sensor configurations;
12. supporting a number of data communication options;
13. managing all communication protocols for the various sensors and other associated data communication equipment;
14. storing all relevant data for immediate or future retrieval as required;
15. allowing manual input of additional information unable of being automatically measured;
16. providing the first level of quality control on both data measurement and message generation, and
17. allowing authorized users to access data remotely;

**Disadvantages of AWS**

1. Some of visual observation, (such as; present weather, precipitation type and intensity, cloud cover and types) can be done but it is not reliable as manned observation
2. it is expensive.
3. If there is any breaking down to AWS especially in data logger or sensors, there will be data losses until it is repaired.
4. Energy supplying and security can be problem for stand-alone AWS.
5. Some observation process is very difficult to get accurate data such as amount of precipitation and snow depth.
6. AWS needs to trained personnel to operate and maintained.

Purpose
Automatic weather stations are used for increasing the number and reliability of surface observations. They achieve this by:
(a) Increasing the density of an existing network by providing data from new sites and from sites that are difficult to access and inhospitable;
(b) Supplying, for manned stations, data outside the normal working hours;
(c) Increasing the reliability of measurements by using sophisticated technology and modern, digital measurement techniques;
(d) Ensuring the homogeneity of networks by standardizing the measuring techniques;
(e) Satisfying new observational needs and requirements;
(f) Reducing human errors;
(g) Lowering operational costs by reducing the number of observers;
(h) Measuring and reporting with high frequency or continuously.

Types of automatic weather stations
Automatic weather stations are used to satisfy several needs, ranging from a simple aid to the observer at manned stations to complete replacement of observers at fully automatic stations. It is possible to classify AWSs into a number of functional groups; these frequently overlap each other, however, and the classification then begins to break down. A general classification could include stations that provide data in real time and those that record data for non real-time or off line analysis. It is not unusual, however, for both of these functions to be discharged by the same AWS.

Real time AWS: A station providing data to users of meteorological observations in real time, typically at programmed times, but also in emergency conditions or upon external request. Typical real time use of an AWS is the provision of synoptic data and the monitoring of critical warning states such as storms and river or tide levels.

Off line AWS: A station recording data on site on internal or external data storage devices possibly combined with a display of actual data. The intervention of an observer is required to send stored data to the remote data user. Typical stations are climatological and simple aid to the observer stations. Both types of stations can
optionally be set up with means both for manual entry and for the editing of visual or subjective observations that cannot yet be made fully automatically. This includes present and past weather or observations that involve high costs, such as cloud height and visibility. Such a station could be described as partially or semi automated.

**Automatic weather station siting considerations**

The siting of an AWS is a very difficult matter and much research remains to be done in this area. The general principle is that a station should provide measurements that are, and remain, representative of the surrounding area, the size of which depends on the meteorological application (Plates 1 and 2). Existing guidelines for conventional stations are also valid for AWSs and are given in WMO reports (1989a; 1990b; 2003a).

Some AWSs have to operate unattended for long periods at sites with difficult access both on land and at sea. They may have to operate from highly unreliable power supplies or from sites at which no permanent power supply is available. The availability of telecommunication facilities should be considered. Security measures (against lightning, flooding, theft, vandalism, etc) are to be taken into account and the stations must, of course, be able to withstand severe meteorological conditions. At an early stage of planning, there should be a detailed analysis of the relative importance of the meteorological and technical requirements so that sites can be chosen and approved as suitable before significant installation investment is made.
Transition to Automated Systems
The role of the weather Observer is more complex than the provision of objective classifications of weather, clouds and instrument readings. Observers use their experience to compare one variable with another, integrate information from multiple sources, make a quality judgment that an instrument is reading incorrectly, provide an onsite fault response, use alternative means to communicate observations when the primary mechanism is unavailable, retain an onsite archive and identify the need to send special weather observations. While an automated system can record measurements more frequently and consistently than humans, all the other roles of field Observers must be addressed during the transition from manual to automated systems. Instead of dispersed staff dealing with single station issues, the automated system will require specialized staff responsible for a component of the system across a wide range of stations. Expert Team on Requirements for Data from Automatic Weather Stations (ET-AWS) of world meteorology organization (WMO) (2008) proposed the following list of guidelines and procedures which should be followed when automating observations.

a) **Management of Change:** Assess how and the extent to which a proposed change could influence the outputs of the Observations network. User requirements should be established by all network users. Ensure that the change management process includes representatives from network planning, engineering, observations, data processing and communications, data services (particularly when dealing with composite networks) and archiving.

b) **Defining and assigning responsibilities:** In the transition from one system to another, particularly for automated systems, additional roles generally with higher skill sets are required. These responsibilities include i) meteorological data processing algorithms, ii) computer programmers, iii) systems integrations, iv) communications specialists, v) data processing and archiving, vi) quality management, and vii) instrument calibration, inspection and maintenance specialist. In addition, many automated systems require regular site support on a weekly to monthly period. This may include tasks such as cleaning glass lenses, cleaning rain gauge funnels, replacing wetbulb water reservoir and trimming vegetation.

