Chapter 8　Automatic Weather Observation

CONTENTS

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8.1　Definitions

WMO defines an automatic weather station (AWS) as a facility that automatically transmits or records observations obtained from measuring instruments. Automatic weather observation refers to the activities involved in converting measurements of meteorological elements into electrical signals through sensors, processing and transforming these signals into meteorological data, and transmitting the resulting information by wire or radio or automatically storing it on a recording medium.

AWSs can be divided into real-time stations, which automatically transmit observed data at fixed times, and off-line stations, which record data on storage devices.

Real-time AWS: A station that outputs observations on a real-time basis, either regularly or upon request by the user. This type of station is used for ordinary synoptic meteorological analysis and monitoring of critical warning states such as storms and river or tide levels. It must be able to transmit observations to a network.

Off-line AWS: A station that records observations on storage devices. This type of station is used for climatological analysis or as an auxiliary facility to manual observations. The data obtained and stored by an off-line AWS need to be transmitted to the user at regular intervals.

Increasing numbers of AWSs now feature both these functions.

Visual observation elements including visibility, cloud cover, cloud type and present/past weather are not recorded by AWSs or monitored by a human observer who transmits the results. Thanks to recent developments in equipment and algorithms that offer comprehensive processing of various observed data, it has become possible to automate the observation of these elements.

8.2　Considerations for Adopting Automatic Weather Observation

8.2.1　Automatic Weather Observing Systems

8.2.1.1　Advantages of Automatic Weather Observation

The following advantages can be expected when automatic weather observation is adopted:

・Continuous observation is possible, and observational data at manned stations can be obtained even when no staff are present. Fully automated systems can also be installed at inaccessible sites. In addition, it is possible to reduce observer numbers and operating costs.

・Since meteorological data are taken as electrical signals, observer errors in reading are eliminated. Standardized observation techniques enable the homogenization of observed data in regions where automatic weather observation is adopted. In addition, new observation elements can be added relatively easily by installing new instruments.

・Optimal measuring instruments with the appropriate level of measurement accuracy for the required observation can be chosen, and the need for observer training is eliminated.

8.2.1.2 Considerations for Adopting an Automatic Weather Observing System

When an automatic weather observing system is to be adopted, consideration not only of its components but also of the overall system is required to ensure the provision of data that satisfy the requirements at hand. It is important to use instruments with high reliability and maintainability for effective system maintenance.

For the components of an automatic weather observing system using software, the following points should be taken into account:

- Each component should have a detailed instruction manual.
- Each component should be highly durable.
- Each component should be easily maintainable.
- Standard devices and interfaces that are adaptable to technological progress should be used.

For the overall system, the following points should be taken into account:

- Detailed technical manuals outlining operating characteristics and the algorithms used in the system should be provided.
- The system should have measures for protection from the influences of lightning, low temperatures and solar radiation.
- The system should be able to perform self-checking diagnosis at regular intervals or upon request.

The specifications of an automated observing system should be carefully considered so that the observation requirements (e.g., observed elements, accuracy, sampling times and averaging procedures) are satisfied and the costs of system introduction are minimized.

Off-line automatic weather observing systems may be deployed in regions where no communication lines are available in order to reduce observer workload. In such cases, it is important to consider the trade-off between the additional maintenance work required for more complex instruments and reductions in the observation workload.

8.2.2 Siting of Automatic Weather Stations

The following points should be taken into account when selecting AWS deployment locations:

- The site should meet the same meteorological requirements as those for conventional observations, and it should be possible to obtain observation data representative of the surrounding area.
- Security measures against severe natural conditions and other interferences, including theft and vandalism, should be considered.

Considerable costs may be incurred in construction, maintenance and security measures for AWSs. An efficient approach in terms of operation and cost is to examine the meteorological and technical requirements before deciding on the specifications and design, including maintenance and security measures.

8.2.3 Management

8.2.3.1 Data Quality Control

Quality control for automatically observed data is essential to provide the user with accurate observational information. This is important not only in obtaining accurate data but also for monitoring the operation of the observing system. When an abnormal observation is reported, the cause should be identified and any maintenance/calibration required should be carried out as soon as possible.

An automatic weather observing system usually has a built-in self-checking diagnosis function for each observation element, and a real-time AWS can report related information immediately. However, as such automated quality control procedures have limitations, additional quality control is recommended. Such procedures include the detection and handling of errors in data transmission on individual communication lines, inspection and handling of the format and content of messages usually transmitted as WMO codes (*Guide on the Global Data-processing System*, WMO-No. 305, 1993), and further data processing to exclude or label erroneous data.

Other methods of quality control include comparing observed values with those at neighboring stations (an auxiliary method), with analyzed values based on numerical analysis, and with statistically analyzed values to identify short- and long-term variations that cannot be detected by ordinary quality control procedures.

