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**ชื่อเอกสาร** WMO.731 Guide to Meteorological Observing and Information Distribution Systems for Aviation Weather Services

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วันที่ 7 มกราคม 2565

# Guide to Meteorological Observing and Information Distribution Systems for Aviation Weather Services

2014 edition

World
Meteorological
Organization
Weather • Climate • Water

WMO-No. 731

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## EDITORIAL NOTE

METEOTERM, the WMO terminology database, may be consulted at http://www.wmo.int/pages/prog/lsp/meteoterm_wmo_en.html. Acronyms may also be found at http://www.wmo.int/pages/themes/acronyms/index_en.html.

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# FOREWORD

Wilbur and Orville Wright, two brothers with a passion for aeronautics, made the world's first successful flight of a man-carrying, power-driven, heavier-than-air machine on 17 December 1903. To reach that point, however, Wilbur wrote to the US Weather Bureau asking for information on the windiest places in the United States of America. Among the possibilities offered, the brothers selected a remote sandy area on the outer banks of North Carolina named Kitty Hawk. They then wrote to the weather observer at Kitty Hawk, who confirmed on 16 August 1900 that: "... the beach here is about one mile wide, clear of trees or high hills and extends for nearly sixty miles same condition. The wind blows mostly from the north and northeast September and October...". That was the first step of a long-standing relationship between meteorology and aviation.

The development of civil aviation in the first half of the twentieth century and its spectacular growth gave an enormous new impetus to the development of Meteorological Services and expanded the horizons of the International Meteorological Organization, the predecessor organization to the World Meteorological Organization (WMO), which had so far flourished to a great extent in response to the need for international cooperation in maritime services. However, international civil aviation required observing stations at airports as well as forecasting offices at the major ones, and a telecommunications system to permit the exchange of data and reports. This rapid expansion led to the enlargement of observing systems and to new Meteorological Services being created in regions where previously there had been none.

This Guide presents some of the observing systems currently available to meet the stated operational requirements in aeronautical meteorology and provides guidance on the ones deemed most appropriate under different circumstances. Where applicable, the Guide encourages the adoption of WMO/International Civil Aviation Organization (ICAO) standards. An important issue considered is the cost of the provision of observations in relation to the expected measurable benefits to be derived from a particular application.

I wish to express my gratitude to all those who have devoted time and efforts to the task of updating this Guide.

(M. Jarraud)
Secretary-General

# CHAPTER 1. INTRODUCTION

1.1 The objective of this Guide is to present a choice of currently available observing systems that meet stated operational requirements, as well as to give guidance on that which is likely to be most suitable in a given set of circumstances. The Guide does not set out to propose any particular observing system but it does encourage the adoption of WMO standards where applicable. In providing this guidance, an important factor always taken into account is the cost of provision compared with the measurable benefits likely to be derived from a particular application. In view of the rapid development and evolution of observing systems, it is hoped that the cost of automated observing systems may decrease with time. As such, it may be possible to justify more sophisticated observing systems based on their longer term cost-benefit ratio.

1.2 When consideration is being given to establishing an observing system at an aerodrome, it must be remembered that, although at present the most important and adaptable link in the system is the human being, there is a real need to integrate and complement the human and automated observing system functions. The human observer is able to record information from a large part of the atmosphere as opposed to a stand-alone electronic sensor. For example, the observer can assess cloud amount and type over a great horizontal distance, limited primarily by the prevailing visibility and over a height of 10–15 km or even more. However, it requires an integrated multiple array of sensors located both within and outside the aerodrome perimeter to achieve the same observational coverage. An important exception to this restriction is weather radar, which is able to sample an extensive region around the aerodrome, some of which may well be invisible to the observer.

1.3 The human observer is becoming more reliant on support from a wide range of appropriately sited basic and automated instrumentation to support observing functions. If consideration is being given to adopting more sophisticated instrumentation, the planning authority must be satisfied that the cost-benefit ratio will support and justify the installation and associated ongoing maintenance costs over the expected lifetime of the equipment. The known and expected levels of aviation activity should be a significant factor in assessing the overall cost-benefit ratio. If only a few movements each day are anticipated and the aerodrome is in a climatic zone where sudden changes of weather significant to aviation are rare, it will be difficult to justify a complex observing system. However, for aerodromes with significant aircraft movements and passenger numbers, combined with a location subject to operationally significant weather phenomena, it may be appropriate to install multiple sensors for wind, visibility, cloud base and present weather. This will inevitably lead to a requirement for strategically located sensors in several locations either on the aerodrome, in the immediate vicinity or even at significantly remote distances from it. A requirement may also arise for remote displays of the weather radar and lightning-detection equipment. However, it must also be remembered that maintenance costs may rise sharply as the observing system becomes ever more complex.

1.4 Considerations should include the staffing levels (current and future) and their availability during any 24-hour period. In particular, the staffing aspect should take into account the ability to align staff rosters with regularly scheduled aircraft arrivals and/or high-density periods of aircraft movements. It is also important to align staff rosters to provide vital observational information for the preparation of aviation forecast products such as terminal aerodrome forecasts (TAFs).

1.5 The subsequent chapters of this Guide have been arranged with these considerations in mind. Chapter 2 deals with the standard surface observations likely to be required at any aerodrome used by commercial operators. The sections dealing with surface wind, height of cloud base, visibility and runway visual range (RVR) are the operating parameters of prime interest and, as such, have been dealt with in some detail and with due reference to other operational publications. Chapter 3 considers equipment that might be provided to observe weather phenomena of special interest to aviation but where the current costs are relatively high. Consequently, such equipment is likely to be cost-effective only at aerodromes with a high traffic density or those subject to operationally significant weather, including low cloud, fog and severe storms. Chapter 4 addresses the distribution of the observational information on the aerodrome, whilst the final two chapters consider the requirements for archiving the data and for quality control and functional monitoring.

1.6 In broad terms, the operational and economic advantages of solutions based on reliable, easily installed and easily maintained equipment cannot be overemphasized. On the other hand, to support the increasingly advanced technology of present day civil aviation, the meteorological community must be prepared to use advanced techniques as and when justified. For example, when a new runway is being built, the cost of an advanced system of instrumentation is minimal compared to the cost of the runway. The aim must be to achieve a balance between the various, and sometimes conflicting, requirements. In this way, the objective of providing the operational meteorological information required for the safe, economic and efficient conduct of the activities of the aviation industry may be achieved. It is strongly recommended that as a preliminary, users of this Guide should read Chapter 1 of the *Guide to Meteorological Instruments and Methods of Observation* (WMO-No. 8) to establish a sound, broad overview of the philosophy behind observing systems.

# CHAPTER 2. AERODROME WEATHER OBSERVATIONS

## 2.1 INTRODUCTION

This chapter deals with the requirements for meteorological observations on an aerodrome in support of aviation weather services. It also addresses the methods and means of obtaining such information through holistic observing systems. The aspects are discussed with reference to routine observations – i.e. those taken hourly and half-hourly – and also with respect to non-routine observations, which are taken whenever special meteorological criteria are met. The criteria for these special reports should correspond to the internationally agreed standards and recommended practices and the significant operational limits of the operators using the aerodrome. Some elements also need to be observed and reported at more frequent intervals, in particular for take-off and landing operations. Meteorological staff working at aerodromes should also be made acutely aware of their role in the event of an aircraft accident (see section 5.2.2).

## 2.2 OVERVIEW

### 2.2.1 General

2.2.1.1 This section should be read with full reference to the following publications:

- *Guide to Meteorological Instruments and Methods of Observation* (WMO-No. 8), Part II Observing systems, Chapters 1 Measurements at automatic weather stations, and 2 Measurements and observations at aeronautical meteorological stations;
- *Guide to the Global Observing System* (WMO-No. 488), Part III The surface-based subsystem, 3.1 General, and 3.5 Aeronautical meteorological stations;
- *Technical Regulations* (WMO-No. 49), Volume II – Meteorological Service for International Air Navigation, Part I International standards and recommended practices: core standards and recommended practices, 4.1 Aeronautical meteorological stations and observations;
- *Guide to Practices for Meteorological Offices Serving Aviation* (WMO-No. 732), Chapter 2 Functions of meteorological offices serving aviation, sections 2.1 Observing and monitoring of meteorological conditions at the aerodrome, and 2.2 Observing and monitoring of meteorological conditions within specific areas, and Chapter 4 Automation and centralization, sections 4.1 General, and 4.2 Automation of aeronautical meteorological observations;
- *Manual on Automatic Meteorological Observing Systems at Aerodromes* (ICAO Doc 9837);
- *Manual of Aeronautical Meteorological Practice* (ICAO Doc 8896), Appendix 2 Location of instruments at aerodromes.

2.2.1.2 Notwithstanding the excellent performance of modern aircraft, weather still has a marked impact on the safe and economic conduct of a flight. Of critical importance is the availability of a reliable and representative observations programme. The programme is provided to support a broad range of aerodrome operations as well as the preparation and monitoring of aviation forecast products applicable to that location.

2.2.1.3 The meteorological elements required to be observed at aeronautical meteorological stations include surface wind, visibility (and RVR on all runways intended for use during periods of reduced visibility), present weather, cloud (and vertical visibility when the sky is obscured), air temperature, dewpoint temperature, atmospheric pressure values and supplementary information concerning significant meteorological conditions, particularly in the approach and climb-out areas.

2.2.1.4 Wind observations, for example, are used for the selection of runways, noise abatement procedures and for the determination of the maximum allowable take-off and landing weights. Temperature is also important and can impact significantly on aircraft engine performance, required take-off speed and runway length. For example, high temperatures mean lower air density that reduces lift, resulting in the need for higher take-off speeds and consequently more runway length. If runway length is insufficient, take-off weight has to be reduced. High temperatures may also impose limitations on take-off power. This is particularly important in the case of high-altitude aerodromes in hot climates.

2.2.1.5 A meteorological observations programme that meets the requirements of aviation shall be provided at aeronautical meteorological stations established, as necessary, at aerodromes and other locations of significance to international air navigation. The observations programme shall be as per the *Technical Regulations* (WMO-No. 49), Volume II, Part I, 4.2 Agreement between air traffic services authorities and meteorological authorities; 4.3 Routine observations and reports; and 4.4 Special observations and reports. Guidance on such agreements between meteorological authorities and air traffic services (ATS) can be found in the *Manual on Coordination between Air Traffic Services, Aeronautical Information Services and Aeronautical Meteorological Services* (ICAO Doc 9377).

2.2.1.6 At aeronautical meteorological stations, observations are made throughout the 24 hours of each day, except as otherwise agreed between the meteorological authority, the appropriate ATS authority and the operators concerned and in accordance with regional air navigation agreements.

2.2.1.7 Due to the importance of meteorological observations for the safe and efficient operation of aircraft, it is vital that personnel responsible for making the observations are well trained for the task. In order to ensure that the observers are well trained, training courses should be established and, once taken, refresher training should be given on a routine basis. For more detailed information on training for observers, reference should be made to the *Technical Regulations* (WMO-No. 49), Volume I – General Meteorological Standards and Recommended Practices, where the competence standards for aeronautical meteorological personnel are defined. Training courses should be arranged in accordance with these requirements to provide observers with the ability to (i) continuously monitor the weather situation, (ii) observe and record aeronautical meteorological phenomena and parameters, (iii) ensure the quality of the performance of systems and of meteorological information and (iv) communicate meteorological information to internal and external users.

