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AES GUIDELINES

FOR

CO-OPERATIVE CLIMATOLOGICAL

AUTOSTATIONS

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Preface

The purpose of the AES Guidelines for Co-operative Climatological Autostations (Version 2.0) is to provide co-operative agencies with guidelines and standards for automatic climatological stations. Automatic stations provide much flexibility for how, when and how often measurements are made. This can lead to better and more frequent observations. At the same time, the introduction of automatic procedures can also introduce inconsistencies into existing climatological data sets which have been compiled mainly from manual observations. With our current focus on climate change and variability, such inconsistencies are unacceptable. It is therefore imperative that these inconsistencies are minimized or at the very least are controlled. This document is one step towards that end. Adherence to these guidelines will ensure that the data collected by automatic stations meet the minimum requirements for compatibility with AES climatological network data. The longer term goal of achieving full compatibility and eliminating all inconsistencies in existing and future data sets will require considerably more effort and co-operation from all agencies concerned with the collection, application and archiving of climatological data. To this end, there is a need for more data from co-located automatic and manual observation sites. We strongly encourage the practice of maintaining an overlapping period of record when the conversion from a manual to an automatic station is made.

The shaded portions within this document indicate changes from Version 1.0 (June 30, 1989). Two major changes have been incorporated within this version: the elimination of the three data level specifications and more detailed information on data logger algorithms.

A supplemental document is being prepared which will implement these guidelines for specific data logger systems.

With the rapidly changing technology for automatic data collection systems and the increasing demands for more sophisticated climate data, this will be a "living and growing" document. Future versions and supplements will be developed as the need arises.

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- the Expert Committee on Agrometeorology; and
- all co-operative agencies.

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1. Introduction

The purpose of this document is to provide co-operative agencies with guidelines and standards for the selection, installation, operation and maintenance of a climatological autostation and to ensure that the data collected will be compatible with the Atmospheric Environment Service (AES) climatological network data.

It is recognized that some measurements by autostations may differ significantly from traditional manual measurements. Some of these differences can be minimized by the data standard specifications. Those measurement differences which cannot be addressed by standards definitions will be identified and the impacts of these differences discussed.

The term "automatic" suggests that manual labour is not required to properly maintain the climate station. **THIS IS NOT THE CASE.** It is **STRONGLY** recommended that regular station inspection be carried out to ensure that all instrumentation is operating properly. It is recommended that each station be visited **WEEKLY** and immediately after severe weather events (e.g. hail, freezing rain, thunderstorms, high winds, etc.), if at all possible. These visits need only be a quick visual inspection to look for such things as ice or dust accumulation, recording of manual snow or rain observations for comparison purposes, cleaning of radiation/sunshine sensors and ensuring equipment has not been damaged by severe weather events. A complete station inspection and sensor calibration is recommended twice a year (spring and fall).

This document consists of three major sections. The section on Descriptions and Definitions defines terms used in this document and describes station classification and observing programs, climatological elements, and other relevant concepts. The section on Requirements and Standards provides siting, site documentation, data accuracy and data logger programming standards. This section must be adhered to if the data are to be acceptable for inclusion in the AES National Climatological Archive. The section on Recommended Practice provides recommendations on system and support requirements, guidelines on installation, site operation and maintenance, procedures for data quality assurance and information on recording format and mediums.

2. Descriptions and Definitions

This section defines terms used in this document and provides descriptions of climatological station classifications, observing programs, climatological elements and other relevant concepts.

2.1 Climatological Autostation

A climatological autostation uses an automatic device or system to make measurements of climatological elements following a set program, processes these measurements to report in the international system (SI) of units, transmits the observations directly to the operator and/or records the observations for periodic retrieval by the operator.

2.2 Co-operative Agency or Agent

A co-operative agency or agent is an individual or group outside of AES who has agreed to follow the AES guidelines on autostations outlined in this document and who provides the data to AES for archiving.

2.3 Climatological Station Classification and Observing Programs

A climatological station is a general term used for any station reporting for climatological purposes (e.g. the preparation of statistics describing the climate of the site). The observation program at a climatological station is determined by the intended use of the climatological data. Observation programs may vary from simple daily temperature extremes to hourly measurements of the full complement of meteorological parameters. For convenience, AES has three climatological observation program categories for its climatological network. Observation programs of climatological autostations may fit into these same categories.

Ordinary Climatological Station: A climatological station at which observations are made at least once daily of temperature extremes and/or precipitation amount. Twice daily readings of temperature are strongly recommended. Data collected by these stations will provide basic information for a general climatological classification of a region.

Principal Climatological Station: A climatological station at which hourly readings are taken, or at which weather observations are made at least three times daily in addition to hourly tabulation from autographic records. In Canada, nearly all Principal climatological stations are synoptic and/or aeronautical stations. Observations from these will consist of the basic climatological elements which include temperature, precipitation amount, humidity, wind, and atmospheric pressure. The more frequent and greater number of climatological elements from these stations provide sufficient information to make climate-dependent operational decisions and input to most models requiring climatological data.

Supplementary Climatological Observations: These are specialized observations which may include evaporation, rate of rainfall, soil temperature, bright sunshine, radiation, snow survey, ice, ozone, etc. and are taken in addition to the basic climatological elements at some Ordinary and Principal climatological stations. Data from these observations serve special applications such as in the development of safe and efficient structural design criteria, developing efficient agricultural and industrial practices, etc.

2.4 Climatological Elements

The primary function of a climatological station is to provide a record of the meteorological elements observed, such that the climate of that area can be accurately described. Over recent decades, climatological data have assumed new importance as a result of social changes, new technological opportunities and impending urgent social and environmental issues in which climate is a dominant factor. New techniques are being developed and investigations carried out to study the application of climatological information in such fields as agriculture and forestry, health and comfort, land use and facility placement, water resources and marine activities. Current concerns about the impacts of climatic change and increased variability on human activities have placed additional emphasis on the need for maintaining **high quality** and **consistent** climatological observations and data sets.

Traditionally, climatological stations using manual techniques have provided quality information by following uniform observing methods and recording formats [1, 2, 3, 4, 5 (Page 71)]. This has been accomplished by expending considerable resources over many years to standardize the content, quality and format of climatological observations. Economic constraints have dictated the need and new technology has provided the means to move toward automating most atmospheric observations. In doing so, it is imperative that we preserve much of what has already been standardized. We must devise means of acquiring data to improve the data base using proven technology for automation and make use of data collected by all agencies.

The following are descriptions of climatological elements currently measured and reported from the above Observation Programs and archived in the AES National Climatological Archive. Brief discussions of their applications and the differences between manual and automatic measurements will also be given.

2.4.1 Temperature

The air temperature is the most basic of climatological elements observed at almost all climatological stations. It is measured at a height between 1.25 and 2.0 metres above ground level. Air temperature sensors must be properly ventilated and protected from direct solar radiation by a screened shelter or radiation shield and preferably located over a surface representative of the general area. Soil temperature at specified levels below the ground surface is measured as part of supplementary observation programs at some climatological stations [6]. Temperature elements which are currently archived in the AES National Climatological Archive are hourly air temperature (at the beginning of the hour), daily maximum air temperature, daily minimum air temperature and daily soil temperatures at 5, 10, 20, 50, 100, 150, and 300 centimetres (cm) below the ground surface.

Air temperature is perhaps the most widely used climatological element. It is a basic indicator of climatic trend and variability; it is used in the derivation of other climatological elements and as a basic input parameter to most climatic models.

Manned climatological stations measure air temperature using traditional liquid in glass thermometers, bimetal thermographs, or electrical thermometers based on resistance elements, thermistors or thermocouples. Soil temperatures are usually measured with electrical thermometers buried at specified depths. Hourly air temperatures are instantaneous readings taken near the beginning of each hour. Daily maximum and minimum temperatures are measured with specially constructed liquid in glass thermometers which retain the maximum and minimum value until they are read and reset. Bimetal thermographs can also provide the maximum and minimum values over a specified period.

Climatological autostations measure temperatures exclusively with electrical thermometers. Temperature data from autostations are comparable with those from manned stations provided careful consideration is given to temperature sensor accuracy, sensor-shield time constants, sensor sampling frequency and measurement averaging. This is particularly important for obtaining comparable daily maximum and minimum values. **WHEN AN AUTOSTATION REPLACES A MANNED CLIMATOLOGICAL STATION, THE TEMPERATURE SENSOR SHOULD BE INSTALLED IN THE EXISTING STEVENSON SCREEN AND CARE SHOULD BE TAKEN TO REPLICATE THE TIMES OF OBSERVATION OF THE PREVIOUS MANNED PROGRAM. AN OVERLAP PERIOD WITH THE MANNED PROGRAM IS STRONGLY RECOMMENDED.**

In addition to instantaneous hourly temperatures to maintain comparability with existing manual observations and technological capability, hourly average temperatures are important for many biological and physical processes. These measurements will be archived in the AES National Climatological Archive under a different element number.

2.4.2 Precipitation

Precipitation is defined as the liquid or solid products of the condensation of water vapour falling from clouds or deposited from the air on the ground. It includes rain, hail, snow, dew, rime, hoar frost and mist precipitation. The total amount of precipitation which reaches the ground in a stated period is expressed as the depth to which it would cover, in a liquid form, a horizontal projection of the earth's surface. Snowfall is also expressed by the depth of fresh snow covering an even horizontal surface. The following quantitative precipitation elements are **currently** archived in the AES National Climatological Archives:

Total rainfall: daily total accumulation of liquid precipitation measured by an AES Type A (**copper**) or Type B (**plastic**) rain gauge.

Total snowfall: the daily depth of freshly fallen snow on flat ground measured with a ruler.

Total precipitation: daily total accumulation of both liquid and solid precipitation. **At ordinary climatological stations, the water equivalent of the snowfall is obtained by simply dividing the amount of snow by ten (10) and adding to the liquid precipitation. At principal climatological stations and special stations, the total precipitation is measured by a Nipher precipitation gauge (or equivalent). Weighing gauges such as the Fischer & Porter and Belfort gauges are also used. The accumulated sum of total rainfall plus total snowfall will not necessarily equal the total precipitation at stations equipped with a Nipher precipitation gauge (or equivalent).**

Rainfall Intensity: the rate of liquid precipitation measured in millimetres per hour (mm/h) for durations from 5 minutes to 24 hours using a tipping bucket rain gauge.

Depth of Snow on the Ground: the total depth on the ground of the snow pack including the depth of any layers of ice which may be present. The area selected for the measurement shall be chosen with a view to avoiding drifts. At the time of observation, this depth is determined by making a series of ruler measurements and taking the average.

Precipitation is a basic climatological element and has wide applications in practically all sectors. It is of particular importance to agricultural and hydrological operations and planning. Rainfall intensity and snow depth data are used in developing structural design criteria.

Manned climatological stations use the gauges noted in the above descriptions to measure the associated precipitation element. Because precipitation measurements are dependent on the catch efficiency of the gauge, different gauges will provide different precipitation values even at the same location. **When more than one type of precipitation gauge is co-located at a site, the AES Type A and Type B gauges have been designated as the standard rainfall gauges.** Their values are used to correct other gauges, in particular, the tipping bucket gauges, to ensure data consistency.

Climatological autostations use tipping bucket type gauges or weighing type gauges which have been adapted with electronic sensors (shaft encoders or potentiometers) to translate the weight displacement into an electrical signal. The major problem with autostation rainfall precipitation measurements is the lack of a standard rain gauge value for correcting the tipping bucket gauge values. The correction factor is significant and can range from 0.5 to over 7.0. The difference between these gauge measurements is the result of not only differences in gauge catch efficiencies but to a larger extent, of the deterioration of the calibration of the tipping bucket bridge. This will have a serious impact on the use of autostation rainfall intensity data in computing design criteria.

For snow depth measurements, a sensor based on a sonic ranging device is now available for autostation use. **Sensor exposure is very important to obtain representative snow depth readings.**

2.4.3 Humidity

Humidity is a measure of the water vapour content of the air. It is calculated with respect to water, both at temperatures above and below freezing. Humidity is commonly expressed in terms of dew point temperature and relative humidity defined below:

Dew point: is the temperature at which the air would become saturated (with respect to water) if cooled at constant pressure and without the addition or removal of water vapour.

Relative humidity: is the ratio, expressed as a percentage, of the amount of water vapour actually present in the air to the amount of water vapour which would be present if the air were saturated at the same temperature and pressure.

Humidity data are used for weather analysis, climatological classification, evaporation calculations, agricultural applications and in heating, air conditioning and ventilation design. **Appendices C and D illustrate the computation of humidity and dewpoint, respectively.**

Manned climatological station instruments for measuring humidity include psychrometers, dewcels and hygrographs. A psychrometer consists of a dry and wet bulb pair of thermometers; the measurements from which are used to compute the **vapour pressure, relative humidity and** dew point temperature. A dewcel consists of a temperature sensor covered with a wick soaked in a solution of lithium chloride which is heated until its vapour pressure is in equilibrium with the ambient air. It is calibrated to provide a direct reading of the dew point temperature. A hygrograph consists of a humidity sensitive element (e.g. strands of hair or gold beaters skin) whose movement is coupled to a pen marking a chart calibrated in percentage units of relative humidity. Humidity sensors require the same ventilation and radiation shielding as the air temperature sensor and they are usually co-located. Humidity measurements are made at scheduled reporting times.

Climatological autostations generally use humidity sensors in which salt crystals absorb moisture and affect the electrical characteristics of the sensing element. Outputs from these sensors can be processed to provide either dew point or relative humidity values. These sensors are particularly vulnerable to dust and dirt which affect their calibration. **When humidity sensors are properly maintained, their data are comparable to manned stations.**

2.4.4 Surface Wind

Wind is defined as air in motion. It is in reality a three dimensional vector quantity but surface wind, measured at **the international standard height** of 10 metres above the ground, is usually treated as a two dimensional vector quantity specified by its horizontal direction and speed. Wind direction by convention, is the direction from which the wind is blowing and is referenced to true north.

Climatological applications of surface wind data include studies of moisture and heat loss, wind break placements, land use planning and structural design criteria.

