

Manual on the Global Observing System

Volume I – Global Aspects

Annex V to the WMO Technical Regulations

2015 edition

Updated in 2017

WEATHER CLIMATE WATER



WORLD
METEOROLOGICAL
ORGANIZATION

WMO-No. 544

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EDITORIAL NOTE

The following typographical practice has been followed: Standard practices and procedures have been printed in **bold**. Recommended practices and procedures have been printed in regular font. Notes have been printed in smaller type.

METEOTERM, the WMO terminology database, may be consulted at <http://public.wmo.int/en/resources/meteoterm>.

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NOTE

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INTRODUCTION

Purpose and scope

1. The Manual is designed:
 - (a) To facilitate cooperation in observations between Members;
 - (b) To specify obligations of Members in the implementation of the World Weather Watch (WWW) Global Observing System (GOS);
 - (c) To ensure adequate uniformity and standardization in the practices and procedures employed in achieving (a) and (b) above.
 2. The first edition of the *Manual on the Global Observing System* was issued in 1980 in accordance with the decisions of the Seventh World Meteorological Congress. Since then it has undergone a number of revisions and amendments. The *Manual on the WMO Integrated Global Observing System* (WMO-No. 1160) will eventually replace the present Manual entirely. The transfer process began with the 2015 edition: some of its provisions have been removed and are now incorporated into the *Manual on the WMO Integrated Global Observing System*. For now these two Manuals are companion documents and must be read together. In particular, the provisions of the *Manual on the WMO Integrated Global Observing System* apply to all component observing systems, including the GOS.
 3. This Manual is composed of Volumes I and II, which contain the regulations for the global and regional aspects of the System, respectively. The regulations stem from recommendations of the Commission for Basic Systems and resolutions of regional associations, as well as from decisions taken by Congress and the Executive Council.
 4. Volume I of the Manual – Global Aspects – has regulatory status and is referred to as Annex V to the *Technical Regulations* (WMO-No. 49).
 5. Volume II of the Manual – Regional Aspects – does not have regulatory status.
 6. In essence, the Manual specifies what is to be observed where and when in order to meet the relevant observational requirements of Members. The *Guide to the Global Observing System* (WMO-No. 488) provides detailed guidance on how to establish, operate and manage networks of stations to make these observations. While some regulatory material concerning instruments and methods of observation is contained in a special short section of the Manual, a full description of how and with what observations are made is contained in the *Guide to Meteorological Instruments and Methods of Observation* (WMO-No. 8). The *International Cloud Atlas* (WMO-No. 407) describes the classification of clouds. The subsequent step of how observations are to be reported and encoded is specified in the *Manual on Codes* (WMO-No. 306). Further guidance on observations for special applications is given in WMO publications such as the *Guide to Meteorological Observing and Information Distribution Systems for Aviation Weather Services* (WMO-No. 731), *Guide to Marine Meteorological Services* (WMO-No. 471), *Guide to Climatological Practices* (WMO-No. 100), *Guide to Agricultural Meteorological Practices* (WMO-No. 134) and various publications of the Global Atmosphere Watch Programme.
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GENERAL PROVISIONS

1. The *Technical Regulations* (WMO-No. 49) of the World Meteorological Organization are presented in four volumes:

Volume I – General Meteorological Standards and Recommended Practices

Volume II – Meteorological Service for International Air Navigation

Volume III – Hydrology

Volume IV – Quality Management

Purpose of the Technical Regulations

2. The Technical Regulations are determined by the World Meteorological Congress in accordance with Article 8 (d) of the Convention.

3. These Regulations are designed:

- (a) To facilitate cooperation in meteorology and hydrology among Members;
- (b) To meet, in the most effective manner, specific needs in the various fields of application of meteorology and operational hydrology in the international sphere;
- (c) To ensure adequate uniformity and standardization in the practices and procedures employed in achieving (a) and (b) above.