2.2.1.8 The issuing of special reports is governed by a list of criteria for changes in certain meteorological elements which are of significance to aviation, drawn up by the meteorological authority in consultation with the appropriate ATS authority, operators and others concerned, and in accordance with ICAO Standards and Recommended Practices. The criteria are therefore tailored to a particular aerodrome to some extent and thus may vary from one to another. A list of these criteria is available in the *Technical Regulations* (WMO-No. 49), Volume II, Part II International standards and recommended practices: appendices and attachments, Appendix 3 Technical specifications related to meteorological observations and reports, 2.3.2 and 3.2.2. Special reports made in response to these criteria are issued to operational units on the aerodrome. However, certain of the criteria are selected as being of universal relevance to aviation operations and, moreover, are considered as information which should be disseminated beyond the aerodrome for use by operational personnel. Special reports made in response to these criteria and for dissemination beyond the aerodrome are issued in the SPECI code format. The criteria for the issuing of special reports are based on internationally agreed criteria, and take account of the aerodrome operating minima, the criteria for selected special reports and other criteria of local significance to the ATS units and operators at the aerodrome. The criteria for the issuing of special reports are also contained in the *Technical Regulations* (WMO-No. 49), Volume II, Part II, Appendix 3, section 2.3 Criteria for issuance of local special reports and SPECI.

NOTE: Details concerning the regional differences in contents of aerodrome reports and requirements for the exchange of these reports can be found in the ICAO air navigation plan publications for the various ICAO Regions.

## 2.3 INSTRUMENT ENCLOSURE

### 2.3.1 General

This section should be read with full reference to the following publications:

- *Guide to Meteorological Instruments and Methods of Observation* (WMO-No. 8), Part I Measurement of meteorological variables, Chapter 1 General;
- *Guide to the Global Observing System* (WMO-No. 488), Part III, 3.2.1.2.1 Station siting or location, and 3.2.1.2.2 Meteorological observing area;
- *Technical Regulations* (WMO-No. 49), Volume II, Part II, Appendix 3, 1 General provisions related to meteorological observations.

### 2.3.2 Operational requirements

All instrumentation at an airport must be sited at locations that do not infringe the obstacle limitation surfaces for that particular airport. Future as well as existing limitation surfaces (e.g. for planned additional runways and taxiways) should be considered. However, a new obstacle located in the vicinity of an existing obstacle may be allowable if it fits the regulatory authority's shielding criteria. The buffer area around the enclosure must, where possible, be covered by the natural vegetation or ground cover of the region and should be maintained below approximately 0.5 metres in height.

### 2.3.3 Instrumentation

2.3.3.1 The instrument enclosure may contain a variety of instruments as annotated in the *Guide to the Global Observing System* (WMO-No. 488), Part III, 3.5.2 Instrumentation. Refer to the siting and exposure requirements of the individual instruments that are referenced later in this publication.

2.3.3.2 At aerodromes where an integrated automatic system for the acquisition, processing, dissemination and display of meteorological parameters in real time is required, it should also be possible to accept the manual insertion of data covering those meteorological elements that cannot currently be observed by automatic means.

2.3.3.3 Where automatic observing equipment forms part of an integrated semi-automatic system, displays of data which are made available to the local ATS units should be a subset of and displayed parallel to those available in the local meteorological service unit. In those displays, each meteorological element should be annotated to identify, as appropriate, the locations of which the element is representative.

2.3.3.4 All airport meteorological sensors and related equipment must also be inspected by suitably qualified experts on a regular basis to ensure the continuing quality and reliability of the data provided.

### 2.3.4 Siting

Siting requirements are provided in the *Manual of Aeronautical Meteorological Practice* (ICAO Doc 8896), Appendix 2.

## 2.4 SURFACE WIND

### 2.4.1 General

This section should be read with full reference to the following publications:

- *Guide to the Global Observing System* (WMO-No. 488), Part III, 3.2.2.2.2 Wind direction and speed;
- *Technical Regulations* (WMO-No. 49), Volume II, Part II, Appendix 3, 4.1 Surface wind;
- *Guide to Meteorological Instruments and Methods of Observation* (WMO-No. 8), Part I, Chapter 5 Measurement of surface wind;
- *Manual of Aeronautical Meteorological Practice* (ICAO Doc 8896), Chapter 2 Meteorological observations and reports, 2.3.7 Surface wind, and 2.3.8 Significant speed and directional variations.

### 2.4.2 Operational requirements

2.4.2.1 At aeronautical meteorological stations, the mean direction and speed of the surface wind should be observed and reported as per *Technical Regulations* (WMO-No. 49), Volume II, Part II, Appendix 3, 4.1.

2.4.2.2 Information on strong surface winds and gusts which could affect aircraft on the ground, including parked aircraft and aerodrome facilities and services, should be issued as per *Technical Regulations* (WMO-No. 49), Volume II, Part I, 7.3 Aerodrome warnings.

2.4.2.3 In the meteorological station, surface wind information is presented in real time on digital or dial indicators. By use of parallel indicators, the information is displayed in the appropriate ATS units. At the aerodrome meteorological office, wind direction is presented in degrees true while in ATS units it is presented in degrees magnetic. At the aerodrome meteorological office, the information is recorded and displayed separately for each sensor site while in the ATS units only the information needed for actual aircraft operations may need to be shown. Instantaneous, 2-minute and 10-minute averaging periods along with gusts and variability data should be made available for operational and flight planning requirements. When more than one sensor is used, the displays must be marked clearly to identify the runway or section of runway of which the information is representative. The assignment of sensors for use for different runways or sections of runway should be agreed upon by the ATS unit and the aerodrome meteorological office in the context of the formal, national agreement between the ATS and meteorological authorities. In some cases, sensor selection may depend upon wind direction instead of runway in use. Agreement should also be reached on which other sensor should be used in the event that one fails.

### 2.4.3 Theory

Wind velocity is a three-dimensional vector quantity with small-scale random fluctuations in space and time superimposed upon a larger-scale organized flow. It is considered in this form in relation, for example, to a landing aircraft. For the purpose of this Guide, however, the surface wind will be considered mainly as a two-dimensional vector quantity specified by two numbers representing direction and speed. A gusty wind is characterized by rapid fluctuations in wind speed. At aerodromes, gustiness is specified by the extreme values of wind speed between which the wind has varied during the last 10 minutes. A variable wind is characterized by large variations in the mean directional flow. The horizontal wind vector, represented by direction and speed, may be resolved into two orthogonal components, for example, along and across the direction of a runway.

### 2.4.4 **Instrumentation**

2.4.4.1 To meet the stated operational requirements for reporting surface wind direction and speed with the desirable accuracy, observations should be made using the most suitable instruments available. Integrated instrumental systems should include a sufficient number of sensors as well as the most appropriate equipment for the collection, processing, display and recording of data. The number and location of sensors depend on the size of the aerodrome, the complexity of the terrain and other features of the aerodrome, such as the number and types of runways. In addition to the number of sensors, the total system design also depends on the types and frequency of operations and the degree of automation necessary for the reporting and recording of relevant surface wind information at different locations around the aerodrome. It should be noted that real-time distribution of surface wind information is essential to meet identified client operational requirements.

2.4.4.2 It is a common practice to measure surface wind by the use of cup-rotor or propeller anemometers and wind vanes, but also increasingly by the use of ultrasonic anemometry. Other types of sensors currently in use for purposes other than routine observations are not included in the brief description below. For further information, other sources should be consulted, for example the *Guide to Meteorological Instruments and Methods of Observations* (WMO-No. 8), Part I, Chapter 5. This publication includes a comprehensive bibliography of literature on meteorological instruments and observing practices. Other relevant sources include:

- *Guide to Practices for Meteorological Offices Serving Aviation* (WMO-No. 732), Chapter 4, 4.2.2.2 Wind;
- *Manual on Automatic Meteorological Observing Systems at Aerodromes* (ICAO Doc 9837), Chapter 3 Wind.

2.4.4.3 The choice of the most appropriate observing system depends on all of the above factors. It must also take into account the possible future development of the aerodrome, as well as the cost-effectiveness of specific observing systems being assessed to meet operational requirements.

### 2.4.5 **Siting**

2.4.5.1 The location of sensors to meet the operational requirement for wind measurements representative of the touchdown and take-off areas of runways involves considerations of the nature of vertical and horizontal variations of the wind. Obstacle restrictions may dictate that wind sensors should be located at a considerable distance from the runway. Guidance material on these matters is available in:

- *Guide to Meteorological Instruments and Methods of Observation* (WMO-No. 8), Part I, Chapter 5;
- *Manual of Aeronautical Meteorological Practice* (ICAO Doc 8896), Appendix 2, 5.5 Surface wind.

2.4.5.2 Wind speed can vary considerably through the first few tens of metres above the ground. Over open terrain (defined as an area where the distance between the anemometer and any obstruction is at least 10 times the height of the obstruction), changes of wind direction with height are relatively small. The sole consideration for the vertical placement of a wind sensor, therefore, is to meet the operational requirement that it should be 10 metres above the runway. Placement of the sensor at 10 metres is preferable in view of compatibility with synoptic and climatological practices and due to the large size (height) of today’s aircraft.

2.4.5.3 In contrast, topographical features, buildings and other obstacles as well as weather systems can considerably affect the speed and direction of the horizontal wind flow at an aerodrome. Wind measured in a sheltered location on a building or even a low hill may differ by 90° or more in direction and by half to twice the speed from the wind over the open runway area.

Variations caused by local weather systems such as thunderstorms and sea-breeze fronts may be even larger. Generally, due to obstacle limitations at aerodromes, the wind over the runway is relatively undisturbed by surrounding terrain and buildings, except for disturbances caused by larger-scale local topographical features. Near the limits of the obstacle clearance area, where wind sensors are likely to be located, however, smaller-scale topography, buildings or vegetation may considerably affect the surface wind. At times, it may be difficult to find suitable open terrain where the rule of at least 10 times the obstruction height is satisfied in all directions. In such cases, it may be necessary to locate a frangible and illuminated mast within the obstacle clearance area, preferably "shielded" by an existing essential navigation aid.

2.4.5.4 If the solution above is adopted, users of this Guide are advised to seek the advice of the responsible aviation authority on the precise definition of frangible. Agreement of the aerodrome authority should be obtained before any expense is incurred.

2.4.5.5 Siting will be governed by obstacle limitation areas and local prevailing surface wind conditions. To identify the number of sensors required and their location, a detailed study, sometimes under different wind conditions, of all relevant factors must be undertaken by experts. At many aerodromes, for example those with homogeneous wind conditions, only one strategically sited wind sensor may suffice. In more complicated cases, and at aerodromes with more than one runway of appreciable length, two or more sensors are usually needed and should be located to provide observations representative of the conditions along the runway(s), such as take-off and touchdown zones. It should also be noted that anemometers located too close to runways and taxiways can be affected by aircraft engine exhaust and thereby give a false indication of a gust. Care should be taken to avoid this possibility when anemometers are sited.

2.4.5.6 Consideration should also be given to the availability of the following siting requirements:

(a) Power (including backup and/or uninterrupted power supply);
(b) Telephone lines, fibre-optic links, satellite links, radio or other communications;
(c) Restrictions to, and licences for, the use of radio frequencies;
(d) Extent of site and civil works required, including restrictions imposed in airfield locations and all cable trenching requirements;
(e) Access roads;
(f) Cost of the site and necessary buffer zone required to maintain the correct long-term instrument exposure (including purchase, lease and rental costs), bearing in mind the likely permanent nature of the installation, security and safety requirements of the site (radar).

### 2.4.6 Maintenance and calibration

2.4.6.1 In choosing an instrumental system, it is essential to take into account the procedures and costs of maintenance and calibration needed to keep the system operating at the required level of availability and accuracy. For example, there are significant differences between analogue and digital signal processing and display techniques. A higher degree of automatic checking is normally an integral part of the digital technique.

2.4.6.2 Regardless of the choice of system, checks must be established to ensure the provision of continuous data of acceptable quality including, as a regular routine:

(a) Checks of all system components, i.e. sensors, cables, signal conditioning and data-processing devices, displays and recorders, by use of signal substitutes as prescribed by the system designer;
(b) Sensor sensitivity and bearing friction checks as recommended by the manufacturer;
(c) Inspection of field installations for physical damage, vane orientation and anemometer zero level;

(d) Inspection and maintenance of recorders and displays, if applicable, for the detection and prevention of faults;
(e) Periodic checks to ensure that exposure of sensors is not impaired by new buildings or other new installations, by the growth of trees or shrubs, etc.