Manned climatological stations use wind sensors usually consisting of an anemometer for speed and a wind vane for direction. These sensors provide electrical outputs to drive chart recorders and/or visual indicators from which the observer takes the measurement. Depending on the type of station and anemometer used, the wind **direction and** speed for a given hour may be based on the wind run for the entire hour or it may be the 2 or 10 minute average just prior to the report time. **It is recommended that all three wind directions and speeds be reported (i.e. 2-minute, 10-minute and 1-hour average).**

Climatological autostations can use similar wind sensors as those used in manned stations. **It is recommended that wind directions and speeds be averaged and reported over 2 and 10 minutes (before the hour) and the entire hour to ensure consistency with manual observations.**

2.4.5 Atmospheric Pressure

The atmospheric pressure on a given horizontal surface is the force per unit area exerted on that surface by virtue of the weight of the atmosphere above. The station pressure is thus equal to the weight of a vertical column of air of unit area above the station site extending to the outer limit of the atmosphere. The sea level pressure is the weight of a vertical column of air of unit area above sea level extending to the outer limit of the atmosphere. Stations situated at sea level will measure sea level pressure directly while other stations must calculate it by adding to the station pressure the equivalent weight of an air column extending from the station elevation down to sea level. **The procedure for computing mean sea level pressure in Canada is shown in Appendix E.**

Atmospheric pressure data are used primarily in weather analyses. Other climatological applications include trajectory and storm track studies, health studies, and for verification and evaluation of climatic models.

Manned climatological stations use mercury or aneroid barometers to measure atmospheric pressure. The basic principle of the mercury barometer is that the pressure of the atmosphere is balanced against the weight of a column of mercury the length of which is measured on a scale graduated in units of pressure. Aneroid barometers consist mainly of a closed metal chamber, completely or partly evacuated, and a strong spring system which prevents the chamber from collapsing due to the external atmospheric pressure. At any given atmospheric pressure there will be an equilibrium between the force of the spring and the external pressure. This equilibrium position is coupled to an indicator against a scale calibrated in units of pressure. Both mercury and aneroid barometers are read and recorded manually at scheduled reporting times.

Climatological autostations use sensors to measure atmospheric pressure based on aneroid pressure transducers which provide a proportional electrical signal. The data logger can measure and convert these electrical outputs into pressure units.

Both manual and automatic pressure sensors are affected by the operating temperature of the instrument, so proper procedures for making temperature corrections should be followed. Manual and automatic atmospheric pressure measurements **are** readily comparable.

2.4.6 Radiation

Solar radiation is the electromagnetic energy of the sun. The solar radiation incident on the top of the terrestrial atmosphere is called extraterrestrial solar radiation. Ninety seven percent of this radiation is confined to the spectral range 0.29 to 3.0 microns which is referred to as short-wave radiation. Part of the extraterrestrial solar radiation penetrates through the atmosphere to the earth's surface, while part of it is scattered and/or absorbed by the gas molecules, aerosol particles, cloud droplets and cloud crystals in the atmosphere.

Terrestrial radiation is the long-wave (wavelength longer than 3 microns) electromagnetic energy emitted by the earth's surface and by the gases, aerosols, and clouds of the atmosphere. It is also partly absorbed within the atmosphere.

For the purpose of observing solar radiant energy at the earth's surface, **the broad range of radiant energy is divided into conveniently handled groups.** These standardized components are assigned identifying numbers and are referred to as Radiation Fields (RF). **Each particular field measures a specific type of long- or short-wave radiation, utilizing equipment designed for that purpose.** The six main radiation fields measured at AES radiation stations are described below **and are illustrated in Figure 1:**

- RF1 Global Solar Radiation is the total incoming direct and diffuse short-wave solar radiation received from the whole dome of the sky on a horizontal surface. **This is measured using pyranometers.**
- RF2 Sky Radiation (Diffuse) is the portion of the total incoming short-wave solar radiation received on a horizontal surface that is shielded from the direct rays of the sun by means of a shading ring. **This is measured using pyranometers.**
- RF3 Reflected Solar Radiation is the portion of the total incoming short-wave radiation that has been reflected from the earth's surface and diffused by the atmospheric layer between the ground and the point of observation onto a horizontal surface. **This is measured using pyranometers.**
- RF4 Net Radiation is the resultant of downward and upward total (solar, terrestrial surface, and atmospheric) radiation received on a horizontal surface. **This is measured using net pyrrometers.**
- RF7 Total Illumination is the total of visible radiant energy (0.51 to 0.61 microns) from the whole dome of the sky received on a horizontally-mounted photovoltaic cell. **This is measured using illuminometers.**
- RF9 Downward Atmospheric Radiation is the total long-wave atmospheric radiation from the whole dome of the sky received on a horizontal surface. **This radiation is primarily emitted by water vapour, carbon dioxide and ozone and is measured with a pyrgeometer.**

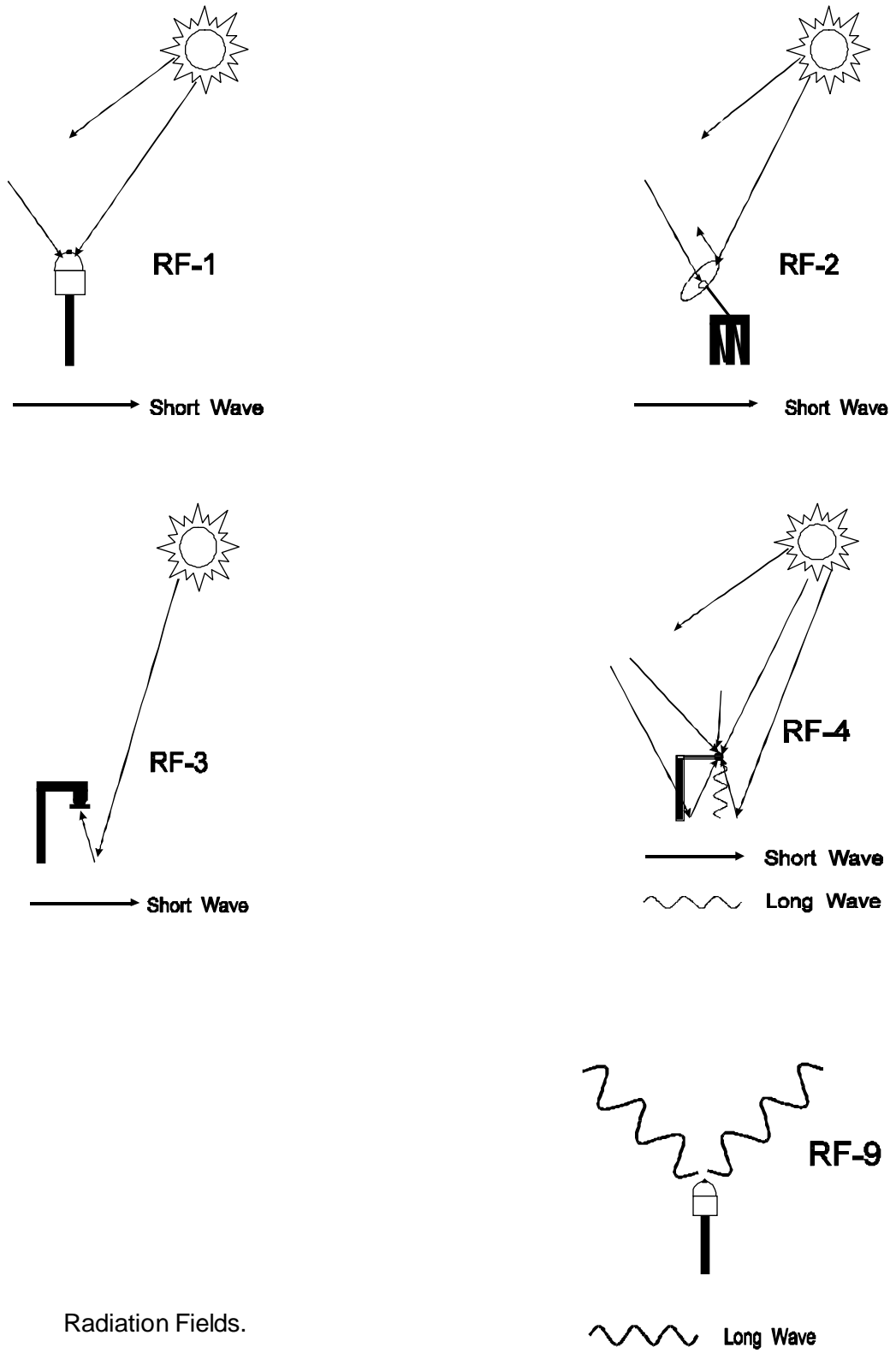


Figure 1: Radiation Fields.

The various fluxes of radiant energy to and from the earth's surface are amongst the most important terms in the heat budget of the earth as a whole, for specific regions on the earth's surface and in the atmosphere. Radiation data are used for the following purposes:

the study of the transformation of energy within the earth-atmosphere system and of its variation in time and space;

the analysis of the properties and distribution of the atmosphere with regard to its constituents such as aerosols, water vapour, ozone, etc.;

the study of the distribution and the variations of incoming, outgoing and net radiation; and

the satisfaction of the needs of biological, medical, agricultural, architectural and industrial activities with respect to radiation.

The AES Solar Radiation Network uses high precision calibrated sensors to convert incident radiation to electrical output. The sensor outputs are processed by a data logger and recorded in engineering units [7].

Climatological autostations use the same sensors as in the AES Solar Radiation Network but the output frequency would be reduced. In addition, climatological autostations may use less precisely calibrated instrumentation.

All radiation sensors require routine cleaning of dust, dirt, frost, snow, etc. from windows and domes which protect the sensing element. Autostations with radiation sensors must therefore have routine servicing and cannot be left unattended for extended periods.

For international comparability of data, radiation data are recorded following Local Apparent Time (LAT). Other time standards are acceptable only if a reduction to LAT does not introduce significant loss of information (i.e. if the sampling frequency is high enough).

Specialized radiation sensors are increasingly being used to measure specific spectral ranges. Two examples of these types of sensors include Ultraviolet (UV-A, UV-B) and Photosynthetically Active Radiation (PAR) - .4 to .7 microns.

2.4.7 Bright Sunshine

Bright sunshine measurements in Canada have been made using the Campbell-Stokes sunshine recorder. This instrument involves the focusing of the solar rays by a glass sphere onto a calibrated paper card. The focused sun rays scorch the card and burn a trace which is used to determine the length of "bright sunshine" in tenths of hours [8].

Bright sunshine data are used as a subjective indicator of climate and have also found applications in agriculture and in other sectors generally as a parameter to estimate a radiative term in a model.

Manned climatological stations use the Campbell-Stokes sunshine recorder as described above.

Climatological autostations do not have a commercially available sensor to provide bright sunshine measurements. Sensors are being developed based on a photoelectric sensor with the **international** adoption of a 120 Watt-m⁻² criterion for bright sunshine. The resulting data, however, may not be directly comparable with the existing bright sunshine records based on the Campbell Stokes recorders.

2.4.8 Evaporation

Evaporation is the net loss of water from a natural surface to the atmosphere. In Canada, evaporation data are obtained from measurements using Class A evaporation pans [9]. A standard correction is applied to pan evaporation data to derive "lake evaporation" values. Lake evaporation is defined as the evaporation loss under identical conditions from small natural open water bodies having negligible heat storage.

Evaporation data are used in agriculture, hydrology and engineering with particular applications in the design and operation of reservoirs, irrigation and drainage systems, and industrial liquid waste treatment systems. **Evaporation data are also increasingly used as direct input into numerical weather prediction models in place of 'cloud parameterization' variables.** Evaporation is also an important term in both the atmospheric and terrestrial water balance.

Manned climatological stations use the Class A evaporation pan which is an open cylindrical pan of non-corrosive metal, 120 cm in diameter and 25 cm deep mounted on a level flat wooden base. The pan is filled with water to a fixed level and the amount of water required to refill the pan each day to maintain this level is the pan evaporation loss. Additional daily parameters required for correcting the pan evaporation to lake evaporation include: maximum and minimum air temperature, maximum and minimum pan water temperature, accumulated precipitation, and total wind run over the pan.

Climatological autostations, **at present**, do not have commercially available systems to provide Class A pan evaporation measurements. **Commercially available systems can be adapted to simulate manual Class A pan measurements BUT need to be tested and compared to the manual measurements.** **Evaporation** values for autostation sites **may** have to be derived from other climatological parameters which have commercially available sensors. These may include air temperature, humidity, radiation and wind.

2.5 AES National Climatological Archive

The AES National Climatological Archive is the national depository of climatological data in Canada. The term climatological data as it relates to this archive is not restricted to the basic climatological elements but also includes upper air data, **marine weather data**, ice data, and air quality data [10]. The archive contains over 300 different data elements representing the various climatological factors which are measured or derived in Canada. The archive stores AES network data in three forms: paper, micrographic and digital. The Canadian Climate Centre (CCC) has the responsibility for maintaining this archive and for facilitating its use. It must also ensure that the data stored therein meet the standards of accuracy and completeness established by the AES to reflect current levels of scientific knowledge and technology.

AES network data for this archive are received in a variety of ways including: source documents, charts from recording instruments, computer compatible media from AES autostations, **AES Regional Offices** and digital data from the AES telecommunications network. Prior to being archived, quality control procedures are applied to the data manually and with the aid of computer produced diagnostic reports to ensure its **completeness and** compliance with the prescribed quality standards.

The inclusion of non-AES data into the AES National Climatological Archive should be routed through the appropriate AES Regional Office where possible. The acceptability of a non-AES data set will be determined by the Canadian Climate Centre **and AES Regional Offices based on adherence to these guidelines. On** acceptance, **the Canadian Climate Centre's** responsibility will be limited to receiving, archiving and providing access to these data sets.

3. Requirements and Standards

Standards in this section provide specifications which must be adhered to by co-operative climatological autostations to ensure that the data collected will be comparable with AES climatological network data and acceptable for inclusion in the AES National Climatological Archive. Other purposes which these standards serve are:

- a) to minimize differences between manual and automatic measurements;
- b) to encourage uniformity of measurement;
- c) to establish a common practice for reporting, recording, and transmitting data for archiving; and
- d) to maintain data quality to meet international standards.

3.1 Siting Guidelines for Climatological Stations

This section describes general siting requirements for obtaining representative temperature, humidity, precipitation, and wind data at ordinary and principal climatological stations. These will serve as basic guidelines for climatological autostations [11].

3.1.1 Siting Guidelines--General

Where available, the applicable instrument manuals and circulars should be consulted to obtain siting and installation requirements for a specific system.

Site location should be consistent with the intended purpose of the data collected at the site. For example, a site which is representative of a micro-climate within a large region should not be selected as a site for synoptic observations.

In selecting sites for synoptic observations, the objective is to choose a site which is representative of a relatively large area with common features. In order to achieve this goal, it is necessary to select sites which are not influenced by small scale geographical or man-made features which are unique to the site but not common to the area for which the data are required. Conversely, if the area is mountainous and contains numerous lakes, then the site should be selected to reflect the effect of these features.

The same principle applies to specialized sites. In the case of an airport site, it should be selected to represent conditions over the runway complex. Thus, if the runways are subject to valley effects, cold air drainage, etc., the site should be selected to represent these effects.