c) **System costing:** Traditional manual equipment often continued to function within specification for decades with minimal maintenance. Modern instrumentation often has a significant asset value and requires regular replacement. The full lifecycle cost including support personnel and laboratory equipment must be determined.

d) **Parallel Testing:** Operate the old system simultaneously with the replacement system over a sufficiently long time period to observe the behavior of the two systems over the full range of variation of the meteorological variable observed.
e) Meta Data: Fully document each observing system and its operating procedures. This is particularly important immediately prior to and following any contemplated change. The recording should be a mandatory part of the observing routine and should be archived with the original data. Algorithms used to process observations need proper documentation. Documentation of changes and improvements in the algorithms should be carried along with the data throughout the data archiving process.

f) Data Quality and Reliability: Assess data quality and reliability of the new system regularly over the first five years of operation. This assessment should focus on establishing that the user requirements have been satisfied.

g) User requirements: In the development of a new system there are generally many unrealistic expectations. Design and implementation should focus on the most strategic issues. Specific users may have peculiar requirements.

h) Data and Meta Data Access: Develop data management systems that facilitate access, use, and interpretation of data and data products by users. Easy access, low cost mechanisms that facilitate use and quality control should be an integral part of data management. This contributes to increased use of the data and feedback concerning errors and omissions.

**Transition to Automated Sensors**

Across the spectrum of observations users there is a range of requirements. The Climate program emphasizes their focus on data continuity and homogeneity of traditional human observations. Observations which do not consist of a deterministic physical quantity provide a particular challenge to automation. The human observation is often an integrated concept due to the ability of the human to assimilate information from various spatial and temporal scales, and various observation characteristics. For example, in the observation of visibility, the observer looks around a 360 degree spectrum and integrates information for distances up to 50km away, and includes knowledge of the immediate history of the event and the climatology of the area. Human observations which are challenging to automate include cloud type identification, present and past weather, identification of phenomena, precipitation types, solid precipitation, obscuration, evaporation, discriminating between sand, dust and haze and the constituents of solar radiation.

When developing an automated system, the following guidelines are recommended.

a) Characterize the human observation: In most cases the human observer integrates sensory cues from sight, sound, touch, and smell over a large space. The Observer has understanding of weather process and has generally monitored the development of weather system over minutes, hours and days. Therefore the human observation needs to be stratified into as many distinguishable constituents as possible.
b) **Characterize the automated observation:** In many cases the automated observation extrapolates from a single point over time. Thus it relies on temporal averaging to represent the three dimensional space.

c) **Compare and contrast under parallel conditions:** Automated sensors often report differently to humans under identical conditions, especially under unusual or spatially variable weather conditions.

**Conclusion**

AWS are being increasingly used to complement and even replace manual observations as the primary mode for weather data collection in Nigeria. Thus it is essential that the transition from manual to automated observation is carefully managed in order that the existing long term climate records are not compromised, but rather enhanced by the close adherence to standards and procedures. Change is a normal part of observations network management. Management of the change process which includes the necessary role players and the allocation of appropriate resources can mitigate the impacts of change and provide meteorological and climate data users with the information they need to preserve standards for climate data and observations used in forecasting.

**Recommendations**

1. A new initiative has been launched in Geneva to radically improve Africa's weather monitoring network. Its aim is to help people across the continent of Africa adapt to the impact of climate change. The Global Humanitarian Forum headed by former UN Secretary-General, Kofi Annan, the United Nations World Meteorological Organization and leading mobile communications companies are behind the initiative dubbed "Weather Info for All." This is a pertinent call to Nigeria Meteorological Agency (NIMET) to strategically position Nigeria to benefit from this novel intervention currently being implemented in East Africa.

2. There is an urgent need for NIMET to improve on the number of Agro meteorological stations available in country as well as improve the availability and quality of meteorological data in Nigeria by (a) Increasing the number stations used for collecting the data to meet the World Meteorological Organization (WMO) standards. (b) Increase the quantity and quality weather measuring instruments. (c) Adopting modern state –of - art technologies for data collection and management. (d) Improve the quality of personnel in NIMET and some other institutions that collect meteorological data.
3. National and International Agricultural intervention projects should include establishment of Weather monitoring station as a component of their project right from the point of planning. These stations could easily be integrated into National weather information Network.

4. NIMET should take inventory of all weather observations stations scattered across the country to ascertain the working conditions, nature and scope of observation with the aim of strengthening the weak or abandoned.

5. There is an urgent need for the establishment of a National weather information Network, that would be saddled with the responsibility of keeping and maintain up-to-date meteorological database management systems (DBMS).

References
World Meteorological Organization, 2008: Development of Guidelines for the Implementation of new data types from either new sensors or following the successful Integration of Sensors CBS/OPAG-IOS (ET-AWS-5)/Doc. 9(1)