2.4.6.3 Aerodromes should ensure that the accuracy of wind speed and direction remain within the operationally desirable accuracy values specified in *Technical Regulations* (WMO-No. 49), Volume II, Part II, Attachment A Operationally desirable accuracy of measurement or observation.

### 2.4.7 **Observing techniques**

2.4.7.1 As stated above, operational requirements can only be met by the use of instruments. Manual observations are limited to:

(a) The estimation of required mean values and extreme values from system outputs, for example from indicators and recorders;
(b) Where more than one measurement site is in use, the selection of wind information appropriate for the runway or runways in use;
(c) Monitoring indicators and graphs for significant changes that necessitate a special report.

These functions may be fully or partly undertaken by automatic aerodrome observation systems and manual observations may be needed only as a backup.

2.4.7.2 In reports for take-off and landing, an averaging period of two minutes is required. As the wind is a vector, a vector-averaging technique should be used to meet this recommendation. However, in some cases, where data are available only in analogue form, scalar averaging is common. Scalar averaging in widely fluctuating winds is one source of error in determining the mean wind resulting in an overestimated mean wind speed and incorrect mean wind direction due to skewed direction distribution. When digital processing of wind data is introduced, a vector-averaging technique should therefore be used.

2.4.7.3 Estimation of scalar averages of wind direction and wind speed by inspection of continuous graphs is most precisely done by the use of an overlay with a window covering the required length of chart. Observation of indicating dials is possible only for a very short period of time and errors are easily introduced. Surface wind direction should be reported in degrees using three figures rounded to the nearest 10 degrees, for example 277° should be given as 280°. Wind speed should be reported in the units adopted by the particular country, the unit used always being indicated in the written or spoken message. The primary unit prescribed in ICAO Annex 5 for wind speed is the kilometre per hour, with the knot permitted for use as a non-SI alternative unit.

2.4.7.4 In the digital processing of wind data, it is common practice to sample the wind speed and direction sensors at least every 1–4 seconds and to calculate a two-minute running average for wind speed and direction every 10–60 seconds. At the same time, the sampled values are stored to be used in obtaining extreme values of wind direction and speed during the 10-minute period preceding the updating of the mean wind. It should be stressed that the sample values to be stored for the extraction of gust data should be derived from three-second actual values and not from the two-minute running averages.

## 2.5 **VISIBILITY**

This section should be read with full reference to the following publications:

– *Guide to the Global Observing System* (WMO-No. 488), Part III, 3.2.2.2.4 Visibility;

- *Manual on Codes* (WMO-No. 306), Volume I.1– Alphanumeric codes, FM 15–XV METAR, 15.6;
- *Technical Regulations* (WMO-No. 49), Volume II, Part I, 4.6.2 Visibility, and Part II, Appendix 3, 4.2 Visibility;
- *Guide to Meteorological Instruments and Methods of Observation* (WMO-No. 8), Part I, Chapter 9 Measurement of visibility.

### 2.5.1 **Operational requirements**

2.5.1.1 The visibility should be measured or observed with reference to objects whose distance from the point of observation is known. Significant directional variations in visibility should also be observed, particularly in the approach area.

2.5.1.2 For reports for take-off, visibility observations should be representative of the conditions along the runway and of the touchdown zone of the runway for reports for landing. For reports disseminated beyond the aerodrome, the visibility observations should be representative of the aerodrome, due account being taken of directional variations in visibility.

2.5.1.3 Information on visibility which could affect ground operations, such as low visibility procedures, should be issued as per *Technical Regulations* (WMO-No. 49), Volume II, Part I, 7.3.

### 2.5.2 **Theory**

2.5.2.1 Visibility is a complex psychophysical phenomenon, intimately tied to the factors involved in human sight. Its estimation is subject to variations in individual perceptive and interpretative ability, as well as the light source characteristics and transmission factors. Thus, any visual estimate of visibility is subjective. While human observations of visibility in daylight are of good quality, those at night are more difficult to define and control, as they are strongly dependent upon the selection of lighted visibility markers and background luminance. It is possible to define and estimate night visibility in terms of equivalent daytime visibility to ensure no artificial changes in the estimate at dawn and at twilight. This concept has the advantage that, to meet meteorological requirements for air mass analysis, etc., it permits the use of instrumental means to measure visibility. This practice does not always meet the requirements of aviation users, however, and other definitions are required to meet their special needs.

2.5.2.2 The factors involved in estimating visibility distance are:

(a) The photometric and dimensional characteristics of the object that is or should be perceived;
(b) The conditions of visual perception, including the effects of extraneous lighting and observer location;
(c) The optical state of the atmosphere between the object and the observer.

2.5.2.3 Factor (a) can be controlled by careful selection of the objects to be perceived, whilst factor (b) can be ameliorated by careful selection of the observer location. The effect of the glare from floodlights on aircraft parking and movement areas is particularly to be avoided. Factor (c) is the only one that depends directly on the meteorological conditions. It is therefore important that this basic parameter relating to the concept of visibility should express the optical state of the atmosphere objectively.

2.5.2.4 A convenient derived parameter is the meteorological optical range (MOR), which is fully explained in the *Guide to Meteorological Instruments and Methods of Observation* (WMO-No. 8), Part I, Chapter 9.

2.5.2.5 A comprehensive discussion on the theory behind visibility observations is provided in:

- *Guide to Meteorological Instruments and Methods of Observation* (WMO-No. 8), Part I, Chapter 9;
- *Manual of Runway Visual Range Observing and Reporting Practices* (ICAO Doc 9328), Chapter 4 Weather phenomena reducing visibility;
- *Manual on Automatic Meteorological Observing Systems at Aerodromes* (ICAO Doc 9837), Chapter 4 Visibility.

### 2.5.3 **Instruments**

2.5.3.1 In a significant number of cases, visibility – including significant directional variations in accordance with operational requirements – is determined by a human observer viewing selected objects of specified characteristics at known distances from the meteorological station. However, there are several instruments available today to measure visibility appropriate to aviation operations.

2.5.3.2 When planning an observational system, the need for an instrumental system to complement visual observations should be considered. Local climatology, the size and topography of the aerodrome and the type and number of operations should be taken into account when making this decision, as well as whether multiple sensors are required. When an automatic RVR system is planned, allowance should be made for the additional capacity needed for MOR measurements outside the range of RVR measurements.

2.5.3.3 Transmissometers and/or forward-scatter meters should be used as sensors for the measurement of visibility. It should be recognized that the data from sensors will provide a snapshot of the visibility over a relatively small area and consequently may not fully represent the visibility over the whole runway or whole airport, especially during periods of fluctuating visibility. As such, users of fully automated observations will need to take account of the potential spatial variations. In non-automated reports, data from visiometers should be supplemented by human observation.

2.5.3.4 Documentation and reference material pertinent to the instrumentation used for the measurement of visibility are as follows:

- *Guide to the Global Observing System* (WMO-No. 488), Part III, 3.5.2;
- *Guide to Meteorological Instruments and Methods of Observation* (WMO-No. 8), Part I, Chapter 9;
- *Manual on Automatic Meteorological Observing Systems at Aerodromes* (ICAO Doc 9837), Chapter 4.

2.5.3.5 Information pertaining to RVR can be obtained from the following references:

- *Manual of Runway Visual Range Observing and Reporting Practices* (ICAO Doc 9328), Chapter 7 Transmissometers, Chapter 8 Forward-scatter meters, and Chapter 9 Instrumented RVR systems;
- *Manual on Automatic Meteorological Observing Systems at Aerodromes* (ICAO Doc 9837), Chapter 5 Runway visual range;
- *Guide to Meteorological Instruments and Methods of Observation* (WMO-No. 8), Part II, Chapter 2.

### 2.5.4 **Maintenance and calibration**

2.5.4.1 It is essential that transmissometers and forward-scatter meters be operated, maintained and calibrated as prescribed by the manufacturer and in conjunction with State regulations. Calibration should be carried out regularly under conditions of good visibility (at least

10 km) and in a stable atmosphere. The instruments are to some extent protected against contamination of optical surfaces. Automatic checking and adjustment of the outputs of light sources and other important functions are normally taken care of in the system design. However, it is still necessary to establish routines for regular periodic maintenance, such as cleaning optical surfaces and replacing components at intervals determined by environmental conditions and in consultation with the manufacturer. In certain cases, lens cleaning must be carried out at intervals as short as one week. In certain circumstances, it may also be necessary to check with the manufacturers regarding the appropriateness of suitable firmware to filter out the effects of the presence of insects from the sensor readings.

2.5.4.2 Further information pertaining to maintenance and calibration can be accessed in the *Guide to Meteorological Instruments and Methods of Observation* (WMO-No. 8), Part I, Chapter 9.

### 2.5.5 **Siting**

2.5.5.1 Sensors should be located such that they provide representative readings for the airport operating area. At some airports, it may be necessary to site additional sensors where localized variations in visibility might occur, for instance close to water where an increased incidence of fog may be expected. Additional sensors might also be required when fully automated aeronautical meteorological reports are generated.

2.5.5.2 The following two documents provide comprehensive information relevant to the siting of visibility instrumentation:

- *Guide to Meteorological Instruments and Methods of Observation* (WMO-No. 8), Part I, Chapter 9, and Part II, Chapter 2;
- *Manual on Automatic Meteorological Observing Systems at Aerodromes* (ICAO Doc 9837), Chapter 4, 4.6 Measurement locations.

### 2.5.6 **Observing techniques**

2.5.6.1 Instrumental observing techniques have been addressed above and information relevant to human observing techniques is provided in:

- *Guide to Meteorological Instruments and Methods of Observation* (WMO-No. 8), Part I, Chapter 9;
- *Guide to the Global Observing System* (WMO-No. 488), Part III, 3.2.2.2.4.

2.5.6.2 Apart from the references above, it is also important to note the following. Human observing techniques use selected targets at known distances from an observing site permitting continuous viewing of the aerodrome and its immediate vicinity. The area of primary interest for visibility observations is that required for take-off and landing operations.

2.5.6.3 Observation of visibility within these areas should be focused on changes and directional variations in visibility of particular significance to operational decisions in connection with landings and take-offs.

2.5.6.4 Apart from the routine hourly or half-hourly observations of visibility, special observations are made when necessary, as required by the criteria agreed locally. Some of these special observations may be disseminated beyond the aerodrome as special reports. Refer to *Technical Regulations* (WMO-No. 49), Volume II, Part II, Appendix 3, 2.3.2, for SPECI criteria.

### 2.5.7 **Observations in daylight**

2.5.7.1 In daylight, visual observations of meteorological visibility give a good approximation of the meteorological optical range. Meteorological visibility by day is defined as the greatest distance at which a black object of suitable dimensions, situated near the ground, can be seen and recognized when observed against a bright background. It should be emphasized that the criterion is recognizing an object, not merely seeing the object without recognizing what it is.

2.5.7.2 Objects used in the determination of visibility, which are usually referred to as visibility points, should be selected at different distances and in different directions, taking into account the criteria for the reporting of prevailing visibility defined as the visibility value observed in accordance with the definition of "visibility", which is reached or exceeded within at least half the horizon circle or within at least half of the surface of the aerodrome. These areas could comprise contiguous or non-contiguous sectors. Only black or nearly black objects that stand out against the sky on the horizon should be chosen. Light coloured objects or objects situated close to a terrestrial background should be avoided as far as possible. This is particularly important when the sun is shining on the object. Provided the albedo of the object does not exceed about 0.25, no error larger than 3 per cent will be caused if the sky is overcast, but it may be much larger if the sun is shining. Thus, a white house would be very unsuitable, but a group of dark trees would be satisfactory except when brightly illuminated by sunlight. If an object with a terrestrial background has to be used, it should stand well in front of the background, for example at a distance at least half that of the object from the point of observation.

2.5.7.3 In order to be representative, the observations should be made using objects subtending an angle of not less than 0.5° to the observer's eye. An object subtending an angle less than this becomes invisible at a shorter distance than larger objects in the same circumstances. It may be useful to note that a hole 7.5 mm in diameter, punched in a card and held at arm's length, subtends this angle approximately; a visibility object viewed through such an aperture should therefore completely fill it. At the same time, however, such an object should not subtend an angle of more than 5°.