Minimum distances from obstructions are specified in order to prevent the rain shadow effect from affecting precipitation data, or turbulence from affecting wind data. If the obstructions are trees, it is recommended that the distances be increased to allow for growth over a long period of time. **An object which subtends a horizontal angle of less than one degree should not be considered an obstruction in most cases.**

In cases where the terrain rises abruptly, for example, a steep cliff, the feature should be treated as an obstruction and be subject to the same minimum distances as trees or buildings.

Generally, sites on flat land with few obstructions will yield representative data where the terrain is flat and free from obstruction. In forested, mountainous, not built-up areas, moderately sheltered sites which meet the minimum distances from obstructions should be selected because they will yield data which are representative of the particular region.

These general guidelines also apply to the siting of automatic stations. Because these stations may be located in remote regions and unattended for long periods of time, consideration should also be given to accessibility and security.

Instruments for measuring other parameters may be located on the site providing that their presence does not affect the meteorological measurements.

After a site is completed it is essential to prepare and maintain documentation of the site. These requirements are given in section 3.2

3.1.2 Siting Guidelines--Ordinary Climatological Stations

These sites should be located:

- a) on open, level ground in at least 6 metres (m) x 6 metres, preferably 15 m x 15 m area, covered with short grass or at least on natural ground (Figure 2);
- b) such that sensors are at a distance from vertical obstructions (e.g. trees, buildings, etc.) of at least four times the height of the obstruction for rain gauges, and two times the height of the obstructions for Stevenson screens; and
- c) in an area which provides ease of access for the observer and security in the case of an unattended automatic climatological station.

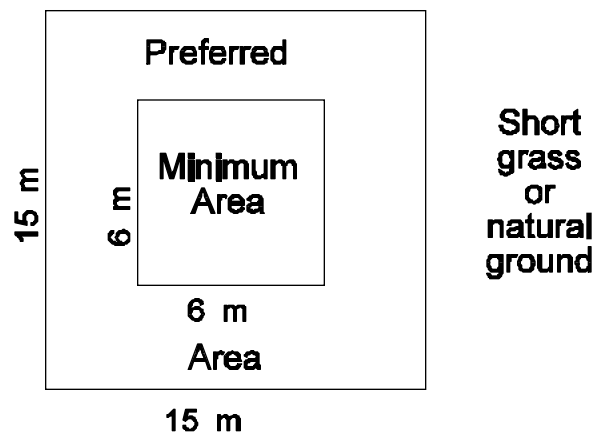


Figure 2: Ideal Ordinary Climatological Station Site.

3.1.3 Siting Guidelines--Principal Climatological Stations

These siting guidelines apply to non-airport synoptic and/or hourly reporting stations. They should be located:

- a) on open, level ground with a primary area of at least 15 m x 15 m covered with short grass or at least on natural ground protected (when necessary) by a single rail, cable, or chain link fence, with a secondary turf covered area of at least 30 m x 30 m, and a protected area of 90 m x 90 m centred on the primary area (Figure 3);
- b) such that sensors are at least a distance from vertical obstructions of ten times the height of the obstruction for anemometers, four times the height of the obstruction for rain gauges, two times the height of the obstruction for Stevenson screens (Figure 4); and
- c) in an area which provides ease of access for the operator, security for the instruments and access to electrical ducts where necessary.

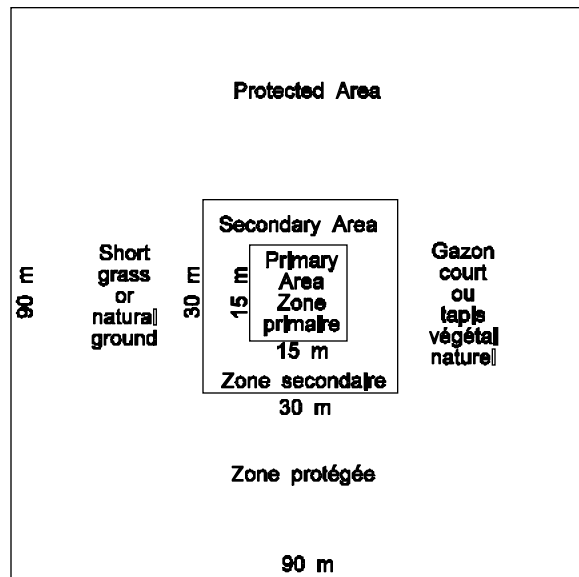


Figure 3: Ideal Principal Climatological Station Site.

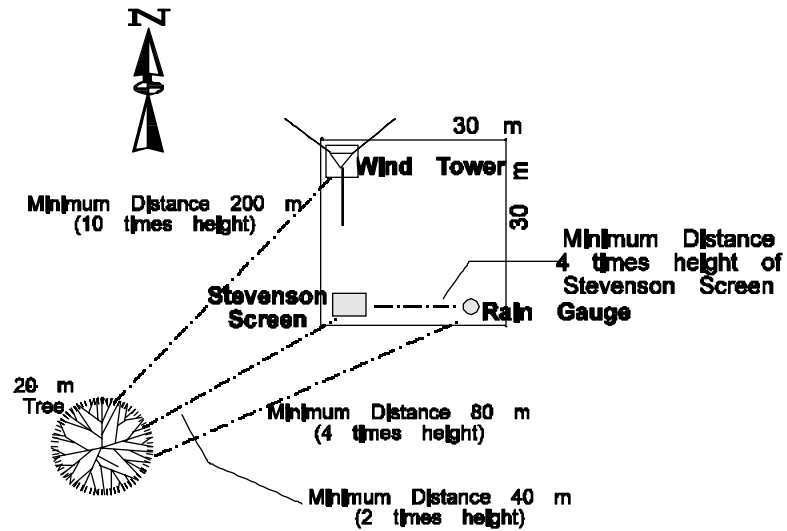


Figure 4: Climatological Station Siting - Minimum Distances.

3.1.4 Siting Guidelines--Supplementary Climatological Observations

Special siting requirements for supplementary climatological elements are given in section 3.3 on Data Standards for each element.

3.1.5 Siting Guidelines--Locations to be avoided

All climatological stations should avoid locations which are:

- a) on the top of hills;
- b) in hollows, at the bottom of narrow valleys, and near ridges or hills or cliffs;
- c) near isolated ponds or streams;
- d) near roads where snow removal equipment can affect the site;
- e) where excessive drifting snow accumulates;
- f) where there is excessive human or animal traffic;
- g) near vehicle parking areas; and
- h) where heat is exhausted by vehicles or buildings.

3.1.6 Siting Guidelines--Exceptions

There may be cases where not all the above siting guidelines can be met or it may be desirable, for specific applications, to take observations at non-standard locations such as on hill tops, in valleys, etc. In these cases, proper station documentation as described in the next section will be of particular importance to the usefulness of the data. The acceptance of such data into the AES National Climatological Archive will be determined by AES for each individual case.

3.2 Station Documentation

The automatic station documentation requirements on the location, exposure, observation schedule, data logger operating software, and instrumentation are outlined below. Initial information for a station must be submitted and accepted by AES before a station's data are submitted for archiving. Additional information must then be provided as needed to record an adequate history for each station.

3.2.1 Initial Information for each station

Station Identification:

station name; and

identifier under which data are given to AES.

Note: Sensors more than 200 m apart must not be considered as one station.

Station Operator(s):

name of agency that owns and maintains station equipment; and

name of agency and/or individual that routinely monitors station operation.

Observing Times:

list of the times at which observations are reported each day.

Station Coordinates:

horizontal coordinates in latitude and longitude (**degrees, minutes and seconds, if available**) or Universal Transverse Mercator coordinates;

elevation of ground above sea level (**nearest 0.1 metres**); and

an indication of roughly how accurate these figures are.

Note: The station coordinates should be obtained carefully from good maps, usually at a scale of 1:50,000 or larger.

Maps and Plans:

topographic maps at a scale of 1:10,000 to 1:50,000 with station location marked on it (1:250,000 scale maps are acceptable only where nothing better is available);

site plan showing station equipment, especially each sensor; and trees, structures, water bodies, roads, landmarks, any other significant features, and some information on the shape of the ground out to 50 m beyond the sensors in all directions; and

if all the station's sensors are not in one small group, additional site plans may be necessary to show everything adequately.

Photographs:

four photographs, one facing each in north, east, south and west directions, showing the station's sensors and their setting; and

if all the station's sensors are not in one small group, additional photographs may be necessary to show everything adequately.

Written information on Station and Sensor Exposure:

measured height above ground for every individual sensor (Note: A few sensors may vary their height above ground, usually to maintain a constant height above snow surface. For such sensors, details on this variation should be given too);

a brief description of the typical summer ground surface under each sensor;

if the data from any sensor are likely to be affected by the exposure, describe this (e.g. wind being funnelled by a valley, precipitation catch being reduced by too open or sheltered an exposure, temperature being reduced because the station is in a "frost hollow"); and

a description of the station's surroundings, including:

the topography, with emphasis on topographic features that may influence the weather at the station;

major water bodies in the area, including when (or to what extent) they normally freeze and thaw, and any influence they have on weather at the station;

the vegetation and land use in the area;

major human activities that may influence the station, such as release of heat, dust, etc. by nearby industry or cities, if any; and

a description of known local weather phenomena that would be helpful for users of the meteorological data to know about, if any (e.g. local weather anomalies that make the station's data look questionable in some respect).

Station Equipment:

the manufacturer and model number of each "device" in the station (Typically, a "device" is a sensor complete with the accessories that are always used with it, or a box of electronics);

description of significant abnormalities in the equipment, if any (e.g. substitution of non-standard parts);

the method used to transmit the data from the station; and

the schedule for routine station monitoring, maintenance and sensor calibration.

3.2.2 Initial Information for Sensors and Other Equipment

Each combination of manufacturer and model number must be described in detail. Occasionally this is done by recording that the device in question is identical to another device or is composed of several other devices, but it is usually done as follows:

Written Summary for Each Device:

manufacturer and model;

a description of the device's structure, function, and characteristics, including its major good points and failings;

for sensors and timers, accuracy specifications and recalibration requirements;

overall results from comparisons between this device and other devices of the same type, if available; and

a bibliography of the more useful books and published papers that provide information on this device.

Other Information for Each Device:

a copy of the most informative manual(s) for the device, including plans, schematics, and full device specifications;

if the manual does not include adequate, good quality photos of the device, these should also be provided; and

if feasible, copies of some of the most useful published papers on the device.

3.2.3 Documentation of the Data Logger Operating Software

For autostations, the operating software of the data logger has a primary role in determining the accuracy and comparability of the resulting data. It is therefore of vital importance that this software be properly documented by including the following:

- a complete source code listing of the operating program including all sampling algorithms and calibration constants;
- a flow chart for the above source code; and
- a log documenting all changes to the operating software and the date(s) and time (HH:MM) of these changes.

3.2.4 Ongoing Records

Notes: All descriptions of conditions at stations must include the date(s) and time (HH:MM) on which the conditions were observed. All descriptions of "devices" must include the date they were prepared.

Minor changes that will not affect the meteorological data may be ignored.

Station Moves and Sensor Moves:

- date(s) and time (HH:MM);
- horizontal distance and direction or new horizontal coordinates;
- vertical distance and direction or new vertical elevation above sea level; and
- new site photographs.

Abrupt Exposure Changes:

- date(s) and time (HH:MM); and
- description of changes.

Abrupt Equipment Changes:

date(s) and time (HH:MM);

device types added, removed, or exchanged; and

significant equipment abnormalities started, ended or changed.

Gradual Changes:

report progress from time to time with date and condition on that date.

Seasonal Changes:

normally ignored unless they cause data problems; and

if recorded, are usually in terms of a typical year, not as an endless series of dated changes.

Conditions After Each Abrupt Change:

dated information on the new condition of the changed aspect of the station, with any maps, plans or photographs needed to show it adequately; and

after a station move, complete new information on the whole station is required.

Other Information on Each Station:

dates of visits to station for major checking or maintenance; and

dates of sensor calibration checks.

Additional Information on Device Types:

as additional information on the failings, comparative characteristics, etc. of a type of device becomes available, it should be given to the AES.

3.3 Data Standards

This section provides data specifications for each climatological element in the AES National Climatological Archive for which automatic sensor systems are currently commercially available. Those climatological elements which cannot be routinely measured by automatic sensors have been identified and discussed in section 2.4.

It should be noted that these data specifications apply to the final value of a climatological element reported by the automatic station just prior to submission for archiving. To meet these specifications, consideration must be given not only to the sensor, but also to the methods used by the data logging system to sample, process (linearize), and convert the sensor output into SI units. An acceptable sensor must therefore have specifications meeting at least the data standard specifications given here.

3.3.1 Specification Levels

Three specification levels have previously been defined [12] to provide a range related to current climatological data needs and available technology.

One OPTIMUM level is being defined which is currently achievable by automatic climatological stations and which meets present climatological data needs [13,14]. Some users may require data of higher quality (e.g. research applications) or of lesser quality than specified. In both cases, the AES data acceptability will be determined on an individual basis.

3.3.2 Specification Terms

The following defines the terms used in the data standard specifications:

Unit:	the SI unit in which the climatological element is archived.
Note:	The automatic station must have the capability to convert sensor outputs into this unit prior to reporting, transmitting and recording the climatological element.
Uncertainty:	the interval in which the "true value" of the climatological element at the time of measurement is expected to lie. Uncertainties may be expressed in absolute value or in percent of actual observed value.
Resolution:	the smallest increment of a climatological element value that is reported and/or recorded.
Range:	the interval between upper and lower value limits for which a climatological element is reported.
Sampling Frequency:	<p>the number of measurements (samples) per unit time that is taken of a climatological element by the data logger.</p> <p>The recommended sampling frequency is once per five seconds. This sampling frequency is faster than necessary for some elements but simplifies data logger programming at the cost of an increase in power consumption.</p>
Output Averaging Time:	the time period (number of samples) used for the purpose of determining the reported value. Unless otherwise specified, ONE-MINUTE averages are suggested as suitable for "instantaneous" values.
Reporting Frequency:	the number of times the value of a climatological element is reported and/or recorded for a specific period. Each reported value is based on a number of measurements (samples) defined by the sampling frequency and the output averaging time .

3.3.3 Time Units and Conventions for Reporting

The basic time intervals will be seconds, minutes, hours and days. The data logger's real-time clock **should be adjusted** to within ± 30 seconds of the actual time referenced to a standard clock **at all times**. **It is recommended that Universal Coordinated Time (UTC) OR local STANDARD time be used as the standard clock time.**

The timing convention for reporting will be at the beginning of each time unit. **For "single (instantaneous)" samples, a ONE-MINUTE AVERAGE (over the last minute) will be computed and reported at the beginning of each time unit.** For accumulations, averages and extremes, the reported value will be based on measurements taken over the interval between the previous report time to the current report time unless otherwise specified.