The periodicity of maintenance work, including occasional comparison in the field with travelling standards, should be determined in consideration of the quality control methods adopted.

8.2.3.2 Maintenance

Maintenance should be organized according to the distribution of observation sites and system functions in order to minimize the related costs without adversely affecting AWS performance. Maintenance at individual stations is frequently shared between work in the field and that at regional/national maintenance centers. Ideally, a function to transmit self-checking diagnostic information at regular intervals should be included as part of AWS processing functions.

Field maintenance: It is more economical to replace faulty sensors or modules than to repair them in the field. Such replacement should be carried out by technical personnel from a maintenance center, and only preventive maintenance such as cleaning and oiling of mechanical parts should be performed by local staff.

Maintenance centers: Technical personnel at maintenance centers should be able to detect and eliminate problems with faulty sensors, modules or means of data transmission. Such centers should therefore be staffed by skilled technical personnel with a knowledge of both hardware and software, and should keep a sufficient stock of spare sensors/modules and appropriate equipment to enable checking and repair for all parts. As frequent faults with the same part suggest a problem in the design of the system itself, repair should be performed by the manufacturer.

8.2.3.3 Calibration

AWS sensors should be compared and calibrated against travelling standards at regular intervals as with conventional stations to ensure performance. If deviations beyond the allowable limit are detected, the sensor should be calibrated against the working standard at a calibration laboratory.

In addition to the calibration of the sensors and equipment for data acquisition and transmission, signal conditioning modules in particular must be calibrated at regular intervals with more accurate measuring instruments or data acquisition systems so that their electronic characteristics (including electric current, voltage, capacitance and resistance) lie within the prescribed ranges. Components repaired at maintenance centers must be recalibrated at a calibration laboratory prior to their re-use.

8.2.3.4 Training

Electronics technologies applied at AWSs are significantly different from those used at conventional manned stations. Accordingly, maintenance and calibration using such technologies should include training for personnel in charge of automatic weather observation. When adopting an automatic weather observing system, it is necessary to train or recruit experienced personnel so that they have knowledge of AWS functions.

Automatic weather observing system manufacturers should provide two sets of documentation for system management: user manuals outlining the operation and usage of system functions, and technical manuals detailing the technical operating characteristics of the system used for maintenance and repair. These manuals should be available for reference in any situation.

8.3 Outline of the JMA-95-type Automatic Weather Observing System

The configuration of JMA's automatic weather observing system is outlined in the figure below (Figure8.1).

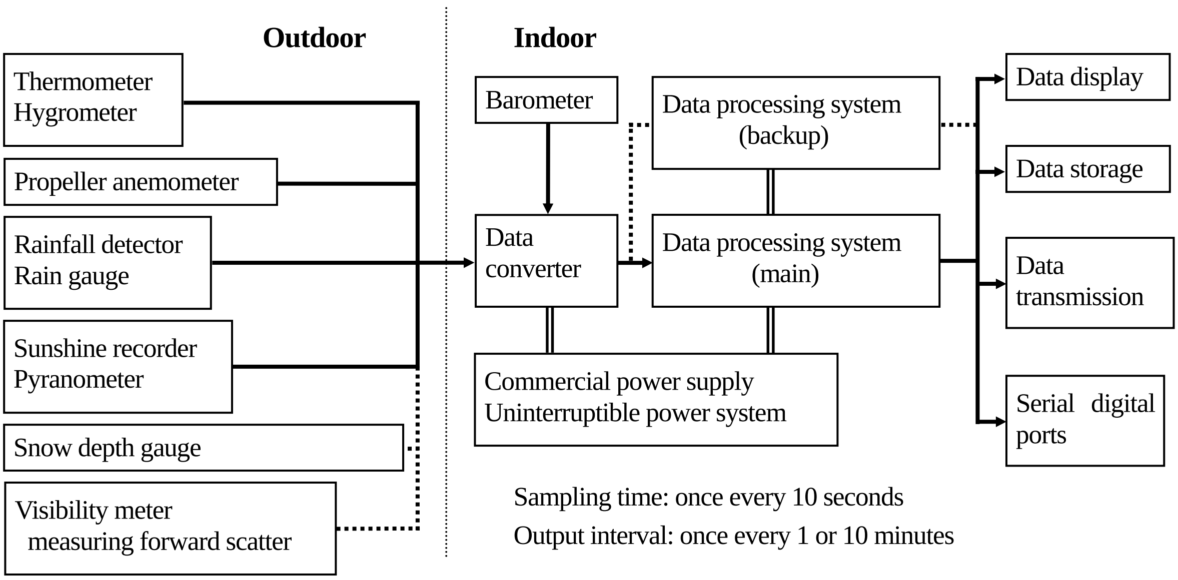

Figure 8.1 Configuration of a JMA automatic weather observing system at a manned station

8.3.1 Hardware Protection

Japan is a country with a subpolar northern part and a subtropical southern part, and has regions of remarkable rain or snow because of the monsoon climate. For this reason, special focus is placed on lightning arresters, tightness, winterization and heat resistance, and corrosion resistance as hardware protection considerations for automatic weather observing systems.