2.5.7.4 A plan of visibility points to be used at the aerodrome should be prepared, showing the distance and bearings from the observing site. A panoramic colour-photograph montage around 360° of the horizon with visibility points marked is extremely useful to newly posted or trainee observers. Alternatively, a schematic diagram would be suitable. Observations should be made without additional optical devices, such as binoculars or telescopes. Also, the observer's vision should be normal or corrected to normal.

### 2.5.8 **Observations at night**

2.5.8.1 The formal definition for visibility at night is provided in the *Guide to Meteorological Instruments and Methods of Observation* (WMO-No. 8) Part I, Chapter 9, which states that meteorological visibility at night is "the greatest distance at which a black object of suitable dimensions (located on the ground) … could be seen and recognized during the night if the general illumination were raised to the normal daylight level".

2.5.8.2 Any source of light may be used as a visibility object, provided that the intensity in the direction of observation is well defined and known. However, it is generally desirable to use lights that can be regarded as point sources, and whose intensity is not greater in any one more favoured direction than in another and not confined to a solid angle that is too small. Care must be taken to ensure the mechanical and optical stability of the light source.

2.5.8.3 A distinction should be made between sources known as point sources, in the neighbourhood of which there is no other source or area of light, and clusters of lights, even though separated from each other. In the latter case, such an arrangement may affect the visibility of each source considered separately. For measurements of visibility at night, only the use of suitably distributed point sources is recommended.

2.5.8.4 It should be noted that observations made at night using illuminated objects may be affected appreciably by the illumination of the surroundings. The physiological effects of dazzling and other lights, even when these are outside the field of vision, can have a significant impact on one's night vision. The effect is enhanced if the observation is made through a window. An accurate and reliable observation is best undertaken from a dark and suitably chosen location situated outdoors. In order to speed the adaptation process, therefore, it is recommended that the illumination in the observing room should be as subdued as possible. It is desirable that desk lamps equipped with a dimming control should be provided; the lighting may thus be reduced to the minimum acceptable level.

2.5.8.5 Further, the importance of physiological factors cannot be overlooked, since they are an important source of dispersion of the measurements. It is essential that only qualified observers with normal vision should make such measurements. In addition, it is necessary to allow for a period of adaptation (usually 5 to 15 minutes) during which the eyes become accustomed to the dark. This will markedly improve night vision and significantly facilitate the determination of visibility.

2.5.8.6 The list of visibility points provided should include the distance and bearings from the observing site of points that are suitable for night observing.

### 2.5.9 Human observing site

2.5.9.1 No operational requirement currently exists concerning the height above the ground of which visibility observations at aerodromes should be representative. The main purpose of visibility observations, however, is to give guidance to the pilot on the final part of approach and landing with visual ground references. This is adversely affected by fog, precipitation and other weather phenomena causing reduced visibility near the ground within the areas described above.

2.5.9.2 Visibility observations should be representative of a height of approximately 2.5 metres above ground level. It is appreciated that an observer standing on the ground observing visibility at eye level will not be able to view the entire aerodrome and its immediate vicinity as required. A location 5–15 metres above the ground is usually sufficient to meet the requirement of continuous viewing of the areas of primary interest. However, at larger aerodromes with more than one runway, it may be difficult to find a single position permitting the simultaneous observation of visibility representative of the conditions near the ground and the viewing of the aerodrome, including all runways. In such cases, the use of instruments and supplementary visual observations should be seriously considered. Increasingly, the aeronautical meteorological observing functions are undertaken from the visual control room at the top of a control tower, often at heights greatly in excess of 15 metres. In such situations, observers should ensure that ground access is available to them to undertake visibility assessments, particularly when the visibility is not homogeneous, to ensure against the effects of slant visibility giving a false impression of the true horizontal visibility.

## 2.6 PRESENT WEATHER

### 2.6.1 Operational requirements

2.6.1.1 There is a requirement for observing and reporting the onset, cessation and intensity of weather phenomena of significance to aviation, such as thunderstorms and their attendant features, freezing precipitation, phenomena which restrict horizontal visibility and, at aerodromes, phenomena which affect the handling and movement of aircraft on the aerodrome itself.

2.6.1.2 Information in the form of aerodrome weather warnings on present weather phenomena that pose a potential hazard to aviation, such as thunderstorms and hail, should be issued as per *Technical Regulations* (WMO-No. 49), Volume II, Part I, 7.3.

2.6.1.3 Further information on present weather relevant to operational requirements is provided in:

- *Technical Regulations* (WMO-No. 49), Volume II, Part I, 4.6.4 Present weather;
- *Guide to Meteorological Instruments and Methods of Observation* (WMO-No. 8), Part II, Chapter 2.

### 2.6.2 Instrumentation and automatic systems

2.6.2.1 Although the observation of present weather still depends primarily on the human observer, instruments have been developed which are not only considered as useful aids to human observation but are also rapidly developing to a high level of credibility on a stand-alone basis.

2.6.2.2 Automated systems are not currently capable of reporting all types of present weather phenomena that are of significance to aviation. However, there are ongoing improvements occurring in this area. In some cases, information on certain weather phenomena can be gathered using algorithms derived from remote-sensing techniques.

2.6.2.3 Further information relevant to instrumentation used for observing present weather phenomena for aviation is provided in the following publications:

- *Manual on Automatic Meteorological Observing Systems at Aerodromes* (ICAO Doc 9837), Chapter 6 Present weather;
- *Guide to Meteorological Instruments and Methods of Observation* (WMO-No. 8), Part I, Chapter 14 Observation of present and past weather; state of the ground, and Part II, Chapter 2;
- *Guide to the Global Observing System* (WMO-No. 488), Part III, 3.5.2.

### 2.6.3 Siting

2.6.3.1 Present weather information should be representative of the aerodrome and its immediate vicinity. When the use of instruments is considered, it is recommended that present weather systems are sited close to the runway strip and, where viable, in the final approach areas.

2.6.3.2 Further information relevant to the siting of present weather sensors can be accessed in the following publications:

- *Manual on Automatic Meteorological Observing Systems at Aerodromes* (ICAO Doc 9837), Chapter 6, 6.7 Measurement locations;
- *Manual of Aeronautical Meteorological Practice* (ICAO Doc 8896), Appendix 2.

### 2.6.4 Observing techniques

2.6.4.1 *Technical Regulations* (WMO-No. 49), Volume II, Part II, Appendix 3, 1.3 notes that "[t]he observers at an aerodrome should be located, in so far as is practicable, so as to supply data which are representative of the area for which the observations are required". Clearly it is not practicable to make detailed visual observations of present weather phenomena except in the immediate vicinity of the aerodrome. However, arrangements should be made to obtain additional information on present weather phenomena, for example through observations made by ATS and aerodrome services personnel, from departing and arriving aircraft. Additional information from radar is covered later in Chapter 3 of this Guide.

2.6.4.2 International agreements concerning present weather phenomena to be observed and reported to arriving and departing aircraft are contained in *Technical Regulations* (WMO-No. 49), Volume II, Part I, 4.6.4, and Part II, Appendix 3, 4.4 Present weather.

2.6.4.3 The sections in *Technical Regulations* (WMO-No. 49), Volume II as presented above list the phenomena and their characteristics as well as the terminology and abbreviations to be used, as agreed upon by WMO and ICAO. It should be noted that a subset of these are required when fully automated aviation weather reports are produced.

2.6.4.4 Observations of present weather phenomena to be reported to arriving and departing aircraft can be provided from two sources. Observations should be representative of the approach and landing area or the take-off and climb-out area, respectively. It will be noted that the areas of primary interest are the same as those defined for observations of visibility. In reports disseminated beyond the aerodrome, observations of present weather should be representative of the aerodrome and its immediate vicinity. Emphasis is placed on the onset, cessation, intensity and location of phenomena of significance for the safe operation of aircraft, such as freezing precipitation, thunderstorms, hail and phenomena that restrict visibility or indicate the presence of super-cooled water droplets. The primary source for the majority of present weather observations is the human observer from an observing site that provides a continuous view of the aerodrome. The second source, and one that is evolving, is from specific present weather sensors located to provide the optimum representation of the aerodrome. In many cases, a single weather sensor is sufficient, though airports need to consider contingency arrangements and specific topography that might influence weather conditions locally.

2.6.4.5 In the list of phenomena contained in *Technical Regulations* (WMO-No. 49), Volume II, Part I, 4.6.4, and Part II, Appendix 3, 4.4, reference is made to code figures to be used in reports disseminated beyond the aerodrome. The *Manual on Codes* (WMO-No. 306), Volume I.1 provides the definition and description of present weather phenomena. These are given in Code table 4678, with reference to Code table 4677 for more detailed specifications.

## 2.7 CLOUD

### 2.7.1 Operational requirements

2.7.1.1 Operational requirements for the observation and measurement of clouds are addressed in the *Guide to Meteorological Instruments and Methods of Observation* (WMO-No. 8), Part II, Chapter 2. It should be noted that cloud observations for local reports for take-off and landing are to be representative of the approach area. For reports disseminated beyond the aerodrome, cloud observations should be representative of the aerodrome and its vicinity.

2.7.1.2 Further relevant information on operational requirements is provided in *Technical Regulations* (WMO-No. 49), Volume II, Part I, 4.6.5 Clouds, and Part II, Appendix 3, 4.5 Clouds.

### 2.7.2 Theory

The base of a cloud is defined as the lowest zone in which the type of obscuration perceptibly changes from that corresponding to clear air or haze to that corresponding to water droplets or ice crystals. Due to the different characteristics of the particles involved, the spectral selectivity within the cloud is significantly different from that below. Further information on the theory behind cloud observations is provided in the *Guide to Meteorological Instruments and Methods of Observation* (WMO-No. 8), Part I, Chapter 15 Observation of clouds.

### 2.7.3 **Instrumentation**

Comprehensive information relevant to the instrumentation associated with cloud observations is provided in:

- *Guide to Meteorological Instruments and Methods of Observation* (WMO-No. 8), Part I, Chapter 15;
- *Manual on Automatic Meteorological Observing Systems at Aerodromes* (ICAO Doc 9837), Chapter 7 Clouds.

### 2.7.4 **Siting**

2.7.4.1 Information relevant to site exposure for cloud observations and the various methods and associated instrumentation is provided in the *Guide to Meteorological Instruments and Methods of Observation* (WMO-No. 8), Part I, Chapter 15.

2.7.4.2 Information on siting for automated cloud observation instrumentation is also provided in the *Manual on Automatic Meteorological Observing Systems at Aerodromes* (ICAO Doc 9837), Chapter 7, 7.6 Measurement locations. Recent studies have shown that, unless dictated by local topography, a single cloud sensor normally provides results that are representative of the aerodrome and approach areas.

### 2.7.5 **Observing techniques**

2.7.5.1 Cloud observations are made for two main purposes:

(a) For take-off and landing operations;
(b) For dissemination beyond the aerodrome for use in flight planning and in-flight information and preparation of aviation meteorological products and services.

2.7.5.2 Cloud observing techniques used for these two purposes are similar. The main difference in operational requirements concerns the cloud type reported and the airspace for which the observations should be representative.

2.7.5.3 Cloud reports for local use and for flight planning comprise information relating to the height, amount and type of clouds.

2.7.5.4 The use of on-site instrumentation (ceilometers) provides measurements of cloud-base height and often cloud cover. These are recommended at all CAT I aerodromes and required at all CAT II and CAT III aerodromes. Visual observations, usually made from one observing position, are made to supplement the output from ceilometers. Although ceilometers are able to estimate cloud base to a greater degree of accuracy than a human, they are presently unable to accurately distinguish cloud types significant to aviation and required in the compilation of aviation weather reports, such as cumulonimbus clouds (CB) and towering cumulus clouds (TCU). Consequently, human observers are normally needed to verify and supplement the ceilometer output as necessary. Increasingly, remote-sensing techniques are being used to generate algorithms that will automatically supplement ceilometer output with reports of CB and TCU activity. This is a significant advancement that helps address the developing requirements for the content of automated weather reports.