Various definitions exist for the "climate day" for the purpose of reporting accumulations, averages, and extremes of basic climatological elements over a 24 hour period. The AES National Climatological Archive maintains a variable definition for the "climate day" as follows:

Ordinary Climatological Station	Local standard time (morning and late afternoon)
Principal Climatological Station	0600 UTC to 0600 UTC (i.e. the period starting at 0600 UTC and ending at 0600 UTC the following day)

The Principal Climatological Station "climate day" definition is precise and provides comparability with current Principal Climatological and Synoptic stations nationally and internationally. The "climate day" ends at the following times for the various time zones across Canada:

Time Zone	Local Standard Time (LST)
Universal Coordinated Time (UTC)	0600
Newfoundland Time (NST)	0230
Atlantic Standard Time (AST)	0200
Eastern Standard Time (EST)	0100
Central Standard Time (CST)	0000
Mountain Standard Time (MST)	2300
Pacific Standard Time (PST)	2200

AUTOSTATIONS WHICH ARE USED TO REPLACE MANUAL CLIMATOLOGICAL STATIONS SHOULD MAINTAIN THE REPORTING TIMES ("CLIMATE DAY" DEFINITION) OF THE MANUAL CLIMATOLOGICAL STATION TO ENSURE THE ARCHIVE DATA SET CONTINUITY.

It is recommended that maximum and minimum temperatures, precipitation, snow depth be reported on an hourly basis. This information will be included in the AES National Climatological Archive under different archive elements, if required. This will allow users to generate daily climatological data over any required time interval.

There are exceptions for the archiving of some supplementary climatological elements which use other time references. Specifically, radiation fields are recorded following Local Apparent Time (LAT) as noted in section 2.4.6 and soil temperatures are referenced to local standard time. These exceptions will be noted in greater detail in the standards given for each element.

3.3.4 Air Temperature

Units:	degrees Celsius (°C)
Uncertainty:	± 0.3°C
Resolution:	0.1°C
Range:	-60 to +50°C
Sampling Frequency:	5 seconds
Output Averaging Time:*	1-minute 1-hour
Reporting Frequency:	1 per hour

*the output averaging taken during the last minute of the hour and reported on-the-hour is the primary and preferable measurement to be reported since it is consistent with the existing archived hourly temperature element.

Hourly average temperature is important for biological systems and will be archived under a different element number.

Sensors in Current Use

Temperature sensors in AES autostations are generally modified commercial sensors, with thermal lag coefficients from 30-100 seconds in air, at the ventilation rate provided by the shield.

- (i) RDF Corporation No. 21C-11-S-Z-C, 100 ohm Platinum temperature probe (modified, AES Model AES/TS-G)
- (ii) Foxboro Dynatherm 7062Wt, Nickel resistance temperature sensor
- (iii) Veco 32A38 thermistor (modified AES Drawing C0240)
- (iv) Yellow Springs Instruments (YSI) Thermilinear thermistor (YSI 17316-72)
- (v) Campbell Scientific Inc. (CSI) 107F temperature probe (YSI 44002A thermistor) or CSI 107 temperature probe (Fenwal UUT51J1).
- (v) YSI 44212 Thermilinear thermistor
- iv) Rotronic 850, MP-100C and MP-100F.

Sensor Requirements

Shielding from solar-related radiation is essential for temperature sensors.

Acceptable shields for autostation temperature sensors include:

- AES Stevenson screen
- Teledyne Geotech aspirated radiation shield
- Canadian Centre for Inland Waters (CCIW) parallel pie plate shield
- AES parallel plate radiation shield
- Six or twelve plate Gill radiation shield
- AES Marine screen

FOR AUTOSTATIONS REPLACING A MANNED CLIMATOLOGICAL STATION, THE TEMPERATURE SENSOR SHOULD BE PLACED IN THE EXISTING AES STEVENSON SCREEN.

Siting & Exposure Requirements

Boom-mounted sensor/shield units for autostations in regions where snow can accumulate are mounted at heights up to 1.5 m above the maximum snow depth (often up to 5 m above ground surface). This applies also to Stevenson screens, if surrounding snow is not frequently cleared; otherwise Stevenson screens are mounted 1.25 to 2 m above a **level surface representative of the general area and clear of obstructions.**

3.3.5 Maximum/Minimum Temperature

Units:	°C
Uncertainty:	± 0.3°C
Resolution:	0.1°C
Range:	-60 to +50°C
Sampling Frequency:	5 seconds
Output Averaging Time:	Maximum/minimum determined from sample of 60 1-minute averages
Reporting Frequency:	1 per hour

Sensors in Current Use

same as for air temperature

Sensor Requirements

same as for air temperature

Siting & Exposure Requirements

same as for air temperature

3.3.6 Accumulated Precipitation

	<u>Tipping Bucket</u>	<u>Weighing Gauge</u>
Units:	mm	mm
Uncertainty:	greater of ± 0.2 mm or $\pm 2\%$ of value	greater of ± 0.6 mm or $\pm 2\%$ of value
Resolution:	0.2 mm	0.2 mm
Range:	0 - 500 mm	0 - 500 mm
Sampling Frequency:	cumulative total and clock synchronous	cumulative total and clock synchronous
Output Averaging Time:	1-hour total	1-minute average
Reporting Frequency:	1 per hour	1 per hour

Sensors in Current Use

- i) AES Tipping Bucket Rain Gauge (AES Drawing Series 0405), normally used unshielded and only for rainfall
- ii) Fischer and Porter No. 35-1559 Weighing Precipitation Gauge (modified by the addition of a Baldwin 5V86, 5V233 or 5V241 optical shaft encoder depending on desired resolution)
- iii) Fischer and Porter No. 35-1559 Weighing Precipitation Gauge (modified by the addition of a potentiometric interface).
- iv) Belfort No. 5915 or 6071 Potentiometric Precipitation Gauge
- v) Texas Tipping Bucket (CSI TE525), rainfall only.

Sensor Requirements

To minimize the effect of wind and eddies on the collection of falling snow, some form of shielding of the collecting mouth of a gauge is necessary. The types of shields used in the AES for weighing gauges include:

- i) Alter (AES Drawing series 0419)
- ii) Large Nipher (AES Drawing C0420-40)

The large Nipher shield should be used in exposed windy environments; in all other cases, an Alter shield should be used. A weighing precipitation gauge should never be installed unshielded.

Siting & Exposure Requirements

On a level, well drained surface, preferably with short vegetation to minimize the collection of splash. Avoid the sides of hills.

As close to the ground as feasible. For all-year precipitation gauges, the orifice should be 1.5 m or more above the expected level of snow surface.

Removed from surrounding obstructions a minimum of four (4) times the height of the obstruction. If this is not possible (such as in forest clearings, etc.) the gauge should never be closer to an obstruction than the height of the obstruction above the gauge orifice.

It is recommended that the weighing gauge be installed in conjunction with a snow depth sensor.

It is highly recommended that a manual collection gauge (AES standard Type A (copper) or Type B (plastic) rain gauge and/or Nipher precipitation gauge) be operated in conjunction with the automated gauges. The manual gauges should be read as often as possible to minimize losses. If at all possible, a suggested frequency is WEEKLY and after significant precipitation events. This will act as checks against the automated gauges and provide correction factors for the data quality assurance program.

3.3.7 Rate of Precipitation

	<u>Tipping Bucket</u>	<u>Weighing Gauge</u>
Units:	mm-h ⁻¹	mm-h ⁻¹
Uncertainty:	greater of ± 0.2 mm-h ⁻¹ or $\pm 2\%$ of value	greater of ± 0.6 mm-h ⁻¹ or $\pm 2\%$ of value
Resolution:	0.2 mm-h ⁻¹	0.2 mm-h ⁻¹
Range:	0 - 500 mm-h ⁻¹	0 - 500 mm-h ⁻¹
Sampling Frequency:	1 per minute	1 per minute
Output Averaging Time:	1-minute total	1-minute average
Reporting Frequency:	1 per minute	1-hour total and/or Significant precipitation

Reporting frequency during precipitation events at one-minute intervals allows generation of maximum rainfall intensities for other periods (≥ 1 minute) by external means. This reduces the demand on the remote processing system BUT increases data outputs. Maximum rainfall intensities will be generated for the following time periods in a 24-hour interval (calendar day): 1-minute, 2-minute, 5-minute, 10-minute, 15-minute, 30-minute, 60-minute, 120-minute, 6-hours and 12-hours.

Sensors in Current Use

- i) AES Tipping Bucket Rain Gauge (AES Drawing Series 0405), normally used unshielded and only for rainfall
- ii) Fischer and Porter No. 35-1559 Weighing Precipitation Gauge (modified by the addition of a Baldwin 5V86, 5V233 or 5V241 optical shaft encoder depending on desired resolution)
- iii) Fischer and Porter No. 35-1559 Weighing Precipitation Gauge (modified by the addition of a potentiometric interface).
- iv) Belfort No. 5915 or 6071 Potentiometric Precipitation Gauge
- v) Texas Tipping Bucket (CSI TE525)

Sensor Requirements

To minimize the effect of wind and eddies on the collection of falling snow, some form of shielding of the collecting mouth of a gauge is necessary. The types of shields used in the AES for weighing gauges include:

- i) Alter (AES Drawing series 0419)
- ii) Large Nipher (AES Drawing C0420-40)

The large Nipher shield should be used in exposed windy environments; in all other cases, an Alter shield should be used. A weighing precipitation gauge should never be installed unshielded.

Siting & Exposure Requirements

On a level, well drained surface, preferably with short vegetation to minimize the collection of splash. Avoid the sides of hills.

As close to the ground as feasible. For all-year precipitation gauges, the orifice should be 1.5 m or more above the expected level of snow surface.

Removed from surrounding obstructions a minimum of 4 times the height of the obstruction. If this is not possible (such as in forest clearings, etc.) the gauge should never be closer to an obstruction than the height of the obstruction above the gauge orifice.

It is highly recommended that a manual collection gauge (AES standard Type A (copper) or Type B (plastic) rain gauge and/or Nipher precipitation gauge) be operated in conjunction with the automated gauges. The manual gauges should be read as often as possible to minimize losses. If at all possible, a suggested frequency is WEEKLY and after significant precipitation events. This will act as checks against the automated gauges and provide correction factors for the data quality assurance program.

3.3.8 Snow Depth

Units:	cm
Uncertainty:	greater of ± 1.0 cm or ± 1 % of value
Resolution:	0.1 cm
Range:	0 - 940 cm
Sampling Frequency:	Sensor dependent.
Output Averaging Time:	1-minute per sensor Mean of multi-sensor measurements
Reporting Frequency:	1 per hour

Sensors in Current Use

Campbell Scientific CSMAL01 ultrasonic depth sensor (8 ultrasonic burst avg.)
Campbell Scientific UDG01 ultrasonic depth sensor (user determined average)

Sensor Requirements

The snow depth sensor has an effective distance measurement window of 40 cm to 1000 cm. Therefore, the sensor must be mounted at a height within this window. Try to pick a height compatible with the maximum snow accumulation for the chosen site. Largest system errors will be at the beginning of the snow season because the path length will be longest. As the season progresses the snow pack builds towards the sensor, shortening the path length and reducing any associated errors.

Care should be taken to orientate the **CSMAL01** sensor so that the sun shield plates block sunlight from the associated temperature sensor. Basically, the shield plates should face East and West. **The UDG01 sensor relies on an external temperature measurement. The snow depth sensor should be mounted in close proximity to this temperature sensor in order to minimize temperature errors. It may be necessary to provide another temperature sensor if the former is not possible.**

When mounting the sensor, care should be taken to ensure that the transducer is perpendicular to the ground to avoid slant range problems.

Siting & Exposure Requirements

A preferred site would be on flat ground, preferably in the open, and free of any downwind drifting caused by buildings, trees, etc. Also, long grass or weeds will be `seen' and can cause a lot of signal scattering and erroneous reading at the beginning of the season. Clear the field of view to short stubble or bare ground.

The siting of snow depth sensors is critical in order to obtain representative readings. Installation of multiple sensors should be considered.

It is highly recommended that manual snow depth readings be taken occasionally during the winter season in conjunction with the automated snow depth sensor. This will act as a check against the automated measurement and provide correction factors for the data quality assurance program.

The snow depth sensor should be installed with an accumulated precipitation gauge.

3.3.9 Atmospheric Pressure

Units:	Hectopascals (Hpa)
Uncertainty:	± 0.5 hPa
Resolution:	0.1 hPa
Range:	880 - 1060 hPa
Sampling Frequency:	5 seconds
Output Averaging Time:	1-minute
Reporting Frequency:	1 per hour

Sensors in Use

- i) Mechanisms Ltd. Type M1991/A Digital Aneroid Barometer (modified)
- ii) Paroscientific Digiquartz Model 215-AS-002
- iii) Setra Systems Model 270 pressure transducer (Example - Campbell Scientific SBP270).

Sensor Requirements

The venting of a barometer or pressure transducer is critical. If the pressure sensor is not in a well vented enclosure, a static vent must be provided. Static pressure vents used in the AES include:

- Bristol Aerospace Modular Acquisition Processing System (MAPS^R) type Pressure Vent No. 695-00103-1
- AES/British Meteorological Office (BMO) Pattern Static Pressure Vent (AES Drawing C0106)
- Hermes Drifting Buoy vent

A routine calibration procedure is essential if pressure data is used for synoptic meteorology purposes. It is recommended that a barometer or pressure transducer quality assurance procedure be implemented.

Pressure accuracy is seriously affected by dynamic pressure (due to the wind) and the transducer temperature coefficient.

3.3.10 Relative Humidity

Units:	(%) percent
Uncertainty:	$\pm 7 \%$
Resolution:	1 %
Range:	10 - 100 %
Sampling Frequency:	5 seconds
Output Averaging Time:*	1-minute 1-hour
Reporting Frequency:	1 per hour

*the output averaging taken during the last minute of the hour and reported on-the-hour is the primary and preferable measurement to be reported since it is consistent with the existing archived hourly relative humidity element.

Hourly average relative humidity is important for biological systems and will be archived under a different element number.

Relative humidity may be computed from air temperature and dew point measurements (Appendix C).

Sensors in Current Use

Humidity sensors in the AES are generally modified commercial sensors, with response times (lag coefficients) from 30-100 seconds in air at the ventilation rate provided by the screen or shield.

- i) Lambrecht Humidity Transmitter, 800L series (Pernix®)
- ii) CSI 207/207F temperature and relative humidity (Phys-Chemical Research PCRC-11) probe.
- iii) Vaisala HMP 35A humidity probe (HUMICAP® H-sensor)
- iv) Rotronic 850, MP-100C and MP-100F.