Types of Regulations

4. The Technical Regulations comprise *standard* practices and procedures and *recommended* practices and procedures.

5. The definitions of these two types of Regulations are as follows:

The *standard* practices and procedures:

- (a) Shall be the practices and procedures that Members are required to follow or implement;
- (b) Shall have the status of requirements in a technical resolution in respect of which Article 9 (b) of the Convention is applicable;
- (c) Shall invariably be distinguished by the use of the term *shall* in the English text, and by suitable equivalent terms in the Arabic, Chinese, French, Russian and Spanish texts.

The *recommended* practices and procedures:

- (a) Shall be the practices and procedures with which Members are urged to comply;
- (b) Shall have the status of recommendations to Members, to which Article 9 (b) of the Convention shall not be applied;
- (c) Shall be distinguished by the use of the term *should* in the English text (except where otherwise provided by decision of Congress) and by suitable equivalent terms in the Arabic, Chinese, French, Russian and Spanish texts.

6. In accordance with the above definitions, Members shall do their utmost to implement the *standard* practices and procedures. In accordance with Article 9 (b) of the Convention and in conformity with Regulation 128 of the General Regulations, Members shall formally notify the Secretary-General, in writing, of their intention to apply the *standard* practices

and procedures of the Technical Regulations, except those for which they have lodged a specific deviation. Members shall also inform the Secretary-General, at least three months in advance, of any change in the degree of their implementation of a *standard* practice or procedure as previously notified and the effective date of the change.

7. Members are urged to comply with *recommended* practices and procedures, but it is not necessary to notify the Secretary-General of non-observance except with regard to practices and procedures contained in Volume II.

8. In order to clarify the status of the various Regulations, the *standard* practices and procedures are distinguished from the *recommended* practices and procedures by a difference in typographical practice, as indicated in the editorial note.

Status of annexes and appendices

9. The following annexes to the *Technical Regulations* (Volumes I to IV), also called Manuals, are published separately and contain regulatory material having the status of *standard* and/or *recommended* practices and procedures:

- I *International Cloud Atlas* (WMO-No. 407) – Manual on the Observation of Clouds and Other Meteors, sections 1, 2.1.1, 2.1.4, 2.1.5, 2.2.2, 1 to 4 in 2.3.1 to 2.3.10 (for example, 2.3.1.1, 2.3.1.2, etc.), 2.8.2, 2.8.3, 2.8.5, 3.1 and the definitions (in grey-shaded boxes) of 3.2;
- II *Manual on Codes* (WMO-No. 306), Volume I;
- III *Manual on the Global Telecommunication System* (WMO-No. 386);
- IV *Manual on the Global Data-processing and Forecasting System* (WMO-No. 485);
- V *Manual on the Global Observing System* (WMO-No. 544), Volume I;
- VI *Manual on Marine Meteorological Services* (WMO-No. 558), Volume I;
- VII *Manual on the WMO Information System* (WMO-No. 1060);
- VIII *Manual on the WMO Integrated Global Observing System* (WMO-No. 1160).

These annexes (Manuals) are established by decision of Congress and are intended to facilitate the application of Technical Regulations to specific fields. Annexes may contain both *standard* and *recommended* practices and procedures.

10. Texts called appendices, appearing in the *Technical Regulations* or in an annex to the *Technical Regulations*, have the same status as the Regulations to which they refer.

Status of notes and attachments

11. Certain notes (preceded by the indication “Note”) are included in the *Technical Regulations* for explanatory purposes; they may, for instance, refer to relevant WMO Guides and publications. These notes do not have the status of Technical Regulations.

12. The *Technical Regulations* may also include attachments, which usually contain detailed guidelines related to *standard* and *recommended* practices and procedures. Attachments, however, do not have regulatory status.

Updating of the *Technical Regulations* and their annexes (Manuals)

13. The *Technical Regulations* are updated, as necessary, in the light of developments in meteorology and hydrology and related techniques, and in the application of meteorology and operational hydrology. Certain principles previously agreed upon by Congress and applied in the selection of material for inclusion in the Technical Regulations are reproduced below. These principles provide guidance for constituent bodies, in particular technical commissions, when dealing with matters pertaining to the Technical Regulations:

- (a) Technical commissions should not recommend that a Regulation be a *standard* practice unless it is supported by a strong majority;
- (b) Technical Regulations should contain appropriate instructions to Members regarding implementation of the provision in question;
- (c) No major changes should be made to the Technical Regulations without consulting the appropriate technical commissions;
- (d) Any amendments to the Technical Regulations submitted by Members or by constituent bodies should be communicated to all Members at least three months before they are submitted to Congress.