2.7.5.5 Techniques for cloud instruments have been referenced in the publications above. Techniques to be employed for estimation and non-automated instrumentation are provided in the *Guide to Meteorological Instruments and Methods of Observation* (WMO-No. 8), Part I, Chapter 15.

### 2.7.6 Maintenance and calibration

Information on maintenance and calibration of any equipment associated with cloud observations is generally provided in the manufacturer's handbook. Supplementary general information on maintenance and calibration and its importance is also provided in the following publications:

- *Guide to Meteorological Instruments and Methods of Observation* (WMO-No. 8), Part I, Chapter 15;
- *Manual on Automatic Meteorological Observing Systems at Aerodromes* (ICAO Doc 9837), Chapter 7, 7.5 Calibration and maintenance;
- *Guide to Practices for Meteorological Offices Serving Aviation* (WMO-No. 732), Chapter 2, 2.1.5 Inspection and maintenance of instruments and equipment.

## 2.8 AIR TEMPERATURE

### 2.8.1 Operational requirements

2.8.1.1 The air temperature should be observed and reported in whole degrees Celsius. The observations should be representative of the runway configuration. These observations are included in reports disseminated beyond the aerodrome and in local reports.

2.8.1.2 The operationally desirable accuracy of temperature measurements is 1 °C. However, temperature readings at aerodromes are frequently used for other purposes that require more accurate measurements, such as climatology and synoptic meteorology.

2.8.1.3 Information relevant to the operational requirements of air temperature is provided in the following publications:

- *Guide to Meteorological Instruments and Methods of Observation* (WMO-No. 8), Part II, Chapter 2;
- *Technical Regulations* (WMO-No. 49), Volume II, Part I, 4.6.6 Air temperature and dewpoint temperature.

### 2.8.2 Theory

2.8.2.1 The theory of temperature measurement in meteorology using the properties of thermal expansion and the variation of electrical resistance is discussed in many widely available textbooks. Consequently, it is not discussed in this Guide. The scale of temperature in general use is the International Practical Temperature Scale (IPTS) of 1990. It is based on assigned values of temperature at a number of reproducible equilibrium states (the defined fixed points) and on specified standard instruments. In addition to the defined fixed reference points, other secondary reference points are available. Temperature on the IPTS is designated "degrees Celsius" (°C).

2.8.2.2 An aspect of temperature measurement of particular importance on aerodromes is the response time of thermometers. Large vertical temperature gradients may exist in the lowest layers of the atmosphere and the air temperature at screen level may fluctuate appreciably within a few seconds. To obtain representative readings for aviation purposes, these rapid fluctuations should be smoothed out.

2.8.2.3 The response times of thermometers has improved with the quality of the temperature sensors now on the market. These are referred to in the next section.

### 2.8.3 **Instrumentation**

2.8.3.1 To meet the operational requirements for reporting air temperature representative of the general conditions over the runway complex, the observations must be made by well-sited and properly exposed instruments. In general, the type of thermometer screen used for observations on aerodromes will not differ from that used for synoptic observations. Screens designed according to the specifications in the *Guide to Meteorological Instruments and Methods of Observation* (WMO-No. 8), Part I, Chapter 2 are readily available from commercial sources. Although screens are still made of wood, designs using plastic materials are increasingly used, as these offer greater protection against radiation effects because of an improved louvre design that provides a better airflow. A further advantage of plastic screens is that they require less maintenance than wooden ones. Many temperature sensors are co-housed with pressure sensors.

2.8.3.2 It is a common practice to measure air temperature by use of electronic measuring techniques permitting the siting of sensors near the runways. Digital procedures are increasingly applied for the transmission, display, storage and processing of data. However, manual readings of liquid-in-glass thermometers in the vicinity of the meteorological station are still applied at smaller aerodromes and are also used as a contingency and for regular checks to ensure that remote-reading thermometers are operating correctly.

2.8.3.3 Information on temperature sensors is provided in:

- *Manual on Automatic Meteorological Observing Systems at Aerodromes* (ICAO Doc 9837), Chapter 8 Air temperature and dewpoint temperature, 8.2.4 Instrument screen;
- *Guide to Meteorological Instruments and Methods of Observation* (WMO-No. 8), Part I, Chapter 2.

### 2.8.4 **Siting**

2.8.4.1 For operational purposes, aviation is interested primarily in the temperature at engine intake levels above the runway. It is clearly impossible to make regular temperature observations at such locations. It is thus important that the site of the temperature screen should be chosen so that temperature observations approximate as closely as possible those required. Observations made at a height of 1.25–2.00 metres above ground level, as generally recommended by WMO, usually meet this requirement within the required accuracy of 1 °C.

2.8.4.2 In order to meet the operational requirements for the reporting of air temperature representative of the general conditions over the runway complex, the observations must be made by well-sited and properly exposed instruments. This means siting sensors away from areas where jet blasts are likely, and from buildings or concrete, which may radiate heat.

2.8.4.3 With today’s complex airports, it is becoming increasingly difficult to find sites where temperature measurement is not affected by concrete or tarmac surfaces or influenced by moving or parked aircraft. As a result, the nearest available sites are frequently a long way from the meteorological observing station. Where the costs of providing cable or radio modems for remote-sensing are prohibitive, provision must be made for the meteorological observer to visit the thermometer screen as often as necessary.

2.8.4.4 Further information on siting and exposure is provided in the *Guide to Meteorological Instruments and Methods of Observation* (WMO-No. 8), Part I, Chapter 2, and Part II, Chapter 2.

2.8.4.5 The *Manual of Aeronautical Meteorological Practice* (ICAO Doc 8896), Appendix 2, 5.8 Air temperature and dewpoint temperature, provides information on temperature sensor exposure.

2.8.4.6 The layout for the location of the thermometer screen to other instrumentation and background information is provided in the *Guide to the Global Observing System* (WMO-No. 488), Part III, 3.2.1.2.2, Figure III.1.

### 2.8.5 Observing techniques

Information on observing techniques for temperature measurement is provided in the *Guide to Meteorological Instruments and Methods of Observation* (WMO-No. 8), Part I, Chapter 2.

### 2.8.6 Maintenance and calibration

2.8.6.1 The necessary routine maintenance and calibration depends on the type of instrument and thermometer screen used as well as regional and local environmental conditions.

2.8.6.2 Information on maintenance, calibration and sources of error for temperature observations is provided in the *Guide to Meteorological Instruments and Methods of Observation* (WMO-No. 8), Part I, Chapter 2.

## 2.9 DEWPOINT TEMPERATURE

### 2.9.1 Operational requirements

2.9.1.1 The dewpoint temperature should be observed and reported in whole degrees Celsius. The observations should be representative of the runway complex. These observations are included in reports disseminated beyond the aerodrome and in local reports.

2.9.1.2 Further information relevant to operational procedures is provided in the *Technical Regulations* (WMO-No. 49), Volume II, Part I, 4.6.6, and Part II, Appendix 3, 4.6 Air temperature and dewpoint temperature.

### 2.9.2 Theory

2.9.2.1 Dewpoint temperature is the temperature at which moist air saturated with respect to water at a given pressure has a saturation mixing ratio equal to the given mixing ratio.

2.9.2.2 The theory applicable to dewpoint observations is provided in the *Guide to Meteorological Instruments and Methods of Observation* (WMO-No. 8), Part I, Chapter 4 Measurement of humidity.

### 2.9.3 Instrumentation

2.9.3.1 The instrument commonly used for manual observations is the psychrometer. Information relevant to this instrument is provided in the *Guide to Meteorological Instruments and Methods of Observation* (WMO-No. 8), Part I. Increasingly, electrical resistance thermometry and relative humidity sensors are being used to generate dewpoint values.

2.9.3.2 Information on dewpoint sensors is provided in the *Manual on Automatic Meteorological Observing Systems at Aerodromes* (ICAO Doc 9837), Chapter 8, 8.2.3 Dewpoint temperature sensors.

### 2.9.4 **Siting**

Dewpoint temperature should be representative of the same volume of air as the air temperature. The discussion in 2.8.4 above concerning the siting of instruments for air temperature is also valid for the dewpoint temperature.

### 2.9.5 **Observing techniques**

2.9.5.1 The observing technique described in the air temperature section (2.8.5. above) should be applied. The management of psychrometers and the observing technique recommended by WMO may be considered rather complicated, but at the same time it is necessary to avoid serious errors. These recommendations are contained in the *Guide to Meteorological Instruments and Methods of Observation* (WMO-No. 8), Part I, Chapter 4.

2.9.5.2 Procedures applicable to observing the dewpoint temperature are provided in the *Technical Regulations* (WMO-No. 49), Volume II, Part I, 4.6.6, and Part II, Appendix 3, 4.6.

### 2.9.6 **Maintenance and calibration**

2.9.6.1 Proper maintenance and calibration are essential for dewpoint measurements, regardless of the type of instrument used. Different routines are needed for different types of measuring systems. The use of humidity sensors requires less proactive maintenance compared to psychrometers. In any case, the sensor housing requires both proactive and reactive maintenance.

2.9.6.2 Information relevant to maintenance and calibration of sensors is provided in the *Guide to Meteorological Instruments and Methods of Observation* (WMO-No. 8), Part I, Chapter 4.

## 2.10 **ATMOSPHERIC PRESSURE**

### 2.10.1 **Operational requirements**

2.10.1.1 Aircraft altitude is calculated from atmospheric air pressure and aircraft altimeters are set according to air pressure readings (QNH or QFE). Aircraft engine performance is affected by air pressure intake.

2.10.1.2 Pressure measurements at an aeronautical meteorological station are essential for setting aircraft altimeters. The atmospheric pressure should be measured and the QNH and/or QFE altimeter settings computed in tenths of a hectopascal.

2.10.1.3 Further information on atmospheric pressure relevant to operational requirements is provided in:

- *Guide to Meteorological Instruments and Methods of Observation* (WMO-No. 8), Part II, Chapter 2;
- *Technical Regulations* (WMO-No. 49), Volume II, Part I, 4.6.7 Atmospheric pressure, and Part II, Appendix 3, 4.7 Atmospheric pressure;
- *Manual on Automatic Meteorological Observing Systems at Aerodromes* (ICAO Doc 9837), Chapter 9 Pressure.

2.10.1.4 Required accuracy for pressure readings is provided in the *Guide to Meteorological Instruments and Methods of Observation* (WMO-No. 8), Part I, Chapter 3 Measurement of atmospheric pressure.

### 2.10.2 **Theory**

2.10.2.1 The principles of pressure measurement and the definitions of the units used are widely available in relevant ICAO and WMO publications listed under this section and are not reproduced here.

2.10.2.2 Further information relevant to atmospheric pressure is provided in:

- *Guide to Meteorological Instruments and Methods of Observation* (WMO-No. 8), Part I, Chapter 3;
- *Manual on Automatic Meteorological Observing Systems at Aerodromes* (ICAO Doc 9837), Chapter 9;
- *Manual of the ICAO Standard Atmosphere: extended to 80 kilometres (262 500 feet)* (ICAO Doc 7488).

### 2.10.3 **Pressure instruments**

2.10.3.1 For the determination of the operationally required pressure values, the atmospheric pressure must be measured by a suitably exposed instrument in accordance with internationally agreed standards and procedures. It is essential for flight safety that all possible efforts should be made to eliminate errors in the altimeter settings caused by shortcomings in the measuring system or in the processing and distribution procedures.

2.10.3.2 Digital barometric pressure sensors are widely used at aerodromes, though precision aneroid barometers are also sometimes utilized as primary or secondary sensors. Mercury and aneroid barometers may also still be used, but mainly as a contingency measure. Aerodromes should ensure that sufficient redundancy exists in the event of a failure of their primary pressure sensor. Regular checking between these sensors with a check sensor should also take place.

2.10.3.3 Further information relevant to barometric instrumentation is provided in the *Guide to Meteorological Instruments and Methods of Observation* (WMO-No. 8), Part I, Chapter 3.