Sensor Requirements

Shielding requirements are similar to those of air temperature sensors.

Humidity sensors can deteriorate with exposure to very high or very low humidity, oil vapours, sulphur gases and compounds and persistent humid, salty environments. Comparison to manual observations are recommended on an annual basis and more frequently in harsh environments. The results of this comparison will determine the need of humidity sensor rejuvenation or replacement.

Siting & Exposure Requirements

Siting and exposure requirements are similar to those of air temperature sensors and are usually collocated in a common screen or shield.

3.3.11 Dew Point Temperature

Units:	°C
Uncertainty:	± 0.5 °C
Resolution:	0.1 °C
Range:	-50 to +45 °C
Sampling Frequency:	5 seconds
Output Averaging Time:*	1-minute 1-hour
Reporting Frequency:	1 per hour

*the output averaging taken during the last minute of the hour and reported on-the-hour is the primary and preferable measurement to be reported since it is consistent with the existing archived hourly dew point temperature humidity element.

Hourly average dew point temperature is important for biological systems and will be archived under a different element number.

Dew point temperature may be computed from relative humidity and temperature measurements (Appendix D).

Sensors in Current Use

Dew point sensors in the AES are generally modified commercial sensors, with response times (lag coefficients) from 30-100 seconds in air at the ventilation rate provided by the screen or shield.

- i) AES Type E Dewcel (AES Drawing series 0306)

Sensor Requirements

Shielding requirements are similar to those of air temperature sensors.

Siting & Exposure Requirements

Siting and exposure requirements are similar to those of air temperature sensors and are usually co-located in a common screen or shield.

3.3.12 Wind Direction/Speed

	Direction	Speed
Units:	degrees (from true North)	kilometres per hour km-h ⁻¹
Uncertainty:	± 10°	greater of ± 2 km-h ⁻¹ or ± 5 % of value
Resolution:	± 5°	1 km-h ⁻¹
Range:	1 - 360 degrees	0 - 180 km-h ⁻¹
Sampling Frequency:	5 seconds	5 seconds
Note:	<p>A gust is defined as the highest 5-second wind speed logged over the past ten minutes, provided it equals or exceeds 28 km-h⁻¹ (15 knots) and provided it exceeds the current two minute mean speed by at least 9 km-h⁻¹ (5 knots).</p> <p>External processing should be used to determine whether or not the gust criteria have been met.</p>	
Output Averaging Time:	2-minutes 10-minutes 1-hour	2-minutes 10-minutes 1-hour
Note:	Wind direction should be vector-averaged over the output averaging time.	
Reporting Frequency:	1 per hour of: mean dir for last 2-minutes mean dir for last 10 minutes mean dir for last hour direction at peak wind speed	1 per hour of: mean for the last 2-minutes mean for the last 10-minutes mean for hour peak speed for the past hour maximum 2-minute wind speed past hour maximum 10-minute wind speed past hour
	<p>Standard deviations of wind direction (sigma theta) and wind speed may be reported for the output averaging times with a resolution of 1 degree and .5 km-h⁻¹, respectively (World Meteorological Organization (WMO) recommendation).</p>	

Sensors in current use:

- (i) AES type 78D sensor
- (ii) AES type U2A direction and wind speed detector. The wind direction detector requires a synchro motor to potentiometer interface.
- (iii) AES type 45B
- (iv) R.M Young 05103
- (v) Met One 014A/024A; Met One 013A/023A

Sensor Requirements

Suitable tower for mounting the sensors, preferably tilt pole.

Anemometer response is characterised by the starting threshold and distance constant for the wind speed and the damping ratio for the wind direction. The distance constant for wind speed is a "first-order response" and is the length of fluid flow past the sensor required to cause it to respond to 63.2% of a step-function change in speed (expressed in metres or feet). The wind vane tends to overshoot when subjected to an instantaneous change in wind direction and experiences a damped simple harmonic motion before reaching a steady state. The damping ration specifies the response of the sensor. The anemometer should satisfy the following:

Starting Threshold	$\leq 3.7 \text{ km-h}^{-1}$
Distance Constant	$< 5 \text{ metres}$
Damping Ratio	0.3 to 0.7
Gust Survivability	280 km-h^{-1}

Siting & Exposure Requirements

On level, open terrain atop a 10 m tower (**international standard height**). Open terrain is defined as an area where the distance to any obstruction is at least 10 times the height of the obstruction.

Where standard exposure conditions cannot be met, the anemometer height may be increased to avoid the effect of local obstructions.

3.3.13 Radiation

RF1	Global Solar Radiation
RF2	Sky Radiation (Diffuse)
RF3	Reflected Solar Radiation
RF4	Net Radiation
RF7	Total Illumination
RF9	Downward Atmospheric Radiation

Units:	RF1-RF4, RF9: Megajoules per square metre (MJ m ⁻²)
	RF7: kilolux hours (Klux-h)
Uncertainty:	RF1-RF4, RF9 greater of $\pm 5\%$ or ± 0.02 MJ m ⁻² per hour
	RF7 greater of $\pm 10\%$ or ± 0.1 Klux-h
Resolution:	RF1-RF4, RF9 0.001 MJ m ⁻²
	RF7 0.001 Klux-h
Range:	RF1 Zero to 5.0 MJ m ⁻² per hour
	RF2 Zero to 5.0 MJ m ⁻² per hour
	RF3 Zero to 5.0 MJ m ⁻² per hour
	RF4 -5.0 to + 5.0 MJ m ⁻² per hour
	RF7 Zero to + 150.0 Klux-h
	RF9 < Zero to 2.0 MJ m ⁻² per hour
Sampling Frequency:	5 seconds
Output Averaging Time:	1-hour average for all RF fields
Reporting Frequency:	1 per hour
Note:	reporting hours are referenced to local apparent time

Sensors in Current Use

- i) Kipp Pyranometer for RF1, RF2 and RF3
- ii) Eppley Model 2 Type PSP pyranometer for RF1, RF2 and RF3
- iii) CSIRO Net Pyradiometer for RF4
- iv) Leeds & Northrup No. 6580 Illuminometer for RF7
- v) Eppley PIR (Precision Infrared Radiometer) Pyrgeometer for RF9.
- vi) Li-Cor Li-200SZ pyranometer.
- vii) Specialized radiation sensors (Li-Cor LI-190SZ Quantum and LI-210SZ Photometric, Solar Light Co. UV-Biometer, Model 501A, etc.)

Sensor Requirements

Installation of cables is critical. Interference from nearby alternating current (AC) lines should be eliminated. Unwanted thermocouple effects should be avoided.

All known sensors require a periodic cleaning of dust, dirt, frost, snow, etc. from windows and domes which protect the sensing element itself. A periodic alignment is required.

The net pyradiometers require a continuous supply of dry Nitrogen or desiccated air at low pressure, for purging.

All sensors require calibration against National Standards, normally annually.

The optimum level requires precision pyranometers. A lower level of accuracy ($\pm 10\%$ or $0.5 \text{ MJ m}^{-2} \text{ day}^{-1}$) may be achievable and desirable using lower cost silicon sensors.

Siting & Exposure Requirements

Sensors are normally mounted on vibration-free mountings, 1.5 m above a level surface in an open area such that:

- i) no shadows will be cast on the sensor at any time the sun is above 5° elevation
- ii) no bright or reflective surfaces will reflect sunlight onto the sensors
- iii) there are no sources of radiant energy other than the sun itself

If condition i) cannot be met due to an unavoidable shadow at an azimuth between sunrise and sunset, the location and effect of the obstruction should be well documented.

Sensors to measure RF1, RF2, RF7 and RF9 may be installed over a level surface other than the earth's surface (e.g. a roof)

Sensors to measure RF3 and RF4 should be installed over a smooth, flat clearing, adequately drained, and representative of the surrounding area. In summer, vegetation should be short. In winter, the location should not be subject to drifting snow.

A more detailed description on radiation sensor, siting and exposure requirements is given in the AES Solar Radiation technical manual [7].

3.3.14 Soil Temperature

Units:		°C
Uncertainty:		± 0.3°C
Resolution:		0.1°C
Range:	5, 10, 20 cm:	-40 to +50°C
	50, 100, 150, 300 cm:	-40 to +40°C
Sampling Frequency:	All depths:	5 seconds
Output Averaging Time:	All depths:	1-minute 1-hour
Reporting Frequency:	5, 10, 20 cm:	1 per hour (1-hour average) 2 per 24 hours (0800 and 1600 LST - 1-minute average)
	50, 100, 150, 300 cm:	1 per 24 hours (0800 LST - 1-hour average) 1 per 24 hours (0800 LST - 1-minute average)

Sensors

same as for air temperature

Sensor Requirements

Properly insulated from moisture penetration. Dual sensors should be installed at the deepest levels (300, 150, and possibly 100 cm) in case of failure.

Siting & Exposure Requirements

Soil levels: 5, 10, 20, 50, 100, 150, 300 cm. Surface should be short grass or a surface representative of the general area. Special procedures apply with respect to soil profile, profile disturbance during installation, and frost heaving of sensors. Researchers requiring soil temperatures under bare soil should follow standards above.

3.4 Data Logger Program

The previous sections provided data specifications for all major meteorological parameters. This section will describe the methods to be used by the data logging system to sample, process (linearize) and convert the sensor output into SI units.

Sensor sampling frequency is dependent on the type of parameter to be measured. Sensor sampling frequency must be high enough not to miss maximum and minimum values attained by the sensor in response to larger higher frequency fluctuations. The choice of sampling frequency should be the minimum specification for all meteorological parameters being measured. This simplifies data logger programming complexity.

Since most autostations will measure wind and/or radiation,

THE RECOMMENDED COMMON SAMPLING FREQUENCY FOR ALL SENSORS:

ONCE PER FIVE SECONDS.

While the above recommendation may be faster than necessary for some elements, the use of a single sampling frequency greatly simplifies the datalogger program. In most cases, this will have little or no impact on the autostation operation except for a small increase in power consumption. A slower sampling frequency may need to be incorporated for high power consumption sensors and relay switch cycling.

ALL sensor measurements should be AVERAGED over a ONE-MINUTE period (except wind) in order to reduce the effects of short-period variations or fast response instrumentation.

Data **EXTREMES** (e.g. maximum/minimum temperatures) will be computed from the aforementioned ONE-MINUTE averages (EXCEPT wind gusts).

On-board data processing should be **MINIMIZED** to reduce programming complexity and to **MAXIMIZE** basic data outputs with the installed instrumentation. The amount of data collected and stored should be limited to observations and accumulations. Derived data values should be calculated externally from this basic data set. This will make it simpler to identify and correct problems.

Table 1 summarizes the sampling frequency, sensor reading processing and reporting frequency for a typical AES Co-Operative Climate Autostation.

Figure 5 illustrates a flow diagram of a typical datalogger program. The procedures followed will be similar regardless of the type of climatological program to be automated.

Element	Sampling Frequency	Output Averaging/ Totalizing Interval	Reporting Frequency
Air Temperature	5 seconds	One-Minute Mean One-Hour Mean	1 per hour 1 per hour
Max/Min Temperature	5 seconds	Extremes computed from 60 One-Minute Means	1 per hour
Accumulated Precipitation	5 seconds or 1-Minute	One-Minute Total and/or One-Minute Average	1 per hour
Rate of Precipitation	5 seconds or 1-Minute	One-Minute Total	1 per minute during precipitation event
Snow Depth	1-Minute or 5 seconds	Sensor Dependent One-Minute Average	1 per hour
Atmospheric Pressure	5 seconds	One-Minute Mean	1 per hour
Relative Humidity	5 seconds	One-Minute Mean One-Hour Mean	1 per hour 1 per hour
Dew Point Temperature	5 seconds	One-Minute Mean One-Hour Mean	1 per hour 1 per hour
Wind Direction Wind Speed	5 seconds	Two-Minute Mean Ten-Minute Mean One-Hour Mean 5-Second Peak Wind Max. 2-Minute Mean Max. 10-Minute Mean	1 per hour 1 per hour 1 per hour 1 per hour 1 per hour 1 per hour
Radiation	5 seconds	One-Hour Total	1 per hour
Soil Temperature 5, 10, 20 cm:	5 seconds	One-Minute Mean One-Hour Mean	0800/1600 LST 1 per hour
50, 100, 150, 300 cm:		One-Minute Mean One-Hour Mean	0800/1600 LST 0800/1600 LST

Table 1: Standard Sampling and Reporting Requirements for Autostations.

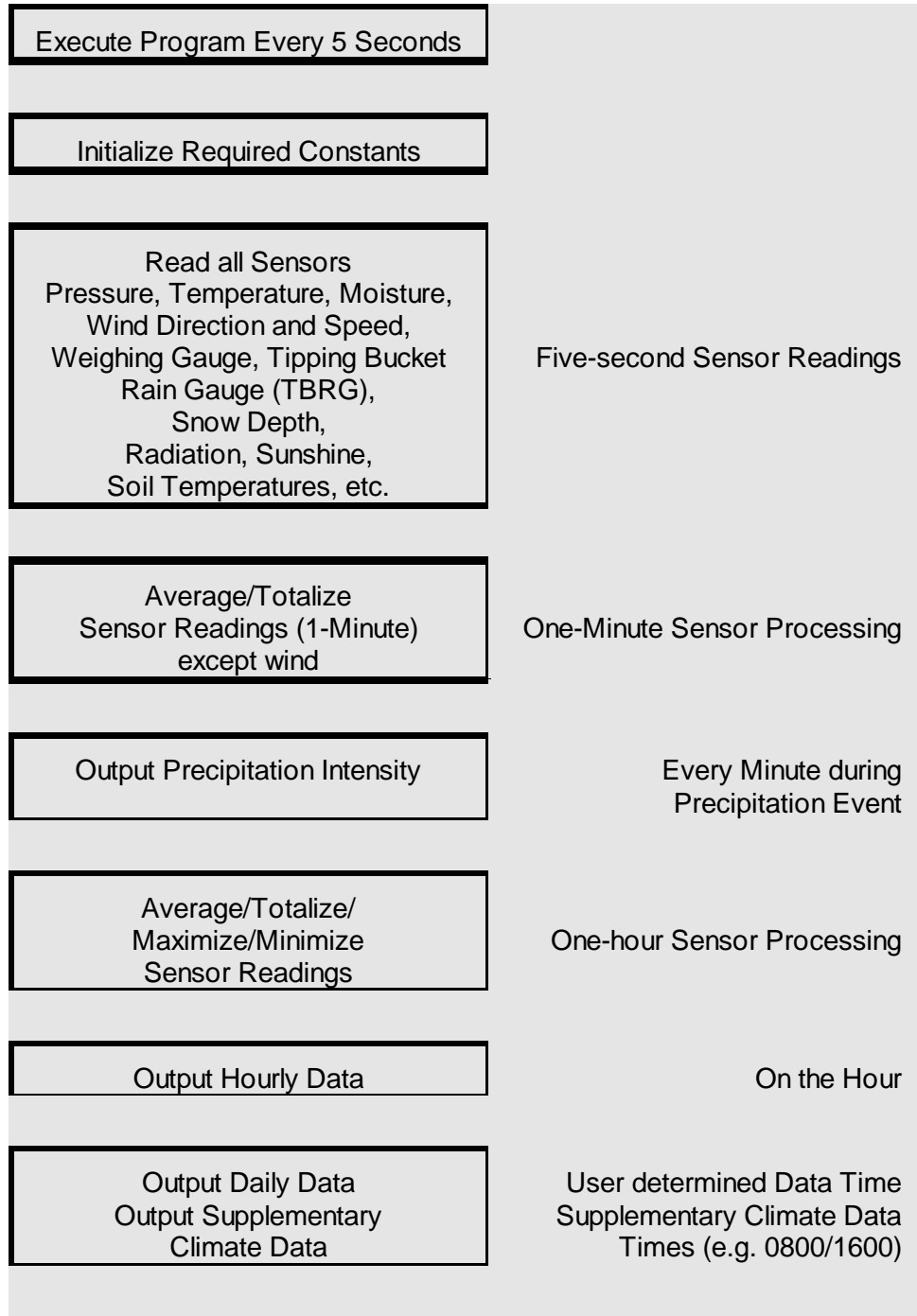


Figure 5: Data Logger Processing Flow Diagram.

