**WORLD METEOROLOGICAL ORGANIZATION**

**COMMISSION FOR BASIC SYSTEMS**
OPEN PROGRAMME AREA GROUP ON
INTEGRATED OBSERVING SYSTEMS

**EXPERT TEAM ON REQUIREMENTS AND IMPLEMENTATION**
**AWS PLATFORMS (ET-AWS)**
***Sixth Session***

GENEVA, SWITZERLAND, 20 – 23 APRIL 2010

CBS/OPAG-IOS (ET-AWS-6)/Doc.11.1

(13.4.2010)

ITEM: 11

Original: ENGLISH

# Advances in AWS Technology

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## Summary and Purpose of Document

This document provides information on advances in AWS technology and the development of standards for integration into AWS networks

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## ACTION PROPOSED

This meeting is invited to take into account this information when discussing individual agenda items.

# ADVANCES IN AWS TECHNOLOGY

## Introduction

The ET-AWS session 5 established a list of advances in AWS technology (as well as limitations).The main advances concern telecommunications means and ability of internal diagnostic to optimize the maintenance. There are fewer progresses in the area of sensor development.

The decreasing cost of an AWS make them more affordable and attractive, however, it has to be recognized that the cost of AWS stations remains marginal compared to the initial and running costs of a network. It is very important not to forget this aspect to avoid useless investments by lack of subsequent network management, maintenance, calibration and training.
The ET-AWS agreed that there is a need for continues monitoring of advances of AWS technology for timely and comprehensive advise to Members. This task was proposed for the future Work Plan.

## 1. Review of progress and advances in AWS technologies

### 1.1 Platform:

- There is a wide range of configurations of AWSs for surface measurements are available; high end systems (e.g. for airport, climate applications) are most often user specific configured.
- AWSs for marine measurements are available and operational (buoys, ships).
- Advances in technology and the decrease of costs of sensors and dataloggers led to the development and integration by manufacturers of compact/low-cost weather stations. This is significantly driven by the ability to integrate and display data from multiple sources, in real time and near real time, primarily through the internet.

The compact AWSs are increasingly used for agricultural, urban meteorology. They normally integrate inexpensive sensors of performance of measurement yet to be assessed. Most of these AWS include pre-programmed data processing algorithms that are the property of the integrator.
Given the affordable cost, including installation, the small foot print required, and the increased availability, these platforms have a good chance to capture a large share of the market for producing meteorological data for various applications.

Advantages;

- compact, self-contained;
- low-cost;
- easily deployable;
- integrating up to date forms of communication which allow networking and spatial integration of data.
- ability to establish a denser network;
- real-time and on site storage of data;
- potential to be used as a subset of a fully equipped AWS (e.g. temperature and precipitation);

Disadvantages:

- unknown performance of measurement (sensors, processing algorithms);
- data processing and siting limited to the system configuration.
- standards for installation and maintenance not developed at this time.

### 1.2 Telecommunication

- More and more telecommunication means are available: GSM, GPRS, WIMAX, satellite communication (Inmarsat, Iridium, etc.), etc, including the ability to provide back-up if needed.

- Frequency of data transmission: selectable, function of the balance between the need for data and the cost of transmission; generally is performed hourly, every 5 or 10 minutes, or even 1 minute, available. The transmission period can be switched to more or less frequent transmission to optimize the cost of the transmission.
- An AWS can more and more be seen as an IP object, thus facilitating a central management of the network. IT Security aspects must be taken into account.
- Availability of two way communication for remote diagnostic, troubleshooting, processing algorithm upgrades, thus minimizing the maintenance costs.
- Cost of communication services and equipment is decreasing, making the automatic data transmission affordable.
- The increase in the bandwidth allows the transmission of increased amounts of data, e.g. raw sensor data together with processed data.

### 1.3 Power

The deployment of AWS in remote areas is greatly facilitated by the availability of alternative affordable power solutions: solar and wind power. Yet, the use of sensors that require heating is limited to locations where power is more readily available.

The power needs of an AWS form the AWS Power Budget and cover:

- measuring sensors.
- central processing unit;
- auxiliary equipment used to mitigate the effects of the environmental factors (heating, cooling, decontamination, etc)
- communication lines between individual sensors and the central processing unit.
- Power supply requirements related to data logger capacity to store data for a predetermined period and allow retrieval on site or remotely.
- System losses/phantom loads.

Power solutions are based on the right balance between AWS power needs and availability of reliable solution to provide it.:

- Primary source which delivers sufficient power to power the AWS system and maintain the batteries charged at full capacity; e.g. power from the grid, aeolian, diesel, solar power, or a combination of those.
- Secondary source: generally a battery (rechargeable or not) which would provide power back-up when the primary source is not available. The AWS load should be adjusted to a reduced consumption when the system is operating on battery, e.g. no venting, no heating.

### 1.4 Data acquisition

The advances in electronics have determined significant improvements in the processing component of an AWS:

- It eliminated the need for the calibration of the acquisition system of an AWS, with very high stability and allows integrated control procedures.
- Increased the processing capacity and speed, allowing the integration of data from multiple sensors and the implementation of advanced algorithms for data processing (e.g. sensor redundancy, advanced data filtering, multiple-sensors integration, additional data, sensor/system diagnostics processing and output)
- Significantly increased the storage capacity, to securely store on site data for longer periods in case of transmission problems (useful mainly for climatology).