### 2.10.4 **Siting**

2.10.4.1 The pressure measured for aeronautical and synoptic purposes should represent the static pressure of the atmosphere at the aerodrome level. It is therefore important to measure the pressure as near that level as practicable. It is even more important that the location of the barometer be selected to ensure proper performance of the pressure measurements, for example when the sensor is sited indoors, it should be vented to the outside.

2.10.4.2 Information on the exposure of pressure instruments is provided in the *Guide to Meteorological Instruments and Methods of Observation* (WMO-No. 8), Part II, Chapter 2.

### 2.10.5 **Observing techniques**

2.10.5.1 There are no special techniques for reading barometers located at an aerodrome. They are the same as for a synoptic station. Information on these is provided in the *Guide to Meteorological Instruments and Methods of Observation* (WMO-No. 8), Part I, Chapter 3. Where a precision aneroid or mercury barometer is used, corrections for QFE and QNH may be achieved manually by reference to a correction card.

2.10.5.2 Information relevant to the use of electronic barometers is provided in the *Guide to Meteorological Instruments and Methods of Observation* (WMO-No. 8), Part I, Chapter 3, and the *Manual on Automatic Meteorological Observing Systems at Aerodromes* (ICAO Doc 9837), Chapter 9, 9.5 Measurement locations. Most digital and electronic sensors can be designed to automatically correct the pressure readings to aerodrome QFE and QNH.

### 2.10.6 **Maintenance and calibration**

Given the importance of the information provided by pressure sensors, a robust regular maintenance and calibration schedule for these sensors should be adopted. Information relevant to maintenance and calibration of barometers and information comparison procedures are provided in:

- *Guide to Meteorological Instruments and Methods of Observation* (WMO-No. 8), Part I, Chapter 3;
- *Manual on Automatic Meteorological Observing Systems at Aerodromes* (ICAO Doc 9837), Chapter 9, 9.4 Calibration and maintenance.

## 2.11 **SUPPLEMENTARY INFORMATION**

2.11.1 The importance of the provision of supplementary information on significant meteorological conditions at aerodromes cannot be highlighted enough. Supplementary information includes recent weather, significant meteorological conditions such as turbulence reports, wind shear alerts and sea-surface conditions (where applicable), and runway state reports.

2.11.2 Procedures relevant to the provision of this information are provided in the following publications:

- *Guide to Meteorological Instruments and Methods of Observation* (WMO-No. 8), Part II, Chapter 2;
- *Technical Regulations* (WMO-No. 49), Volume II, Part I, 4.6.8 Supplementary information, and Part II, Appendix 3, 4.8 Supplementary information;
- *Manual on Automatic Meteorological Observing Systems at Aerodromes* (ICAO Doc 9837), Chapter 10 Supplementary information;
- *Manual of Aeronautical Meteorological Practice* (ICAO Doc 8896), Chapter 2 Meteorological observations and reports, 2.3.15 Supplementary information;
- *Manual on Coordination between Air Traffic Services, Aeronautical Information Services and Aeronautical Meteorological Services* (ICAO Doc 9377).

# CHAPTER 3. REMOTE-SENSING SYSTEMS

## 3.1 INTRODUCTION

3.1.1 This chapter deals with remote-sensing systems used to observe weather phenomena that are of special interest to aviation operations and where, in many cases, more data are required than can be provided by the standard surface observations covered in Chapter 2 of this Guide. In some cases, these systems provide data for airspace surrounding the aerodrome and can be important tools for ensuring safe and efficient operations to and from the aerodrome.

3.1.2 Information obtained from these systems is often summarized in the supplementary information portion of the aerodrome meteorological reports (see section 2.11.2). However, some remote-sensing techniques are increasingly being used to enhance the quality of information on cloud and weather phenomena within the main body of aerodrome meteorological reports.

3.1.3 Remote-sensing systems generally provide information that must be handled in a manner completely separate from the routine and special meteorological observations. Because of their nature, these systems are more complex (and expensive) than equipment used in obtaining data for the standard METAR/SPECI. As has been emphasized previously in this Guide, it is important that a critical evaluation that includes a cost-benefit ratio analysis of the need for such systems be conducted prior to a decision to procure and install such equipment. The major factors to be considered are the climatology of the aerodrome location and the density of air traffic. Only if a clear benefit, compared to costs incurred, and enhanced safety can be obtained, should implementation of the installation be undertaken.

3.1.4 Further background information on remote-sensing systems is provided in the *Manual on Automatic Meteorological Observing Systems at Aerodromes* (ICAO Doc 9837), Chapter 12 Remote-sensing.

## 3.2 WEATHER RADAR

3.2.1 One of the most important tools for the detection of weather information of interest to aviation is weather radar, which can provide continuous information, in real time, about conditions over a large area surrounding an aerodrome.

3.2.2 Weather radar is particularly valuable in areas where thunderstorms occur frequently, but is also very useful for the detection of areas of rain or snow. Doppler weather radar can be used to detect low-level wind shear, a serious hazard to aviation operations.

### 3.2.3 Operational requirements

3.2.3.1 The need to supply ground weather radar information as is available to ATS personnel and aircrew is referred to implicitly in connection with observations and reports for take-off and landing.

3.2.3.2 There is a requirement, inter alia, for an aerodrome meteorological office to maintain a continuous survey of meteorological conditions over the aerodromes for which it is designated to prepare forecasts. This survey is necessary for the routine preparation of aerodrome and wind shear warnings, forecasts for take-off, landing forecasts (including trends) and the observation and reporting of supplementary information.

3.2.3.3 Further information relevant to operational requirements for radar is provided in the *Guide to Meteorological Instruments and Methods of Observation* (WMO-No. 8), Part II, Chapter 2.

### 3.2.4 **Equipment and background information**

Information relevant to the use of radar for meteorological purposes is provided in the following:

- *Guide to Meteorological Instruments and Methods of Observation* (WMO-No. 8), Part II, Chapter 9 Radar measurements;
- *Manual on Automatic Meteorological Observing Systems at Aerodromes* (ICAO Doc 9837), Chapter 12, 12.2.1 Radar images.

## 3.3 WIND SHEAR DETECTION SYSTEMS

3.3.1 In some areas, low-level wind shear, particularly when associated with microbursts and downbursts, can be a serious hazard to aviation operations. A number of fatal accidents have been attributed to this phenomenon. If warranted by the climatology of the area where an aerodrome is or is to be located, consideration should be given to installation of a wind shear detection system.

3.3.2 Although there have been significant developments and advances in low-level wind shear detection systems, there is currently no single system which can detect low-level wind shear adequately in all circumstances. It should also be noted that the systems available are very expensive. Again, a thorough evaluation of the cost-benefit ratio of such a system would need to be pursued prior to purchase.

3.3.3 Furthermore, low-level wind shear information is usually transmitted to pilots at a time of high workload on the flight deck during the approach or take-off phases. Consequently, when considering the installation of a wind shear detection system, the means of transmission to the pilot must be given equal consideration.

### 3.3.4 **Operational requirements**

3.3.4.1 There is a requirement to provide wind shear warnings concerning the observed or expected existence of wind shear that could adversely affect aircraft on the approach or take-off paths. Wind shear warnings should be cancelled when aircraft reports indicate that wind shear no longer exists or, alternatively, after an agreed elapsed time. The criteria for the cancellation should be defined locally for each aerodrome as agreed between the meteorological authority, the appropriate ATS authority and the operators concerned. See the *Technical Regulations* (WMO-No. 49), Volume II, Part I, 7.4 Wind shear warnings and alerts. Information relating to the coding of wind shear information in aerodrome weather reports can be found in *Technical Regulations* (WMO-No. 49), Volume II, Tables A3-1 and A3-2.

3.3.4.2 Further information relevant to operational requirements for wind shear is provided in the *Guide to Meteorological Instruments and Methods of Observation* (WMO-No. 8), Part II, Chapter 2.

### 3.3.5 **Equipment and background information**

3.3.5.1 A number of systems used to detect wind shear include:

(a) Low-Level Wind Shear Altering System (LLWAS);
(b) Doppler radar;
(c) Sound Detection and Ranging (SODAR);
(d) Light Detection and Ranging (LIDAR).

3.3.5.2 A Doppler weather radar can be used to detect the existence of wind shear in the vicinity of an aerodrome. The siting of the radar and the scan strategies used are chosen to enhance the possibility of detecting hazardous wind shear events.

3.3.5.3 A system deployed in the United States is used for the detection of microbursts, gust fronts, wind shifts and precipitation. The radar should be located outside the airport boundary where possible. The system should be operated in two modes. When algorithms within the system's processor determine that hazardous weather is unlikely, it will be operated in a monitor mode. In this mode it will use 360° azimuth scans at various elevation angles. When the algorithms determine that hazardous weather is present or is likely, the system will shift to the hazardous weather mode. In this mode, the system will use a combination of sector scans, which cover the area being protected, and 360° horizontal scans.

3.3.5.4 Information relevant to the use of wind shear equipment is provided in the following:

- ICAO Circular 186 – Wind Shear (1987);
- *Guide to Meteorological Instruments and Methods of Observation* (WMO-No. 8), Part I, Chapter 5, and Part II, Chapter 9;
- *Manual on Automatic Meteorological Observing Systems at Aerodromes* (ICAO Doc 9837), Chapter 12, 12.2.4 Wind profilers, and 12.2.5 Light detection and ranging (LIDAR).

3.3.5.5 The *Manual of Aeronautical Meteorological Practice* (ICAO Doc 8896), Appendix 6, provides an example of an operational wind shear and inversion warning system.

## 3.4 LIGHTNING DETECTION SYSTEMS

3.4.1 In areas where there are a significant number of thunderstorms or in mountainous terrain where the effectiveness of radar is much reduced, consideration could be given to the installation of a lightning detection system to detect lightning discharges in the aerodrome's vicinity.

3.4.2 These systems can be installed and used independently or in conjunction with weather radar. In some ways, lightning detection systems provide information that supplements weather radar data. These systems have been demonstrated to detect thunderstorm activity before weather radar. Also, the presence of lightning in a storm is a definite indication that it is a thunderstorm. There is also evidence that the rate of lightning from a thunderstorm is a good indication of its severity.

### 3.4.3 Operational requirements

3.4.3.1 Although there is no stated aeronautical requirement for the provision of specific information on lightning, this information is useful in meeting the requirement to observe and report the location of thunderstorms in the vicinity of the aerodrome and can be obtained at reasonable cost.

3.4.3.2 The presence of lightning is recognized as a considerable occupational health and safety risk for aerodrome ground staff. Routine ground procedures such as refuelling and the use of air bridges are normally changed when a lightning risk is present and the early detection of lightning can provide early warning of this hazard.

### 3.4.4 Equipment and background information

3.4.4.1 Lightning detection systems are available on the commercial market. The following provides a generic description of the equipment that would make up such a system. Lightning detection systems rely on the fact that a lightning stroke produces a strong radio wave that travels in all directions from the location of the stroke. A detection system can be built upon one of two basic principles: time of arrival of the radio wave, or the direction from which the wave arrives.

3.4.4.2 Information relevant to the use of lightning detection equipment is provided in the following:

- *Guide to Meteorological Instruments and Methods of Observation* (WMO-No. 8), Part II, Chapter 7 Locating the sources of atmospherics;
- *Manual on Automatic Meteorological Observing Systems at Aerodromes* (ICAO Doc 9837), Chapter 6, 6.2.10 Lightning detectors.

## 3.5 REMOTE-SENSING TECHNIQUES FOR CLOUD AND WEATHER IDENTIFICATION

3.5.1 Whilst the remote-sensing equipment mentioned above can be used to support and enhance the overall observations provided for airports, remote-sensing techniques are increasingly being used to enhance the quality of fully automated weather reports, particularly for cloud types and certain weather phenomena.