The data processing flow can be described as follows:

- (a) Execute the data logger program ONCE every FIVE SECONDS;
- (b) Initialize required constants or program locations as required;
- (c) Read all sensors and obtain instantaneous data values. Linearize the sensor readings to obtain SI engineering units;
- (d) Totalize/average the individual 5-second sensor readings over a one-minute period (except wind);
- (e) Output accumulated one-minute precipitation during precipitation events (see Table 2);
- (f) Average/Totalize/Maximize/Minimize sensor readings over designated time periods. The usual processing time is over a one-hour period except wind. Typically the following data processing is carried out:

Averages:	Two-Minute (Minute 58-60)	Wind Direction and Speed
	Ten-Minute (Minute 50-60)	Wind Direction and Speed
	One-Hour	Air Temperature Air Moisture Wind Direction and Speed Soil Temperature
Accumulations:	One-Hour	Rainfall (TBRG) Total Precipitation Radiation Sunshine Hours
Extremes:	Two-Minute	Max. 2-minute wind speed
	Ten-Minute (Minute 50-60)	Peak Wind Speed Max. 10-minute wind speed
	One-Hour	Wind Speed (maximum) Air Temperature (maximum and minimum)

- (g) Output hourly data values on the hour. A typical hourly output from an ideal principal/supplementary climatological station is shown in Table 4. Autostations which do not have a complete complement of instrumentation will report the appropriate entries **ONLY**.
- (h) Process sensor readings for various other data time outputs. Examples would include daily climatological data outputs (0800, 1600, 0000 LST, 0600 UTC), and supplementary climatological program outputs (evaporation, soil temperatures). See Table 3 for typical supplementary outputs. In addition, diagnostic information (battery voltage, program signature, etc.) should be output at least once-per-day.

CONDITIONAL TBRG PRECIPITATION

1	-	Record Identifier
2	-	Year
3	-	Julian Day of Year
4	-	Hour and Minute (LST or UTC)
5	-	Station Identifier
6	-	Precipitation Amount (mm)

Table 2: One-Minute Precipitation Event Output (for computation of precipitation intensity)

SUPPLEMENTARY PROGRAM OUTPUTS

1	-	Record Identifier	
2	-	Year	
3	-	Julian Day of Year	
4	-	Hour and Minute (LST or UTC)	
5	-	Station Identifier	
6	-	5 cm Soil Temperature	- 1-Minute Mean
7	-	10 cm Soil Temperature	- 1-Minute Mean
8	-	20 cm Soil Temperature	- 1-Minute Mean
9	-	50 cm Soil Temperature	- 1-Minute Mean
10	-	100 cm Soil Temperature	- 1-Minute Mean
11	-	150 cm Soil Temperature	- 1-Minute Mean
12	-	300 cm Soil Temperature	- 1-Minute Mean
13	-	50 cm Soil Temperature	- 1-Hour Mean
14	-	100 cm Soil Temperature	- 1-Hour Mean
15	-	150 cm Soil Temperature	- 1-Hour Mean
16	-	300 cm Soil Temperature	- 1-Hour Mean

Table 3: Typical Supplementary Climatological Program Outputs.

1	-	Record Identifier	
2	-	Year	
3	-	Julian Day	
4	-	Hour (LST or UTC)	
5	-	Station ID	
6	-	Data Availability	- Percent
		Diagnostic	- Ensures data output integrity
7	-	Station Pressure (hPa)	- On-the-hour (1-min mean)
8	-	Air Temperature (C)	- On-the-hour (1-min mean)
9	-	Relative Humidity (%) or Dew Point	- On-the-hour (1-min mean)
10	-	Mean Wind Speed	- Minute 58-60
11	-	Mean Wind Vector Magnitude	- Minute 58-60
12	-	Mean Wind Vector Direction	- Minute 58-60
13	-	Sigma Theta	- Minute 58-60
14	-	Wind Speed Standard Dev.	- Minute 58-50
15	-	Peak 5-second Wind Speed	- Past hour
16	-	Peak wind speed time	- Past hour
17	-	Peak wind speed direction	- At peak speed
18	-	Max. 2-minute wind speed	- Past hour
19	-	TBRG Precipitation (mm)	- Past hour
20	-	Snow Depth (mm)	- Minute 59-60
21	-	Weighing Gauge Precipitation (mm)	- Past hour
22	-	Weighing Gauge Reading (mm)	- 15 Minutes
23	-	Weighing Gauge Reading (mm)	- 30 Minutes
24	-	Weighing Gauge Reading (mm)	- 45 Minutes
25	-	Weighing Gauge Reading (mm)	- On the Hour
26	-	Mean Wind Speed	- Minute 50-60
27	-	Mean Wind Vector Magnitude	- Minute 50-60
28	-	Mean Wind Vector Direction	- Minute 50-60
29	-	Sigma Theta	- Minute 50-60
30	-	Peak Wind Speed	- Minute 50-60
31	-	Max. 10-minute wind speed	- Past hour
32	-	Temperature (C)	- 1-hour mean
33	-	Relative Humidity (%) or Dew Point	- 1-hour mean
34	-	Mean Wind Speed	- 1-hour mean
35	-	Mean Wind Vector Magnitude	- 1-hour mean
36	-	Mean Wind Vector Direction	- 1-hour mean
37	-	Sigma Theta	- 1-hour mean
38	-	Maximum Air Temperature	- Past Hour
39	-	Minimum Air Temperature	- Past Hour
40	-	RF1 Solar Radiation	- 1-hour mean
41	-	RF4 Solar Radiation	- 1-hour mean
42	-	Hours of Bright Sunshine	- 1-hour total
43	-	5 cm Soil Temperature	- 1-hour mean
44	-	10 cm Soil Temperature	- 1-hour mean
45	-	20 cm Soil Temperature	- 1-hour mean

Note: Sigma Theta is the standard deviation of the wind direction (a parameter which can be related to atmospheric stability).

Table 4: Ideal Climatological Station Hourly Data Output.

4. Recommended Practice

This section provides recommendations on system and support requirements, guidelines on maintenance, quality assurance, recording standards and system reliability.

These recommendations should also simplify the project design phases for new installations. For existing sites at co-operative agencies, these recommendations could help in a re-evaluation of current operations.

4.1 System Requirements

The following describes the system components for a climatological autostation and provides general recommendations for the operating environment and reliability level.

4.1.1 System Components

An automatic climatological station **may be** composed of **some or all of the** following:

- (a) a suite of sensors to measure the desired climatological elements;
- (b) a data logger complete with:
 - the necessary interfaces for acquiring and digitizing sensor data (**without degrading the sensor data**) and doing on-site processing;
 - a real-time clock to schedule sampling and reporting;
 - the necessary software to control the sampling, processing, storage and communications; and
 - an on-site readout for verification/maintenance.
- (c) an on-site recording device which can be used to save the digital data for shipment to an archiving facility. **This data storage option includes data logger internal memory, cassette tape, electronic storage modules or computer storage;**
- (d) optional communication equipment for direct transmission of data to the operator. **Communications options include telephone modem, satellite telemetry and radio telemetry;**
- (e) a suitable shelter and instrument tower;
- (f) lightning and electromagnetic interference (EMI) protection; and
- (g) installation and maintenance documentation.

4.1.2 Environmental Factors for Automatic Stations

The automatic climatological station components, as listed in Section 4.1.1, should operate and survive under the conditions specified below. Under the heading CONDITIONS, various environmental factors are listed. For each of these factors, the OPERATE column indicates the required range over which reliable data should be produced. The SURVIVE column includes the extreme conditions that the equipment should be able to withstand and then resume operations when normal conditions return.

CONDITION	OPERATE	SURVIVE
Temperature	-50°C to +50°C	-65°C to +55°C
Humidity	10% to 100%	5% to 100%
Wind	0 to 180 km-h ⁻¹	0 to 280 km-h ⁻¹
Precipitation	Heavy rain, hail, or snow driven by strong winds	Accumulation of up to 15 mm of freezing precipitation accompanied by wind gusts to 100 km-h ⁻¹
Dust & Dirt	outdoors	
Vibration	may be high on site	extreme in transportation
Shock	1.3m drop	1.3m drop
Lightning	occasional surge on power and signal lines	strike in local area
Corrosion	normally low except in coastal environs	normally low except in coastal environs
Security	low protection	low protection
Safety	Should meet Canadian Standards Association (CSA) and local electric utility standards, as well as Labour Canada Code.	
Isolation	In isolated areas, the station should operate trouble free for extended periods.	
Power	Battery operation capability regardless of availability of AC Power.	
ElectroMagnetic Interference (EMI)	Rural levels with no near-field sources are preferred.	

4.1.3 Equipment Shelter

Equipment shelters (enclosures) are required to ensure that the data logger and associated equipment operate within their environmental limits. **It is recommended that enclosures meet CSA Standards for weatherproof (Enclosure 3) and water-tight (Enclosure 4) per rule 2-400 of the Canadian Electrical Code, Part I, 16th Edition, C22.1-1990).** National Electrical Manufacturer's Association (NEMA) and Canadian Electrical Manufacturer's Association (CEMA) standards are equivalent and comply with the CSA regulations.

For small installations, the data logger may be mounted directly on the sensor tower. However, a weatherproof environment is essential for the data logger electronics. A single weatherproof enclosure is often not sufficient since accumulated condensation in such an enclosure can still cause electronic failure. It is recommended that a double enclosure be used consisting of an inner water tight box housing the data logger and an **non-air tight** outer weatherproof shelter. For large installations, a shed type shelter may be required to contain all the necessary equipment and maintain operating conditions. Generally, the larger the shelter, the further away it should be from the sensors in accordance with siting guidelines in Section 3.1.

4.1.4 Instrument Tower

Several sensors for climatological autostations can be conveniently mounted on towers. Anemometers in particular require mounting on towers at a height of 10 metres. For safety **and Canada Labour Code considerations, the use of a tilting tower is recommended.** These towers permit the inspection and servicing of sensors on the ground by one person.

If use of fixed triangular sectional towers cannot be avoided, they should have anti-fall protection and servicing should be performed by two people following proper **Canada Labour Code** safety procedures.

4.1.5 Lightning Protection

Complete protection from lightning is impossible to attain but the following precautions will help to reduce damage due to nearby lightning strikes and transient voltages:

- (i) Proper grounding of the wind tower is essential;
- (ii) Lightning rods, connected to a good earth ground offer some protection;
- (iii) The datalogger **MUST** be connected to a **COMMON** good earth ground;
- (iv) Surge/transient protection should be installed on all sensor leads, and
- (v) Surge/transient protection should be installed for telephone communications lines.

4.1.6 Grounding

All climatological autostation system components (datalogger, sensors, external power supplies, mounts, housings, etc.) should be referenced to a common good earth ground. In addition, sensor signal shielding should be provided and tied to the common earth ground.

4.1.7 Power

Power may be provided to the autostation by AC line current or by battery. The choice of power options is dependent on sensor and other equipment requirements. Regardless of the availability of AC power, battery operation capability is preferred to operate the data logger system and low power sensors.

If AC power is used, rectification and regulation is required to minimize transient voltages or surges which can lead to erroneous readings or damage to equipment. Fail-safe procedures should be implemented to detect problems with external heaters, lamps, motors, etc..

It is important to ensure that sufficient battery reserve is provided to the station in case of prolonged AC power outages or prolonged periods of darkness with solar charging systems. Dual battery operations with a solar panel and voltage regulator have proven to be very reliable even in Arctic winter conditions.

4.1.8 Reliability

Target data recovery rate of a system is computed from the mean failure frequency and duration for the system and the projected maintenance schedule. A target data recovery rate of near 80% is achievable using the data handling and processing systems of the AES National Climatological Archive. To achieve this recovery rate for the archive, a climatological autostation should attain at least a 90% reliability rate for its data.

4.2 Site Operation

4.2.1 Installation

The installation of a climatological autostation, including any equipment shelter and instrument towers, should follow manufacturer specifications and adhere to the siting guidelines in section 3.1.

4.2.2 Suitable Systems and Sensors

The sensors and instrument system used at AES network stations must be AES approved. The term "approved" is used in the sense that the sensor and instrument system have met AES requirements with respect to performance and specification.

A general listing of AES approved sensors and instrument systems can be found in chapter 3 of the General Operations Reference Manual (GORM) [11]. However, this list contains mainly manual instrument systems with only a few of the sensors suitable for autostation use. Most of the newly developed sensors and instrument systems suitable for autostation use have not been AES approved. Users must therefore rely on the [data standards outlined in Section 3.3](#), manufacturer specifications and the experience of other users to determine the suitability of new sensors and data loggers.

Suitable data loggers and sensors which are commercially available and have been found acceptable for climatological autostation use are listed in Appendices A and B respectively. New and improved data loggers and sensors are being developed continuously and it is difficult to maintain a current listing. The lists provided in Appendices A and B are neither exclusive nor exhaustive and the inclusion of a particular data logger or sensor should not be construed as an exclusive endorsement of that device by AES.

4.2.3 Maintenance and Calibration Schedule

All sensors and measurement devices are subject to wear and calibration drift when used in an operational environment. Sensors which are particularly prone to wear and calibration drifts include: humidity sensors, tipping bucket rain gauges, radiation sensors, and anemometers. In order to maintain a specified reliability level, all climatological autostations should have an established routine maintenance and calibration schedule for all its equipment. In addition, a data quality assurance program should also be established to routinely monitor the data collection and provide notification of any problems.