(1) Lightning arresters

Protective devices are essential to guard against high voltages that may damage electronic components. These are attached to JMA-type AWSs to specifically protect against lightning. Sufficient grounding is necessary to carry high-voltage current to the ground.

(2) Tightness

Because electronic parts are sensitive to moisture, electronic equipment for outdoor use should be enclosed in watertight casing. However, if such casing is airtight, a pressure difference develops between the inside and the outside, and temperature changes may cause rainwater to be drawn into the enclosure. As such, JMA-type AWS casings have a ventilation hole of about 3 mm in diameter covered with waterproof but air-permeable cloth.

(3) Winterization and heat resistance

Some JMA AWSs are equipped with air conditioning in order to keep the temperature within the operation range of the system's electronic parts. In cold regions, some sensors are warmed to avoid icing. At observation sites with heavy snow cover, instruments are installed at such a height that they are not buried under snow.

(4) Corrosion resistance

Components in coastal or industrial areas should be protected against corrosion. It is necessary to select corrosion-resistant materials that require little maintenance or are protected by a paint layer, though the latter requires periodical maintenance. JMA-type AWSs use corrosion-resistant aluminum, carbon materials and stainless steel, which provide corrosion-free performance.

8.3.2 Software-based Management

The software built into AWSs includes a routine to monitor the operation of the overall system and a quality control function to check the reliability of observed data.

(1) Routine to monitor operation

JMA-type AWSs have the built-in self-checking diagnostic functions outlined below; if an abnormal signal is detected, it is reported.

- The power supply status, provision of power to each sensor, heater operation and transmission conditions of each signal are monitored.
- The accuracy of converter circuits is monitored by measuring the reference signal every hour.

(2) Quality control function

If a measurement gives a meteorologically incorrect value or exceeds the measurable range, if the difference between an observed value and the one ten seconds before exceeds the prescribed limit, or if there is a contradiction between observational data (e.g., no solar radiation is observed during a period of sunshine), the data are automatically deemed unreliable, and this information is reported. At the same time, a message with the unreliable data omitted is prepared and issued as output.

8.3.3 Sensors Used in the JMA-95-type Automatic Weather Observing System

The JMA-95-type automatic weather observing system uses sensors with easier maintainability than those in previous automatic weather observing equipment that meet WMO accuracy recommendations as closely as possible. In addition, sensors capable of measuring observation elements that were previously impossible to measure without human input have been adopted. Some of the automated sensors in the JMA-95-type system are described below.

(1) Visibility meter measuring forward scatter

This instrument automatically measures visibility and weather phenomena whose observation used to require manpower. It measures the scattered components of monochromatic near-infrared beams radiated in the atmosphere and converts the measurements into values representing visibility. Using the secular fluctuation of scattered light and information from a capacitance-type rainfall detector on the occurrence and intensity of rainfall, the instrument's algorithm determines present and past weather conditions. The device enables automatic ongoing objective observation, which was previously possible only with human input.

(2) Ultrasonic snow depth gauge

This instrument automatically observes the total depth of snow on the ground – a value previously recorded by a human observer using a snow stake. It consists of an ultrasonic transmitter and receiver at a certain height, and measures the turnaround time of ultrasonic waves reflected from the snow surface. The sound speed is corrected for air temperature, and the distance from the sensor to the snow surface is calculated from the corrected sound speed, thereby allowing the snow depth to be ascertained on a continuous basis. The device is protected against noise, which may otherwise disturb its ultrasonic-wave-based measurements.

(3) Pyranometer and automated tracking sunshine recorder

This instrument consists of a pyrheliometer directed toward the sun by an automatic tracking system to measure direct solar radiation. The period of direct solar radiation exceeding the 120-Wm^{-2} value recommended by WMO as the sunshine threshold is counted as the sunshine duration. The automatic tracking system is also equipped with a pyranometer, and tracks the sun directly using a sunlight sensor when there is sunshine and a built-in arithmetic and logic unit when there is no sunshine. This system enables accurate measurement of sunshine duration throughout the year, and the amount of maintenance work required for the tracking setup is reduced. As a further application, it can also measure either global solar or diffuse sky radiation in addition to direct solar radiation. Diffuse sky radiation is measured by shading only direct solar rays reaching the pyranometer using a tracking shade disk.