3.5.2 A composite radar network can be used to remotely provide an indication of the presence of CB and TCU activity over an aerodrome and its immediate vicinity. Research has found that a radar reflectivity threshold of 33dBZ or more strongly indicates the presence of TCU activity, and a reflectivity threshold of 41dBZ or more strongly indicates the presence of CB activity. Activity within 30 km of the aerodrome reference point is regarded as being representative of the typical horizontal distance a human observer would be able to report similar cloud types.

3.5.3 A composite radar network allied to a lightning detection network can also provide remote reports of thunderstorm activity at the aerodrome (TS) or in the vicinity of the aerodrome (VCTS). In this case, the detection of a lightning stroke allied to high radar reflectivity values would allow the provision of TS and VCTS information in aviation weather reports (with activity within 8 km of the aerodrome reference point closely correlating to a TS report, and activity between 8 and 16 km from the aerodrome reference point correlating to a VCTS report).

3.5.4 Further information relating to this may be found in the *Manual on Automatic Meteorological Observing Systems at Aerodromes* (ICAO Doc 9837), Chapter 7, 7.2.3 Cloud Type – Detection of cumulonimbus (CB) and towering cumulus (TCU) clouds, and Chapter 12, 12.2.2 Lightning network.

# CHAPTER 4. DISSEMINATION OF AERONAUTICAL METEOROLOGICAL INFORMATION

## 4.1 INTRODUCTION

4.1.1 This chapter deals with the distribution of aeronautical meteorological data to users. It is critical to the safe and economic management of an aerodrome that data should be disseminated without delay and in a format that enables an easy interpretation and application to aviation operations.

4.1.2 Users of this data include flight crew, airline operators, ATS personnel, aerodrome operators, aviation forecasters, the local meteorological service, and pilot-briefing service. It must be remembered that users' requirements for data can vary significantly with respect to the type of data and timeliness.

## 4.2 DISSEMINATION

The field of telecommunications technology is changing rapidly and as such, a state-of-the-art telecommunications infrastructure should be available wherever possible and economically feasible. The availability of this technology will ensure the rapid communication between the meteorological offices and all users both on and off the aerodrome. A description of these communication systems, including guidelines on the use of the Internet, is provided in the following publications:

- *Guidelines on the Use of the Public Internet for Aeronautical Applications* (ICAO Doc 9855);
- *Weather on the Internet and Other New Technologies* (WMO/TD-No. 1084);
- *Guidelines on the Improvement of NMSs–Media Relations and Ensuring the Use of Official Consistent Information* (WMO/TD-No. 1088).

## 4.3 PROCEDURES AND BACKGROUND

The procedures applicable to the distribution of meteorological data to users are provided in the following:

- *Technical Regulations* (WMO-No. 49), Volume II, Part I, 11 Requirements for and use of communications, and Part II, Appendix 10 Technical specifications relating to requirements for and use of communications;
- *Guide to the Global Observing System* (WMO-No. 488), Part III, 3.5 and 3.5.5 Communications;
- *Manual of Aeronautical Meteorological Practice* (ICAO Doc 8896), Chapter 4 SIGMET information, tropical cyclone and volcanic ash advisory information, AIRMET information, aerodrome warnings and wind shear warnings and alerts;
- *Guide to Practices for Meteorological Offices Serving Aviation* (WMO-No. 732), Chapter 2, 2.1.8 Display and dissemination of reports.

## 4.4 PHYSICAL DISTRIBUTION

4.4.1 The dissemination of meteorological reports should be accomplished in the most expedient and economical manner possible. However, this should not be to the detriment of the quality and integrity of the data. It is vital that the possibility of errors occurring in the message as received should be reduced to an absolute minimum. It is noted that if the telephone is used, the possibility of error rises sharply, so this means of communication should be regarded as a last resort if no other system is available. The telephone is, however, essential as a standby in case of failure of the normal system and as a first alert to advise of sudden significant changes.

4.4.2 A number of communications systems have been used over the years and are now rapidly becoming redundant. These have included: physical links, teleprinters, television and electrowriters.

4.4.3 Today's communication systems focus on the following means of distribution either as a single means, or more commonly, a combination of all.

### 4.4.4 Facsimile

Facsimile machines can be used to send and receive observations via standard telephone circuits and/or integrated into high-speed dedicated computer networks. They have the advantage of delivering a hard copy of the observation(s) that provides proof of delivery and receipt of the data. The delivery of a hard copy can also have the added benefit of being a "physical alert" for the recipient. However, this is a somewhat slower communication or dissemination medium relative to computer-based systems and is generally being overtaken by more responsive and flexible methods of dissemination.

### 4.4.5 Computer

4.4.5.1 Computing infrastructures can be, and are by some Members, used exclusively to disseminate observations. As with other techniques, the various locations served by the system are connected through circuits or exclusive high-speed dedicated networks.

4.4.5.2 Purpose-built computer-based observing systems can be fully automated or allow for manual input. They can collect, process, display and archive meteorological data. They also prepare METAR/SPECI reports and distribute these through a network such as the aeronautical fixed telecommunication network (AFTN). The system monitors the data, checks the measurable elements, assembles the information in the correct format and then transmits. The system can also be programmed to monitor the values recorded and alert an observer to the need for a special observation. Systems such as these offer many advantages in terms of speed and efficiency as well as a significant cost-benefit ratio in terms of managing an observational network.

### 4.4.6 Telephone

4.4.6.1 The telephone is used in a number of ways to distribute weather observations. This includes the basic procedure of an observer reporting observations via a telephone as well as, where available, the use of a mobile phone network Short Message Service (SMS). Whilst the use of telephones is a relatively inexpensive means of distributing the information, it has drawbacks in that the possibility for error exists in receiving the information and it is labour-intensive. In situations where there are a number of users to be called this is a time-consuming process, especially when the weather is changing rapidly and special observations are being made in addition to the routine ones. The standard telephone service is an excellent choice for a backup system to the more sophisticated systems identified above. In most cases, a telephone system will already exist at an aerodrome.

4.4.6.2 Due consideration should also be given to the recording of aviation operational telephone conversations within the meteorological office. Without a recording of operational conversations, there is no record. This may have legal implications if there is an aviation incident that is associated with that conversation.

4.4.6.3 Some services also use a telephone answering machine with pre-recorded messages. Persons interested in specific data can call and receive the pre-recorded information. This is used generally for pilots' pre-flight information and Automatic Terminal Information Service (ATIS) messages, particularly in the case of general aviation. The system has the advantage for the providers of the information that, once the tape is prepared, there is no further involvement for them until the next update.

4.4.6.4 The telephone can also be used by the aviation industry to access real-time observational data from automatic weather stations (AWS). However, to do so, the AWS must be fitted with the appropriate communication equipment that interfaces with the public telephone network.

4.4.6.5 Increasingly, weather information is made available via internet enabled smartphones and on mobile phone apps. Such technology makes weather information available "on the go" and without the need to access other communication infrastructures.

### 4.4.7 **Radio**

4.4.7.1 Radio is used for the transmission of weather reports to aircraft taxiing, taking off or approaching to land. One means of accomplishing this is for a recording to be made of the information and then broadcast. As with recordings accessed by telephone, this has an advantage for the organization responsible for dissemination of the data in that, once the tape is prepared, there is no further involvement necessary until the next update. There is also an advantage for users in that the information is available over a relatively large area and is available simultaneously for everyone. Moreover, the information is normally repeated continuously.

4.4.7.2 At many aerodromes, the local weather information is integrated into a message with other information about the aerodrome such as the runway(s) in use, runway surface conditions, transition level and other important operational information. This provision is known as the Automatic Terminal Information Service. Regulations governing ATIS may be found in ICAO Annex 11, Chapter 4 Flight information service.

4.4.7.3 Apart from ATIS, the transmission of observational data from AWS via VHF is adopted by a number of Members. This service, VOLMET, generates automated and continuous VHF aerodrome weather broadcasts providing near-to-real-time information on weather parameters. The process makes use of technology that converts the AWS data to speech through the use of pre-recorded spoken words and phrases. VOLMET is operated in accordance with regional air navigation agreements.

4.4.7.4 Further information is available in:

- *Manual on Coordination between Air Traffic Services, Aeronautical Information Services and Aeronautical Meteorological Services* (Doc 9377);
- *Technical Regulations* (WMO-No. 49), Volume II, Part II, Appendix 10, 4 Use of aeronautical data link service – D-VOLMET.

### 4.4.8 **Internet**

4.4.8.1 A rapidly growing method for the dissemination of aeronautical meteorological information is via the Internet. This methodology has been adopted by a significant number of National Meteorological or Hydrometeorological Services (NMS). The Internet offers a flexible and responsive way of uploading a variety of graphical and alphanumeric data, including OPMET data. Members that are contemplating providing their services via this medium are encouraged to visit the websites of other WMO Members.

4.4.8.2 Guidelines on the use of the Internet are provided in the *Guidelines on the Use of the Public Internet for Aeronautical Applications* (ICAO Doc 9855).

### 4.4.9 **Aeronautical fixed telecommunication network**

The AFTN is used to disseminate a large amount of alphanumeric information, such as TAFs and METARs. Information relating to requirements and standards for AFTN bulletins is found in *Technical Regulations* (WMO-No. 49), Volume II, Part II, Appendix 10.

### 4.4.10 **Satellite**

Satellite technology is used by the World Area Forecast Centres in the dissemination of World Area Forecast System products through the aeronautical fixed service (AFS) satellite broadcasts. This is regarded as a particularly efficient method, as it combines excellent quality with relatively low-cost, user-friendly receiving equipment.

# CHAPTER 5. ARCHIVING

## 5.1 INTRODUCTION

5.1.1 Meteorological observations at aerodromes are required not only as real-time information but also for other purposes. Each meteorological authority, on request and to the extent practicable, should make available to any other meteorological authority, operators and others concerned with the application of meteorology to international air navigation, copies of original meteorological observational data required for research, investigations in cases of accidents/incidents or operational analysis. Moreover, several user groups require statements about climatological situations at aerodromes. Therefore, it is important to build databases for both en-route and non-routine aerodrome meteorological observations.

5.1.2 In the following, details are provided on which meteorological elements observed or measured should be stored, the necessary storage media and the period during which the elements should be archived. See *Technical Regulations* (WMO-No. 49), Volume II, Part I, 8 Aeronautical climatological information, and Part II, Appendix 7 Technical specifications related to aeronautical climatological information, 3 Content of aeronautical climatological information.

## 5.2 ELEMENTS

### 5.2.1 Requirements for climatological information

5.2.1.1 The *Technical Regulations* (WMO-No. 49), Volume II prescribes that aeronautical climatological information required for the planning of flight operations shall be prepared in the form of aerodrome climatological summaries. Such information shall be supplied to aeronautical users as agreed between the users and the meteorological authority and be exchanged on request between meteorological authorities. The aerodrome climatological summaries should cover the frequency of:

(a) The occurrence of RVR/visibility and/or height of the base of the lowest cloud layer of broken (BKN) or overcast (OVC) extent below specified values at specified times;
(b) Visibility below specified values at specified times;
(c) The height of the base of the lowest cloud layer of BKN or OVC below specified values at specified times;
(d) The occurrence of concurrent wind direction and speed within specified ranges;
(e) Surface temperature in specified ranges of 5 °C at specified times;
(f) Mean values and variations including maximum and minimum values of meteorological elements required for operational planning purposes including take-off performance calculations.

5.2.1.2 Climatological summaries should be prepared using the models specified in the reference under 5.1.2 above and should be updated as necessary. More detailed information is given in the form of climatological tables that are generally produced upon request on the basis of computer-stored specific climatological data. The format of meteorological information should be agreed upon in each case between the user and the Meteorological Service.

5.2.1.3 For the purposes of planning the construction of runways, for example, wind statistics should be provided for the calculation of the "usability" factor in order to determine the maximum mean cross-wind components for planning the orientation of the runways (see ICAO Annex 14, Volume I, Chapter 3.1 Runways, and Attachment A Guidance material supplementary to Annex 14, Volume I, 1 Number, siting and orientation of runways). This evaluation should be based on a period of not less than five years. The observations used should preferably be made at least eight times per day and spaced at equal intervals of time. In many cases, a windrose provides an excellent summary of wind speed and direction over a period of time. In addition to the statistical evaluation of mean wind conditions, a study should be made of the frequency and type of gusts and the occurrence of poor visibility and/or low cloud.