Recommended practice for the routine maintenance and calibration of autostations follows:

- (a) It is strongly recommended that all sites be visited **WEEKLY** and **immediately after severe weather events** (e.g. hail, freezing rain, thunderstorms, high winds, etc.), if at all possible. These visits should entail visual inspections for damage and ice or dust accumulations, cleaning of solar radiation/sunshine equipment, recording of manual snow and/or rain observations and data logger real-time clock checks (unless real-time communications is used).
- (b) all sites should be inspected at least annually to ensure continued adherence to sensor siting requirements and to document any changes;
- (c) all sensors, measuring devices and the data logger should be calibrated annually (preferably twice a year - spring and fall) or as per manufacturer's specifications (sensors which react by chemical changes, such as humidity sensors, will require more frequent calibration or replacement). Sensor comparisons and calibrations should be undertaken whenever the autostation is visited;
- (d) the accuracy of the real-time clock controlling the data logger should be checked when stored data are retrieved (manually or real-time) and/or as part of the data quality assurance program; and
- (e) a data quality assurance program should be established to routinely monitor the collected data and implement remedial action to correct any problems within one month after the problem has been identified. A faster response time may be required depending on the operational requirements for the data.

The above are essential for insuring the reliability of collected data. It is therefore important that the resource requirements for their operations be included in the planning for a climatological autostation.

4.3 Quality Assurance of Data

All data collection and processing systems are vulnerable to systematic and random errors. In order to maintain the desired level of reliability in the collected data, a quality assurance program must be an integral part of the data collection system. A complete quality assurance program requires elaborate procedures with careful attention given to the order in which the tests are conducted. In some cases, comparison statistics from historical data sets and spatial checks from surrounding stations are taken into account. Such procedures are used on AES network data by the Canadian Climate Centre and AES Regional offices.

Simplified procedures for monitoring and testing data validity for some climatological elements are given below [15]. Although these procedures are a subset of the AES Canadian Climate Centre quality assurance program, they are only intended for the early detection and identification of instrumentation problems so that quick remedial action can be taken. For this reason, these simplified procedures should be applied to the collected data as soon as possible and preferably in near real-time. A more comprehensive set of quality assurance procedures should then be applied to the data prior to submission for archiving.

4.3.1 Data Modification

When an observation error is detected by the quality assurance procedures, it must be flagged for further processing and to alert the user. The data record in the AES National Climatological Archive uses a common data type for fifteen-minute values, hourly, daily and monthly values. Within a data record, a variable is represented by a seven alphanumeric character field consisting of a leading sign field, followed by a five digit integer and by a flag field suffix. Conventions on data records, the units, decimal position and flags are stated in "Documentation for the Digital Archive for the Canadian Climatological Data Identified by Element" [16].

The simplified quality assurance procedures described for the climatological elements in the following sections are based on two basic principles. The first tests whether an observation is within its expected range limits and the second tests for a reasonable rate of change of an observation over time. Only two flags are specified for these simplified procedures. An observation which passes both tests will be assigned a blank flag and can proceed to the next level of quality assurance. Failure of either test will result in the rejection of the observed value and it will be flagged as missing using the following modification:

Modification	Explanation and Action
M	Data is rejected or missing; put > 99999 M in the seven-digit field.

The basic range check applied to each variable will use the range limits given in sections 3.3.4 to 3.3.14 of these guidelines. For example, if hourly air temperature is outside limits > 60 °C to + 50 °C, apply modification **M** to hourly air temperature. Other components of the recommended quality assurance program are given under Sections 4.3.2 to 4.3.12 for each variable. Individual tests may not be mutually exclusive. Testing sequence ends at the first test that fails, or after completion of the last recommended test.

4.3.2 Quality Assurance for Hourly Air Temperature

- (a) Basic range checks apply; apply modification **M** to out of range values.
- (b) If the same value is read for 10 or more hours, apply modification **M** to last 10 hourly air temperatures.

4.3.3 Quality Assurance for Maximum and Minimum Air Temperatures

- (a) Basic range checks apply; apply modification **M** to out of range values.
- (b) If daily minimum temperature is more than 3 °C above the daily maximum temperature, apply modification **M** to daily minimum temperature and daily maximum temperature.

4.3.4 Quality Assurance for Accumulated Liquid Precipitation

Hourly precipitation

- (a) Basic range checks apply; apply modification **M** to out of range values.
- (b) If hourly accumulated liquid precipitation is **greater than** zero when hourly air temperature is available and less than 0 °C for the same period , apply modification **M** to hourly accumulated liquid precipitation.
- (c) If hourly accumulated liquid precipitation is greater than 89.0 mm, apply modification **M** to hourly accumulated liquid precipitation.
- (d) If the hourly accumulated liquid precipitation (P3) is non zero and if it is the same as that of the two preceding hours (P1 and P2), apply modification **M** to P1, P2 and P3.

Daily precipitation

- (a) Basic range checks apply; apply modification **M** to out of range values.
- (b) If the daily accumulated liquid precipitation is **greater than** zero when the daily maximum temperature is available and less than 0 °C, apply modification **M** to daily accumulated liquid precipitation.

4.3.5 Quality Assurance for the Rate of Precipitation

Tests applicable to hourly precipitation (section 4.3.4) are also applicable to rates of precipitation that are reported each hour in $\text{mm}\cdot\text{h}^{-1}$. The following tests are specific to precipitation rate.

- (a) If the 60-minute maximum rate of precipitation in a 24 hour period is less than that for 30 minutes, apply modification **M** to 60-minute maximum rate of precipitation.
- (b) If the 30-minute maximum rate of precipitation in a 24 hour period is less than that for 15 minutes, apply modification **M** to 30-minute maximum rate of precipitation.
- (c) If the 15-minute maximum rate of precipitation in a 24 hour period is less than that for 10 minutes, apply modification **M** to 15-minute maximum rate of precipitation.
- (d) If the 10-minute maximum rate of precipitation in a 24 hour period is less than that for 5 minutes, apply modification **M** to 10-minute maximum rate of precipitation.

4.3.6 Quality Assurance for Snow Depth

Ultrasonic snow depth instrumentation features preliminary quality checking. The instrumentation automatically assigns a value of zero to out of range depths. However, quality checking at the cooperative site is still recommended due to the possibility of malfunction in the instrument/data logger system.

Hourly snow depth.

- (a) Basic range checks apply; apply modification **M** to out of range values.

Daily snow depth.

- (a) Basic range checks apply; apply modification **M** to out of range values.
- (b) Let S_1 be the snow depth from the preceding day, and S_2 the current daily value, if $|S_2 - S_1| > 80$ cm, apply modification **M** to daily snow depth.

4.3.7 Quality Assurance for Atmospheric Pressure (hourly)

- (a) Basic range checks apply; apply modification **M** to out of range values.
- (b) If the same value is read for 10 or more hours, apply modification **M** to last 10 hourly atmospheric pressures.

4.3.8 Quality Assurance for Relative Humidity.

- (a) Basic range checks apply; apply modification **M** to out of range values.
- (b) If the same value is read for 10 or more hours, apply modification **M** to last 10 hourly relative humidity values.

4.3.9 Quality Assurance for Dew Point Temperature

- (a) Basic range checks apply; apply modification **M** to out of range values.
- (b) If the same value is read for 10 or more hours, apply modification **M** to last 10 hourly dew point temperature values.

4.3.10 Quality Assurance for Wind Direction and Speed

Hourly Wind Direction

- (a) Basic range checks apply; apply modification **M** to out of range values (except CALM).
- (b) If the same direction value (other than calm) is read for 12 or more consecutive hours, apply modification **M** to wind direction for all these hours.

Hourly Wind Speed

- (a) Basic range checks apply; apply modification **M** to out of range values.
- (b) If the same speed value (other than calm) is read for 12 or more hours, apply modification **M** to wind speed for each of these hours.

Hourly Wind Direction and Wind Speed

- (a) If wind direction and wind speed are both zero for 24 or more consecutive hours, apply modification **M** to wind direction and speed for all these hours (wind sensor icing).

4.3.11 Quality Assurance for Radiation Fields (RF1 - RF4, RF7 and RF9)

Hourly RF1-RF4

- (a) Basic range checks apply; apply modification **M** to out of range values.
- (b) If hourly RF2 exceeds RF1 value by more than (+0.008) MJ m⁻² per hour, apply modification **M** to hourly RF2.
- (c) If hourly RF3 exceeds RF1 value by more than (+0.008) MJ m⁻² per hour, apply modification **M** to hourly RF3.
- (d) If hourly RF4 exceeds RF1 value by more than (+0.008) MJ m⁻² per hour, apply modification **M** to hourly RF4.

Hourly RF7 and RF9

- (a) Basic range checks apply; apply modification **M** to out of range values.

Daily RF1-RF4

- (a) Basic range checks apply; apply modification **M** to out of range values.
- (b) If daily RF2 exceeds RF1 value, apply modification **M** to daily RF2.
- (c) If daily RF3 exceeds RF1 value, apply modification **M** to daily RF3.
- (d) If daily RF4 exceeds RF1 value, apply modification **M** to daily RF4.

Daily RF7 and RF9

- (a) Basic range checks apply; apply modification **M** to out of range values.

4.3.12 Quality Assurance for Soil Temperature

- (a) Basic range checks apply; apply modification **M** to out of range values.
- (b) If the morning 10 cm soil temperature does not lie within 6.0 °C of the average of the 5 and 20 cm soil temperatures, apply modification **M** to the three values.
- (c) If the morning 20 cm soil temperature does not lie within 5.0 °C of the average of the 10 and 50 cm soil temperatures, apply modification **M** to the three values.
- (d) If the morning 50 cm soil temperature does not lie within 4.5 °C of the average of the 20 and 100 cm soil temperatures, apply modification **M** to the three values.
- (e) If the morning 100 cm soil temperature does not lie within 4.0 °C of the average of the 50 and 150 cm soil temperatures, apply modification **M** to the three values.
- (f) If the morning 150 cm soil temperature does not lie within 3.5 °C of the average of the 100 and 300 cm soil temperatures, apply modification **M** to the three values.

4.4 Recording Standards

Climatological autostations can record data in a variety of formats and media. The Canadian Climate Centre has the responsibility for determining the acceptability of non-AES data for archiving into the AES National Climatological Archive. These data must be provided to the Canadian Climate Centre in one of two ways: directly to the Canadian Climate Centre through the standard AES formats and on a medium which the AES archival system normally handles or **directly to AES Regional Offices in raw element form**. Such arrangements will be made between the co-operative agency and the Canadian Climate Centre or the appropriate AES Regional Office.

Other factors that are considered in determining the acceptability of data include the equipment in use, adherence to the data standards outlined in this document and the length of record of individual sites. Co-operative agencies may be provided advice and limited assistance on meeting AES archiving format and media requirements. After acceptance of a non-AES data set into the AES National Climatological Archive, the Canadian Climate Centre's responsibility will be limited to receiving, archiving and providing access to the data set.

4.4.1 Recording Formats

For entry into the AES National Climatological Archive, autostation data that have been quality controlled will be forwarded in a Standard AES archive format. The formats in use are presented in "Documentation for the Digital Archive of Canadian Climatological Data Identified by Element" [16]. The Canadian Climate Centre will be responsible for assigning element and station numbers for all data entering digital archive. This information will be provided by the Canadian Climate Centre and must be included in the data records.

The following are guidelines for the use of the documented formats:

Data which are nearly instantaneous or short-term averages such as temperature and wind information should be recorded in the "Daily Record of Hourly Values (HLY)" element format.

Accumulated or averaged data will be placed in the "Monthly Record of Daily Values (DLY)" format if only one observation per day is available. More frequent observations of this type will be placed in the hourly format.

Each data file forwarded to AES for archiving must be externally identified as to:

- (a) Agency or supplier
- (b) Station(s)
- (c) Formats (HLY) or (DLY) and elements
- (d) Period of coverage (beginning and ending date/time)
- (e) Measure of the data volume being forwarded

4.4.2 Recording Medium

Acceptable exchange mediums for climatological data files submitted to AES for archiving into the AES National Climatological Archive are:

9 track Magnetic Tape

Coding: EBCDIC or ASCII
Density: 800, 1600 or 6250 bpi
Blocking: Fixed block (4,000 to 23,000 approximately)
Labelling: Standard OS Labels or unlabelled

5.25 inch Floppy Diskettes

Format: IBM PC or MS DOS 2.1 or higher
Coding: ASCII
Density: 360K or 1.2M

3.5 inch Micro Floppy Diskettes

Format: IBM PC or MS DOS 3.2 or higher
Coding: ASCII
Density: 720K or 1.44M

5. References

1. Atmospheric Environment Service, 1977: Manual of Surface Weather Observations (MANOBS), Seventh Edition.
2. Atmospheric Environment Service, January 1992: Manual of Climatological Observations, Third Edition.
3. World Meteorological Organization, 1990: Guide to Meteorological Instruments and Methods of Observation, Fifth Edition, WMO - No. 8.
4. World Meteorological Organization, 1988: Technical Regulations, Three volumes, WMO - No. 49.
5. World Meteorological Organization, 1990: Guide to Climatological Practices, Second Edition, WMO - No. 100.
6. Atmospheric Environment Service, 1978: Soil temperature - Manual of standard procedures for obtaining soil temperature data, Second Edition.
7. Atmospheric Environment Service, 1989: Technical Manual: Solar Radiation (TM-14-01-01).
8. Atmospheric Environment Service, 1974: Sunshine - Manual of Standard Procedures for obtaining sunshine data, First Edition.
9. Atmospheric Environment Service, 1978: Evaporation - Manual of standard procedures for obtaining evaporation data, First Edition.
10. Atmospheric Environment Service, 1988: Handbook on Climate Data Sources of the Atmospheric Environment Service. Supply and Services Canada catalogue no. En56-52-1988E.
11. Atmospheric Environment Service, 1977: General Operations Reference Manual (Observational Systems) - GORM.
12. Atmospheric Environment Service, 1989: AES Guidelines for Co-operative Climatic Autostations (Guide 89-1). Available from Climate Information Directorate, Canadian Climate Centre, Atmospheric Environment Service, 4905 Dufferin Street, Downsview, Ontario, M3H 5T4.
13. World Meteorological Organization, 1990: Commission for Instruments and Methods of Observation. Abridged final report of the Tenth Session, Brussels, 11-22 September 1989. WMO - No. 727.