14. Amendments to the *Technical Regulations* – as a rule – are approved by Congress.

15. If a recommendation for an amendment is made by a session of the appropriate technical commission and if the new regulation needs to be implemented before the next session of Congress, the Executive Council may, on behalf of the Organization, approve the amendment in accordance with Article 14 (c) of the Convention. Amendments to annexes to the *Technical Regulations* proposed by the appropriate technical commissions are normally approved by the Executive Council.

16. If a recommendation for an amendment is made by the appropriate technical commission and the implementation of the new regulation is urgent, the President of the Organization may, on behalf of the Executive Council, take action as provided by Regulation 9 (5) of the General Regulations.

Note: A simple (fast-track) procedure may be used for amendments to technical specifications in Annexes II (*Manual on Codes* (WMO-No.306)), III (*Manual on the Global Telecommunication System* (WMO-No.386)), IV (*Manual on the Global Data-processing and Forecasting System* (WMO-No.485)), V (*Manual on the Global Observing System* (WMO-No.544)), VII (*Manual on the WMO Information System* (WMO-No.1060)) and VIII (*Manual on the WMO Integrated Global Observing System* (WMO-No.1160)). Application of the simple (fast-track) procedure is defined in the [appendix](#) to these General Provisions.

17. After each session of Congress (every four years), a new edition of the *Technical Regulations*, including the amendments approved by Congress, is issued. With regard to the amendments between sessions of Congress, Volumes I, III and IV of the *Technical Regulations* are updated, as necessary, upon approval of changes thereto by the Executive Council. The *Technical Regulations* updated as a result of an approved amendment by the Executive Council are considered a new update of the current edition. The material in Volume II is prepared by the World Meteorological Organization and the International Civil Aviation Organization working in close cooperation, in accordance with the Working Arrangements agreed by these Organizations. In order to ensure consistency between Volume II and Annex 3 to the Convention on International Civil Aviation – *Meteorological Service for International Air Navigation*, the issuance of amendments to Volume II is synchronized with the respective amendments to Annex 3 by the International Civil Aviation Organization.

Note: Editions are identified by the year of the respective session of Congress whereas updates are identified by the year of approval by the Executive Council, for example “Updated in 2012”.

WMO Guides

18. In addition to the *Technical Regulations*, appropriate Guides are published by the Organization. They describe practices, procedures and specifications which Members are invited to follow or implement in establishing and conducting their arrangements for compliance with the Technical Regulations, and in otherwise developing meteorological and hydrological services in their respective countries. The Guides are updated, as necessary, in the light of scientific and

technological developments in hydrometeorology, climatology and their applications. The technical commissions are responsible for the selection of material to be included in the Guides. These Guides and their subsequent amendments shall be considered by the Executive Council.

APPENDIX. PROCEDURES FOR AMENDING WMO MANUALS AND GUIDES THAT ARE THE RESPONSIBILITY OF THE COMMISSION FOR BASIC SYSTEMS

1. DESIGNATION OF RESPONSIBLE COMMITTEES

The Commission for Basic Systems (CBS) shall, for each Manual and Guide, designate one of its Open Programme Area Groups (OPAGs) as being responsible for that Manual and its associated technical guides. The Open Programme Area Group may choose to designate one of its Expert Teams as the designated committee for managing changes to all or part of that Manual; if no Expert Team is designated, the Implementation Coordination Team for the OPAG takes on the role of the designated committee.

2. GENERAL VALIDATION AND IMPLEMENTATION PROCEDURES

2.1 Proposal of amendments

Amendments to a Manual or a Guide managed by CBS shall be proposed in writing to the Secretariat. The proposal shall specify the needs, purposes and requirements and include information on a contact point for technical matters.

2.2 Drafting recommendation

The designated committee for the relevant part of a Manual or a Guide, supported by the Secretariat, shall validate the stated requirement (unless it is consequential to an amendment to the WMO Technical Regulations) and develop a draft recommendation to respond to the requirement, as appropriate.