### 1.5 Sensors

- More and more sensors have internal diagnostics. There is a great interest in transmitting these diagnostics to facilitate distance diagnostics and thus to optimize the maintenance management and associated costs.
- Some sensors (such as barometers) include integrated redundant elements.

But

- The rate of advancements in sensors is slower than a decade ago. Efforts of many NMS to develop new sensors are reduced, due to budget restrictions.
- The technology cycle of about 3 years means that the design stability of sensors is increasingly difficult to maintain for extended periods of time, with impact in the ability to ensure data homogeneity, in particular for climate applications.
- Sensors for “visual observation” or for observation in harsh conditions (cold, icing) require significant power supply, incompatible with an autonomous solar panel system. Therefore, the infrastructure costs may be very high or it becomes unfeasible to implement those sensors where power is not available (e.g. remote area, arctic)

### 1.6 Quality of measurements

- Observations from modern sensors and AWS are more and more repeatable and comparable, without the subjectivity which may exists with human observation.
- AWS helps in the standardization, allowing for spatial and temporal consistency.
- The current processing capacity of AWS allows the implementation of advanced data quality check, on site, building on the availability of concurrent measurements.

### 1.7 Infrastructure, siting, maintenance

- Care in the installation, electrical equipotentiality and lightning protections minimize failure and corrective maintenance.
- Not being linked to the infrastructure needed by a human observer, an AWS offers more flexibility for the choice of its site.

But

- An AWS cannot be left unattended more than one year (and sometimes less, depending on the sensors and the site).

### 1.8 Network

- In area with quite dense networks, the response to a new user need is not necessarily the set up of a new station, but it can come from the spatialization of merged observations (i.e. precipitation radars and rain gauges).
- Function of the intended use of data, a network could be designed on several overlapping layers, with the primary layer consisting of highly performing, complex AWS. The subsequent layers would consist on AWS of various performances and configurations, serving specific purposes, e.g. identifying start and stop of an event, but not offering info on the quality and quantity of the event. This concept could offer the option of an increased density, with a manageable cost.

1.9 Cost

- The cost of procuring and installing an AWS is small compared to the cost of operating it. Adding an additional AWS to an existing network should be assessed based on the life cycle costs, over the expected life span of the system and the expected performance.
- The cost of an AWS is decreasing, but this remains marginal compared to the total initial and running costs of a network: infrastructure, maintenance and calibration, management and training costs.
- Due to the increasing complexity of the data acquisition system, sensors and telecommunication system, the level of skill required for maintenance is higher than for traditional (manual) stations.

## 2. Review existing standards and guides:

### 2.1 CIMO Guide No. 8

Part 2, Chapter 1, Measurements at Automatic Weather Stations. Provides standards and guidelines for requirements (meteorological, climatological,), types, configuration (sensors, central processing unit), data acquisition, data processing, data transmission, AWS software (system and application software, manual entry of observations), data reduction, message coding, quality control, maintenance and calibration, data display, siting configuration, central network data processing, training

Part 1: guidelines for the sensors implemented on an AWS, and the overview of the formulas and mathematical principles that are applied for deriving meteorologically meaningful data, from raw sensor data.

Part 3: presents data reductions and quality management of meteorological sensors and systems, including those used as part of AWS.

## 2.2 EUMETNET Technical Specification (2000) and FUNCTIONAL DEFINITIONS (1999)

*EUMETNET Technical Specification (2000) and FUNCTIONAL DEFINITIONS (1999) of Automatic Weather Stations***,** *prepared by:* ITALIAN AIR FORCE METEOROLOGICAL SERVICE, Ufficio Generale per la Meteorologia: presents in details specifications of aviation and synoptic AWS.

## 2.3. Classification of observation based on siting and measuring performance

*Classification of observation based on siting and measuring performance: CBS.*
Draft of guidelines for the classification of observations based on siting and the maintained performance of instruments is available.

## 2.4. WMO/TD No. 1160, 2003 ALGORITHMS USED IN AUTOMATIC WEATHER STATIONS

*a) Evaluation of questionnaire by M. D. Gifford, USA*
This document lists, by country, the operational use of AWS, the algorithms applied, by parameter, the real time quality control algorithms used, and whether the algorithms are documented and published. It does not include any description of AWS algorithms.