14. Expert Committee on Agrometeorology, 1992: Guidelines for Agrometeorological Autostations; A supplement to the AES Guideline for Co-operative Autostations. K. M. King and D. L. Trivers, January 1992. Available from Chairman, ECA, Peter Dzikowski, c/o Alberta Agriculture, Room 206, 7000 - 113 Street, Edmonton, Alberta, T6H 5T6.
15. Environment Canada, 1983: Policy on Services for Communication and Archiving of Data from Automatic Stations.
16. Atmospheric Environment Service, 1987: Documentation for the Digital Archive of Canadian Climatological Data (surface) Identified by Element. Available from the Canadian Climate Centre, Information Directorate, Atmospheric Environment Service, 4905 Dufferin Street, Downsview, Ontario, M3H 5T4.
17. Tetens, O. 1930. Uber einige meteorologische Begriffe. Zeitschrift fur Geophysik, Vol. 6: 297.
18. List, 1984: Smithsonian Meteorological Tables, 6th Edition, Smithsonian Institution, Washington.
19. Savdie, I., 1982: AES Barometry Program - A Technical Record, Data Acquisition Services Branch, Publication TR9, August 1982.

6. AES Instrument Manuals

IM 10	Pressure measurements with mercury barometers, Edition 1, 1954 (TM 01-01-00).
IM 11	Barographs (type A and Type B), Edition 1, 1957 (TM 01-03-01).
IM 12	Regional Standard Barometer (Amend. #1 15 April 70), Edition 1, 1965 (TM 01-01-04).
IM 15	Altimeter Setting Indicator (Amend. #1 20 Apr 74), Interim Edition, 1965.
IM 20	Liquid-in-glass thermometers, Edition 2, 1971 (TM 02-05-01).
IM 21	The bi-metal thermograph, Edition 1, 1953.
IM 22	Temperature and humidity recording instrument, Lambrecht thermo-hygrograph Model 252C, Edition 1, 1970 (TM 02-02-02).
IM 30	MSC Psychrometers, Edition 3, 1970 (TM 03-04-01).
IM 31	The MSC remote reading psychrometer, Edition 1, 1957.
IM 32	Remote temperature and dewpoint measuring system, Type 2, Edition 1, 1971 (TM 03-04-03).
IM 42	Long duration precipitation recorder, Type Q12M, Edition 1, 1966.
IM 43	CMS rain gauge, Type B (non recording), Edition 1, 1971.
IM 50	Wind measuring equipment, Type U2A, Edition 2, 1969 (TM 05-01-02).
IM 51	Wind Measuring equipment, MSC anemometer, Type 45B, Edition 3, 1966 (TM 05-01-01).
IM 60	Pilot balloon observations, Edition 1, 1964.
IM 70	Ceiling projector and associated equipment, Edition 1, 1955 (TM 07-05-01).
IM 75	Operation of the rotating beam ceilometer, Edition 1, 1962.
IM 76	Routine maintenance of the rotating beam ceilometer, Edition 1, 1968.
IM 80	MSC Type G bi-metal actinograph, Edition 1, 1952.
IM 81	Sunshine recorders, Edition 3, 1973 (TM 08-01-01).
IM 82	Operation of the transmissometer, Edition 1, 1962.
IM 83	Routine maintenance of the transmissometer, Edition 1, 1962.
TM 04-01-03	Tipping Bucket Rain gauge System, 1981.
TM 04-02-01	AES Rain Gauge Type B System, 1985.
TM 07-01-01	Ceiling Balloon equipment 76 mm (3 inch), 1977.
TM 14-01-01	Solar Radiation, 1989.

Appendix A -- Suitable Data Loggers

AES conducted a limited evaluation of commercially available data loggers in 1987. Two **data loggers** were found to be suitable for climatological autostation use. Both of these data loggers are available off-the-shelf and already have a wide user base across Canada. They are:

i) Campbell Scientific **21X** Micro-Logger

Campbell Scientific Canada Corp.	
9525 41 st Ave.	188 St. Clair St.
Edmonton, Alberta	Chatham, Ontario
T6E 5X7	N7L 3J6

ii) OMNIDATA Easy Logger

OMNIDATA International
P.O. Box 3489
Logan, Utah
U.S.A. 84321

Electronic Data Solutions
P.O. Box 31
Jerome, Idaho
U.S.A. 83338

GENEQ Inc.	
7978 Jarry East	233 Signet Dr.
Montreal, Quebec	Weston, Ontario
H1J 1H5	M9L 1V1

Geo-Met Instruments
P.O. Box 845
Kentville, Nova Scotia
B4N 4H8

It should be noted that this selection was based on an evaluation of a limited number of data loggers made available to AES at the time. This should not be construed as an exhaustive list nor as an exclusive endorsement for these two data loggers.

Appendix B -- Suitable Sensors

Section 3.3 gives, under each element, a series of sensors in current use that are suitable for climatological autostations. The following is a summary of these sensors listed by climate element.

New and improved sensors are continuing to be developed. The following list is based on sensors that have been used on climatological autostations but not all are necessarily AES certified. This list is neither exclusive nor exhaustive. Known suppliers are current at the time of publication. They are provided for convenience only and endorsement is neither intended nor implied.

Temperature (Air/Max-Min/Soil)

RDF Corp No. 21C-11-S-Z-C, 100 ohm Platinum temperature probe (modified, AES Model AES/TS > G)

RDF Corp	Willer Engineering Ltd.
23 Elm Ave.	422 Consumers Rd.
Hudson, New Hampshire	Toronto, Ontario
U.S.A. 03051	M2J 1P8

Foxboro Dynatherm 7062Wt, Nickel resistance temperature sensor
Meteorological Automatic Reporting System (MARS I)

Foxboro Canada Ltd.
246 Matheson Blvd. E.
Mississauga, Ontario
L4Z 1X1

Veco 32A38 thermistor (modified AES Drawing C0240)

Victory Engineering Corp
Victory Rd. P.O. Box 559
Springfield, N.J.
U.S.A. 07081

CSI 107F and 107 temperature probe, YSI Thermilinear (44002A)

Campbell Scientific Canada Corp.	
9525 41 st Ave.	188 St. Clair St.
Edmonton, Alberta	Chatham, Ontario
T6E 5X7	N7L 3J6

Temperature (Air/Max-Min/Soil)

YSI 44212 temperature probe

Finnay Engineered Products Ltd
1149 Bellamy Rd. North Unit 22
Scarborough, Ontario
M1H 1H7

Rotronic MP100F

Rotronic Instrument Corp.
7 High Street
Huntington, NY 11743

Precipitation

Accumulated Precipitation

Fischer and Porter No. 35-1559 Weighing Precipitation Gauge (modified by addition of a Baldwin 5V86, 5V233 or 5V241 optical shaft encoder)

Belfort Instrument Co.
727 South Wolfe St.
Baltimore, Maryland
U.S.A. 21231

Allied Signal Aerospace
Bendex Avelex Inc.
Aero-Marine Division
Casier Postal 2140
Montreal, Quebec
H4L 4X8

Belfort No. 5915 or No.6071 Potentiometric Precipitation Gauge

Belfort Instrument Co.
727 South Wolfe St.
Baltimore, Maryland
U.S.A. 21231

Allied-Signal Aerospace Canada
Bendex Avelex Inc.
Aero-Marine Division
Casier Postal 2140
Montreal, Quebec
H4L 4X8

Rate of Rainfall

AES Tipping Bucket Rain Gauge (AES Drawing Series 0405) for rain only

Atmospheric Environment Service
4905 Dufferin St.
Downsview, Ontario
M3H 5T4

Snow Depth

Campbell Scientific CSMAL01/UDG01 Ultrasonic snow depth sensor

Campbell Scientific Canada Corp.
9525 41st Ave. 188 St. Clair St.
Edmonton, Alberta Chatham, Ontario
T6E 5X7 N7L 3J6

Humidity/Dewpoint temperature

Lambrecht 800L

J.W. Stevenson & Co.
2000 Ellesmere Rd. Unit B
Scarborough, Ontario
M1H 2W4

CSI 207 temperature and relative humidity probe

Campbell Scientific Canada Corp. 9525 41 st Ave. Edmonton, Alberta T6E 5X7	188 St. Clair St. Chatham, Ontario N7L 3J6
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AES Type E Dewcel (AES Drawing series 0306)

Atmospheric Environment Service
4905 Dufferin St.
Downsview, Ontario
M3H 5T4

Vaisala HMP 35C Humicap/HMP 35A Humicap

Campbell Scientific Canada Corp. 9525 41 st Ave. Edmonton, Alberta T6E 5X7	188 St. Clair St. Chatham, Ontario N7L 3J6
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Hoskins Scientific

239 E 6 Avenue
Vancouver, B. C.
V5T 1J7

4210 Morris Drive
Burlington, Ont.
L7L 5L6

8425 Devonshire
Montreal, P. Q.
H4P 2L1

Rotronic MP100F

Rotronic Instrument Corp.
7 High Street
Huntington, NY 11743

Atmospheric pressure

Mechanism Ltd Type M1191

Miles Associates
411 Birchmount Rd.
Scarborough, Ontario
M1K 1N3

Paroscientific 215-AS-002

John Degroot Associates Ltd.
P.O. Box 241 Station A
Scarborough, Ontario
M1K 5C1

Setra 270

Setra Systems Ltd.
45 Nagog Park
Acton, Massachusetts
U.S.A. 01720

B.H. McGregor Instrument Sales Ltd.
P.O. Box 156 Station H
Toronto, Ontario
M4C 5H1

Campbell Scientific Canada Corp.	
9525 41 st Ave.	188 St. Clair St.
Edmonton, Alberta	Chatham, Ontario
T6E 5X7	N7L 3J6

Alpha Controls
361 Steelcase Road West, Unit 3,
Markham, Ontario
L3R 3V8

Wind Speed/Direction

AES type 77C/78D sensor

Valcom Ltd.
P.O. Box 603
Guelph, Ontario
N1H 6L3

R.M. Young 05103

R.M. Young Co.
2801 Aero-Park Dr.
Traverse City, Michigan
U.S.A. 49684

Canadian Environmental Monitoring Inc.
#1 - 2121 - 41 Avenue NE
Calgary, Alberta
T2E 6P2

Campbell Scientific Canada Corp.	
9525 41 st Ave.	188 St. Clair St.
Edmonton, Alberta	Chatham, Ontario
T6E 5X7	N7L 3J6

Met One 014A/024A; Met One 013A/023A

Campbell Scientific Canada Corp.	
9525 41 st Ave.	188 St. Clair St.
Edmonton, Alberta	Chatham, Ontario
T6E 5X7	N7L 3J6

Radiation

RF1, RF2, and RF3

Kipp Pyranometer

Metermaster
 Division of R.H. Nichols Co. Ltd.
 80 Vinyl Court
 Woodbridge, Ontario
 L4L 4A3

Eppley Model 2 Type PSP pyranometer

The Eppley Laboratory Inc.
 12 Sheffield Ave.
 Newport, Rhode Island
 U.S.A. 02840

RF4

CSIRO Net pyradiometer

	Hoskin Scientific Ltd.	
1156 Speers Rd.		239 East 6 th Ave
Oakville, Ontario		Vancouver, B. C.
L6L 2X4		V5T 1J7

RF7 Leeds & Northrup No. 6580 Illuminometer

Leeds & Northrup Co.
 4901 Stenton Ave.
 Philadelphia, Pennsylvania
 U.S.A.

RF9 Eppley PIR (Precision Infrared Radiometer) Pyrgeometer

The Eppley Laboratory Inc.
 12 Sheffield Ave.
 Newport, Rhode Island
 U.S.A. 02840

RF1 - Silicon Pyranometers

Li-Cor Inc.
 P. O. Box 4425
 Lincoln, Nebraska
 U. S. A. 68504

Appendix C -- Relative Humidity Computation

The following equation is based on the empirical relationship developed by Tetens [17] and will produce acceptable results for most applications. A more exact formula can be found in the Smithsonian Tables [18].

Output: RH - Relative Humidity (%)

Input: T air temperature (°C)
 T_d dewpoint temperature (°C)

Process:

$$RH = 100 \left[10^{\frac{ab(T_d - T)}{(b + T_d)(b + T)}} \right]$$

where a = 7.5 (9.5 over ice)
 b = 237.3 (265.5 over ice)

Reference [17]: Tetens, O.: Z. Geophys., 6:297 (1930)

Appendix D -- Dewpoint Temperature Computation

The following equation is based on the empirical relationship developed by Tetens [17]. This approximation is accurate to within $\pm 0.1^\circ\text{C}$ over a wide range of air temperatures and relative humidity.

Output: T_d dewpoint temperature ($^\circ\text{C}$)

Input: T air temperature ($^\circ\text{C}$)
 RH relative humidity (%)

Process:

$$T_d = \frac{b}{\left[\frac{a}{\log_{10} RH + \left(\frac{aT}{b+T} \right) - 2} \right] - 1}$$

where $a = 7.5$ (9.5 over ice)
 $b = 237.3$ (265.5 over ice)

Reference [17]: Tetens, O.: Z. Geophys., 6:297 (1930)

Appendix E -- Mean Sea Level Pressure ComputationOutput: P_{msl}

Input: P_s station pressure (hPa)
 H station elevation (m)
 T station temperature ($^{\circ}$ C)
 T_{12} station temperature 12 hours prior to observation time ($^{\circ}$ C)

Process: $P_{msl} = P_s * \text{EXP}(0.0341636 * H / T_{mv})$

$$T_{mv} = T_{zero} + t + (a * H / 2) + e_s C_h + F(t)$$

$$t = (T + T_{12}) / 2$$

a = lapse rate (0.0065 $^{\circ}$ C/metre)

$$e_s = (T_{zero} + T) ** (-0.00014t^2 + 0.0116t + 0.279)$$

$$C_h = 2.8322E-9 * H^2 + 2.225E-5 * H + 0.10743$$

$F(t) = at^2 + bt + c$ (Plateau Correction)
 (a , b , c are empirically derived and site specific - available from AES)

$$T_{zero} = \text{Freezing Point of Water (273.16K)}$$

NOTES: The procedure is modified somewhat to compute the mean temperature. If T_{12} is missing, the temperature at T_{11} , T_{13} , T_{10} , T_{14} , ... T_0 is used. The worst case scenario is that the current air temperature is used to compute the mean temperature.

Reference [19]: Savdie, I. "AES Barometry Program - A Technical Record"
 Data Acquisition Services Branch
 Publication TR9, August 1982.

DOCUMENT IMPROVEMENT PROPOSAL

This form is to solicit comments regarding the contents of this document. The identification of deficiencies or errors, any constructive criticism or other comments that will enhance the use of this document are encouraged and welcomed. If additional pages are required, attach them to this form and submit in an envelope to:

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Climate Information Branch
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4905 Dufferin Street
DOWNSVIEW, Ontario
M3H 5T4

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