5.2.1.4 Climatological data for operational planning purposes and calculations of take-off conditions should include the following parameters: mean daily maximum and minimum temperatures, mean pressure and, if available, mean absolute humidity at approximately the times of maximum and minimum temperatures for each month of the year.

5.2.1.5 Recommendations and procedures about the climatological data to be published in aeronautical information publications can be found in ICAO Annex 15, Appendix 1 and WMO *Technical Regulations* (WMO-No. 49), Volume II, Part II, Appendix 7. Besides the climatological data required for take-off performance requirements, the aerodrome reference temperature defined in ICAO Annex 14 should be published. The aerodrome reference temperature is the monthly mean of the daily maximum temperatures for the hottest month of the year (the hottest month being the one with the highest monthly mean temperature). This temperature should be averaged over a period of several years.

### 5.2.2 Requirements for other purposes

Meteorological data are needed not only for aerodrome climatological purposes but also for many other purposes, according to national requirements. Some examples are:

(a) In inquiries such as those investigating an accident, the meteorological conditions in the vicinity of the aerodrome at the time of the accident should be available at any time. It is therefore necessary to archive the routine and non-routine meteorological observations. Moreover, if available, meteorological information concerning the approach and climb-out area, especially radar and wind shear measurements, should be stored. All reports issued to air traffic control units and other users should be available with the exact time of issue for investigation. The period over which such reports are to be available should be agreed upon with the aviation authority;
(b) Research programmes where, for example, statistical evaluations of wind shear measurements could lead to an improvement in the detection of this dangerous meteorological phenomenon, especially significant in the approach and climb-out area;
(c) The verification of TAF and trend-type forecasts through archived routine and non-routine weather reports;
(d) Improved quality control of observational data to recognize and eliminate systematic errors can be achieved with the aid of statistical procedures.

## 5.3 STORAGE PERIODS

Meteorological elements measured and observed at aerodromes are needed both at and beyond the aerodrome. Different sites for the storage of prepared and/or transmitted information are therefore necessary.

### 5.3.1 Internal archiving of meteorological information at the aerodrome

5.3.1.1 Information disseminated at the aerodrome should be stored for a given period so that it remains possible to recover information that has been passed on to users at the aerodrome. When automatic systems are used for data acquisition, processing and dissemination, large amounts of data are generated. As these data are generally required for internal purposes, it is recommended that they should be stored at the aerodrome.

5.3.1.2 At aerodromes where there are no automatic systems for the acquisition of data, information disseminated internally at the aerodrome should be documented in written form as far as possible. This can be done manually by entering routine and non-routine meteorological information on a special form. Further information for take-off and landing can be stored to a limited extent only, but it is possible to reconstruct the values recorded by means of an evaluation of the recorder tapes or autographic charts of the corresponding measuring instrument. These records should be stored for an unlimited period if the data cannot be transferred to a suitable data archive.

### 5.3.2 Archiving of meteorological information at a facility away from the aerodrome

5.3.2.1 Information disseminated beyond aerodromes via AFTN, regional or national telecommunication networks should be stored by the responsible meteorological centre. The data, disseminated generally at hourly or half-hourly intervals in METAR code, serve on the one hand as current real-time information and on the other as the basis for subsequent reconstruction of the meteorological conditions prevailing at the relevant aerodrome.

5.3.2.2 In addition, as the climatological data from the aerodrome are required, the information should then be stored for an unlimited period for the preparation of long-term time series. It is recommended that aerodrome climatological information be based on data series covering at least five years.

# CHAPTER 6. QUALITY CONTROL

## 6.1 INTRODUCTION

6.1.1 This chapter provides a clear focus on the quality control of observational data and includes the monitoring of the functioning of meteorological and other equipment used in observing and disseminating meteorological observations.

6.1.2 However, there is also the need to recognize that quality control should be an integral component of an overall quality management framework. The *Technical Regulations* (WMO-No. 49), Volume II, Part I, 2.2 Supply, use and quality management of meteorological information, 2.2.2 (Regulation) states the following:

> Each Member shall ensure that the designated meteorological authority referred to in 2.1.4 above establishes and implements a properly organized quality system comprising procedures, processes and resources necessary to provide for the quality management of the meteorological information to be supplied to the users listed in 2.1.2 above.

6.1.3 The user of meteorological information must be able to rely on the accuracy and availability of the data in accordance with WMO and ICAO specifications, and Meteorological Services should therefore develop procedures to ensure the high quality of the observational data issued to the users.

6.1.4 Quality control of observational data is achieved through screening faulty reports and, when possible, correcting the errors. This function can be performed at different times and at different points:

(a) At the observation site, for example through the provision of suitable initial training, ongoing competency and managed documentation;
(b) Prior to their dissemination both nationally and globally at the telecommunications centre, for example through inbuilt quality control of observations collected from an integrated meteorological observing system;
(c) Prior to archiving at the meteorological centre, for example through a consistent approach to quality improvement, such as post-event feedback.

6.1.5 In general, the quality control of current observations should be enough to achieve the required accuracy without delaying unduly the transmission of the data. For this reason, more elaborate quality control procedures can usually only be applied prior to archiving the data at the meteorological centre.

## 6.2 QUALITY CONTROL PROCEDURES

6.2.1 The *Technical Regulations* (WMO-No. 49), Volume II, Part I, 1 Definitions, presents the following quality definitions that may be of value when addressing issues of quality:

(a) Quality assurance. Part of quality management focused on providing confidence that quality requirements will be fulfilled (ISO 9000);
(b) Quality control. Part of quality management focused on fulfilling quality requirements (ISO 9000);
(c) Quality management. Coordinated activities to direct and control an organization with regard to quality (ISO 9000).

6.2.2 As a matter of principle, current meteorological data should be subject to quality control prior to their dissemination or their being utilized by users. This implies that current observations must be checked at origin, i.e. at the aerodrome. Following their transmission to the telecommunication unit or the meteorological centre, the data may be subjected to a more elaborate quality control (see 6.2.3 below).

6.2.3 Any observed or measured parameter consists of a true value and a systematic and/or random variation, i.e. the error. The objective of quality control is to minimize this variation as far as possible, that is, to detect the error and to correct it as far as possible. In observations and measurements, the most frequent errors are:

(a) Those inherent in the technical equipment used (instruments, telecommunications, indicators);
(b) Those due to subjective inputs by the observer (reading errors, observational errors);
(c) Those caused by defective observational procedures;
(d) Those due to unrepresentative siting of instruments.

The possibility of errors increases with the number of intermediate steps between the measurement and the transmission to and receipt of the data by the user. Those intermediate steps should therefore be as few as possible.

6.2.4 In services where there is not a high level of automation, transferring measured data from instruments to the telecommunications terminal (e.g. teleprinter) as well as computing or extracting from tables or graphical representation values not immediately available in final form is often a considerable source of error.

6.2.5 In automated systems, data are usually collected by interrogation of the instruments (or the sensors), thus avoiding successive transformations of raw data and potential sources of error.

6.2.6 Identification and elimination of errors may be performed manually or automatically, provided that no significant delays are introduced in the distribution of the data.

## 6.3 MONITORING OF EQUIPMENT

6.3.1 One of the fundamentals of the quality control of meteorological information is ensuring that the appropriate maintenance and calibration schedules are sustained.

6.3.2 The meteorological instruments covered in Chapter 2 of this Guide each had a reference to its appropriate maintenance and calibration programme. These should be adhered to wherever possible.

6.3.3 In addition to periodic maintenance, meteorological observers should monitor the status of the equipment used to make and transmit observations. Defective functioning or failures of the system or its components should be reported without delay to the designated unit responsible for maintenance. Duplication of certain instruments for stand-by purposes should be considered.

6.3.4 Automatic systems should monitor the status of the connected sensors and transmission facilities. Defective functioning or outages should be brought to the attention of the observer optically and/or acoustically. In the case of interconnected automatic systems between the meteorological service and the air traffic control unit, the recipient of the data should be required to confirm receipt of the data by means of a return signal.

## 6.4 RESOURCES ON QUALITY

6.4.1 A prime source of information on quality management and its implementation is contained in the *Guide to the Quality Management System for the Provision of Meteorological Service for International Air Navigation* (WMO-No. 1001). See also ICAO Doc 9873.

6.4.2 Further information on all facets of quality and in particular quality systems, management and standards, can be obtained through the International Organization for Standardization (ISO website at: http://www.iso.org/iso/home.html).

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# GLOSSARY

This glossary refers specifically to this publication. For a more extensive list of agreed definitions please refer to *Technical Regulations* (WMO-No. 49), Volume II, Part I, or authorized documentation specific to aviation operations, such as that provided by WMO and ICAO.

***Aerodrome.*** A defined area on land or water (including any buildings, installations and equipment) intended to be used either wholly or in part for the arrival, departure and surface movement of aircraft.

***Aeronautical fixed telecommunication network (AFTN).*** A worldwide system of aeronautical fixed circuits provided, as part of the aeronautical fixed service, for the exchange of messages and/or digital data between aeronautical fixed stations having the same or compatible communications characteristics.

***Aeronautical meteorological station.*** A station designated to make observations and meteorological reports for use in international air navigation.

***Albedo.*** Surface reflectivity; the ratio of the amount of light reflected by a surface in relation to the total amount of light falling upon that surface.

***Analogue signal.*** Any continuously variable signal typically associated with sound or speech. It differs from a digital signal in that small fluctuations in the signal are meaningful.

***ICAO Annex 3.*** The Annex to the Convention on International Civil Aviation (Chicago Convention) that is essentially identical to the WMO T*echnical Regulations* (WMO-No. 49), Volume II, on International Standards and Recommended Practices.

***Automated observation.*** Meteorological elements recorded by electronic means without human intervention.

***Broken Cloud (BKN).*** 5/8 to 7/8 of sky covered.

***Buffer zone.*** An area of land between areas that require specific separation from other surrounding land.

***Cost-benefit ratio.*** A ratio used to determine if the expected benefits from a specific acquisition (for example an AWS) will provide an acceptable return on the estimated investment and costs.

***Digital signal.*** A way of transmitting voice data that reconstructs the signals using binary codes (1s and 0s) for transmission. Digital audio signals can be transmitted faster and more accurately than analogue signals.

***Human observer.*** A meteorological observer that meets the minimum WMO standards to provide aviation meteorological observations.

***METAR.*** Meteorological aerodrome report – hourly or half-hourly coded weather observation from an aerodrome.

***Meteorological authority.*** The entity which has been notified by the Member/State to ICAO as being responsible for providing or arranging for the provision of meteorological service for international air navigation, in accordance with the *Technical Regulations* (WMO-No. 49), Volume II, Part I, 2.1.4.

***Meteorological report.*** A statement of observed meteorological conditions related to a specified time and location.

***Obstacle clearance area.*** An area on an aerodrome that has specific clearance criteria to ensure objects do not extend above the obstacle limitation surface of that aerodrome.

***Observing system(s).*** Provide the basic observing functions necessary to generate surface weather observations. This includes wind direction and speed, visibility, runway visual range, weather phenomena, sky condition, air temperature/dewpoint temperature, altimeter setting and remarks. This information is distributed to or accessed by aviation industry for a range of operational needs.

***Operating minima.*** Limiting meteorological conditions prescribed for the purpose of determining the usability of an aerodrome, either for the take-off or landing of aircraft.

***Photometric.*** Quantitative measurements of light levels and distribution.

***QNH.*** The pressure reading that an altimeter should be set to so that the geometric altitude it reads is correct when at the level of the aerodrome.

***SPECI.*** Special aerodrome report issued for an aerodrome when meteorological conditions have changed according to set criteria.

***TAF.*** A forecast of meteorological conditions for an aerodrome usually covering a period from 9 to 30 hours in the future.

***Touchdown zone.*** The portion of a runway, beyond the threshold, where the landing aircraft is intended to first contact the runway.

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