*b) WMO Integrated Global Observing System (WIGOS), Concept Of Operations (CONOPS), Version 4.0*

The CONOPS document for WIGOS, version 4.0 states the following, which could represent the guide for future development of the AWS, in support of the implementation of the WIGOS:

c) Classes of Users and Application areas
NMHSs continue to be the principal owners/operators and major users of data and information generated by the existing observing systems mentioned above. However, the user community is also represented by a growing diversity of stakeholders and decision makers, including national agencies, academia, non-governmental organization, public and private sectors and other societal areas. Depending on the observational data requirements and services provided, the end-user is affiliated to and represents the following application areas:

- Weather analysis and forecast, including early warning
- Agriculture and food production
- Aviation
- Land transport
- Marine resources and shipping services
- Hydrology and water resources
- Industry
- Environmental monitoring
- Disaster mitigation and prevention, emergency response
- Energy
- Public weather services, health and safety
- Climatology and climate services

Furthermore, the Statement of Guidance (SoG) for each of the application areas below has been developed and updated by the CBS OPAG IOS through the RRR process (see section 5.2.5):

- Global Numerical Weather Prediction
- Regional Numerical Weather Prediction
- Synoptic meteorology

- Nowcasting and Very Short Range Forecasting
- Seasonal and Inter-annual Forecasts
- Atmospheric chemistry
- Aeronautical Meteorology
- Ocean Applications
- Climate
- Hydrology
- Agricultural meteorology

### 2.5 Expert Team On Observing Requirements And Standards For Climate WCDMP-No. 65, WMO-TD No. 1403

The meeting of the Expert Team on Observing Requirements and Standards for Climate (ET-ORSC- ET1.2), of the Commission for Climatology (CCl); Open Programme Area Group on Climate Data and Data Management of March 2007 reviewed the AWS impacts on climate-related issues in the context of the climate monitoring principles.

It identified the AWS benefits such as: high frequency in the records, better ability to measure extremes, ability to be deployed in remote areas; general cost-effectiveness; potential use as a quality control tool, and consistency in measurements.

AWS shortcomings identified included data losses; inhomogeneity when migrating from manual observations to AWS; management and maintenance problems; data spikes; rainfall accuracy problems; and loss of visual observations, vandalism affecting AWS.

These negative aspects have implications that include making them generally unsuitable for climate change studies, and constructing climatologies of several parameters, with phenomena and visual parameters especially affected.

Existing recommended Australian standards for AWS network including:

- Data availability greater than 99 %;
- Need for Visual observation sensors;
- Need for an alert system for failure, and adequate data backup ;
- Consider redundant sensors ( Us reference Network);
- High precision measurements meeting Wmo standards;
- Regular inspection and maintenance;
- Preferably intersperse with conventional stations to provide a mutual check;
- Quality control procedures ( Guidelines )

The ET established as objectives the following tasks related to AWS:

a) Develop an updated list of standards for AWSs for climate purposes including:

- sensor precision/network spacing;
- sensor redundancy;
- non-instrumental observations, such as visibility, cloud type and amount, phenomena, and sea state ( provide options and advice on cost-effective means of establishing this capacity within AWS),
- data back-up and transmission.

b) Work on the required precision of climate-related variables:

- CCl to revisit the standards required for AWS.
- Identify the key parameters to be measured for climate purposes.
- Are there “essential” versus “desirable” variables? (Temperature, precipitations, humidity, pressure, surface wind).
- Are the current suggested precisions and network spacing variables too stringent? If so, can we define a “breakpoint” which indicates the most cost-effective values that are acceptable to the climate programme.
- Precipitation is a particularly important variable that poses problems for AWSs (e.g., frequently reads low). More significant problem with solid precipitation: is there a case for specific instrumentation or additives (e.g., heating elements on all stations regularly exposed to extreme cold?);

- Is there a case for “tiered” networks? – i.e., where a certain subset of AWSs has considerably enhanced capacity – e.g., being equipped with visual/phenomena sensors such as lightning detectors.
- Noting the continual conflict between meeting the needs for the climate programme and resource limitations in most countries, this ET would like to seek Policy guidance from WMO on question of cost-effectiveness versus high standards – is there a policy?

c) The issue of loss of visual observations
Need for specialized observational sensors; options include: tiered stations, some with high-end capacity; or else intersperse with conventional stations with capacity to observe phenomena, visual obs, etc.

d) Develop guidance and advices continuity and homogeneity issues

AWS can potentially lead to a loss of continuity of the climate record through problems such as data losses, introduction of inhomogeneities (e.g., migration from manual to AWS), and existence of data spikes.
Issues: Inspection frequency, mechanism for data back-ups (e.g. should all AWSs be fitted with loggers, and with what characteristics (e.g., how many days data?), system alarms on failure, whether to have redundant sensors.

**3. Current Gaps:**

- The assessment of uncertainty at AWS system level, for each of the reported parameters, to fully characterize the measurement, and to include the sensor, the sensor configuration, the data acquisition and processing uncertainties.
- The low cost, compact weather stations are becoming more and more a reality and it’s important to manage the expectations related to their implementation and operation, as a full-blown system or a subsystem (e.g. Temperature and Precipitation); this would cover their configuration, the disclosure of algorithms, the measuring performance, maintenance, installation.
- The potential of using video imaging devices to detect subjective observations and developing methods for the digital interpretation of image data.
- The opportunity of integrating remote area measurements within the AWS algorithms, e.g. lightning, radar data.
- Definition of guidelines for interoperability of sensors across AWS platforms.
- Addressing evolving network requirements (e.g. tiered systems), from an AWS configuration perspective.
- Document standard AWS processing algorithms that could be implemented by integrators, to ensure consistency of data across platforms.