2.3 Procedures for approval

After a draft recommendation of the designated committee is validated in accordance with the procedure given in section 7 below, depending on the type of amendments, the designated committee should select one of the following procedures for the approval of the amendments:

- (a) Simple (fast-track) procedure (see section 3 below);
- (b) Standard (adoption of amendments between CBS sessions) procedure (see section 4 below);
- (c) Complex (adoption of amendments during CBS sessions) procedure (see section 5 below).

2.4 Date of implementation

The designated committee should define an implementation date in order to give WMO Members sufficient time to implement the amendments after the date of notification. For procedures other than the simple (fast-track) one, if the time between the date of notification and implementation date is less than six months, the designated committee shall document the reasons for its decision.

2.5 **Urgent introduction**

Regardless of the above procedures, as an exceptional measure, the following procedure accommodates urgent user needs to introduce elements in lists of technical details, or to correct errors:

- (a) A draft recommendation developed by the designated committee shall be validated according to the steps defined in section 7 below;
- (b) The draft recommendation for pre-operational use of a list entry, which can be used in operational data and products, shall be approved by the chairperson of the designated committee and the chairperson of the responsible OPAG, and the president of CBS. A listing of pre-operational list entries is kept online on the WMO web server;
- (c) Pre-operational list entries shall then be submitted for approval by one of the procedures in 2.3 above for operational use;
- (d) Any version numbers associated with the technical implementation should be incremented at the least significant level.

2.6 **Issuing updated version**

Once amendments to a Manual or a Guide are adopted, an updated version of the relevant part of the Manual shall be issued in the languages agreed for its publication. The Secretariat shall inform all Members of the availability of a new updated version of that part at the date of notification mentioned in 2.4 above. If amendments are not incorporated into the published text of the relevant Manual or Guide at the time of the amendment, there should be a mechanism to publish the amendments at the time of their implementation and to retain a permanent record of the sequence of amendments.

3. **SIMPLE (FAST-TRACK) PROCEDURE**

3.1 **Scope**

The simple (fast-track) procedure shall be used only for changes to components of the Manual that have been designated and marked as “technical specifications to which the simple (fast-track) procedure for the approval of amendments may be applied”.

Note: An example would be the addition of code list items in the *Manual on Codes* (WMO-No. 306).

3.2 **Endorsement**

Draft recommendations developed by the responsible committee, including a date for implementation of the amendments, shall be submitted to the chairperson of the relevant OPAG for endorsement.

3.3 **Approval**

3.3.1 **Minor adjustments**

Correcting typographical errors in descriptive text is considered a minor adjustment, and will be done by the Secretariat in consultation with the president of CBS. See Figure 1.

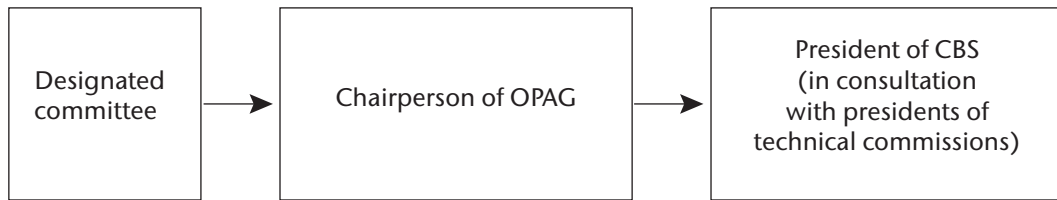


Figure 1. Adoption of amendments to a Manual by minor adjustment

3.3.2 **Other types of amendments**

For other types of amendments, the English version of the draft recommendation, including a date of implementation, should be distributed to the focal points for matters concerning the relevant Manual for comments, with a deadline of two months for the reply. It should then be submitted to the president of CBS for consultation with presidents of technical commissions affected by the change. If endorsed by the president of CBS, the change should be passed to the President of WMO for consideration and adoption on behalf of the Executive Council (EC).

3.3.3 **Frequency**

The implementation of amendments approved through the simple (fast-track) procedure can be twice a year in May and November. See Figure 2.

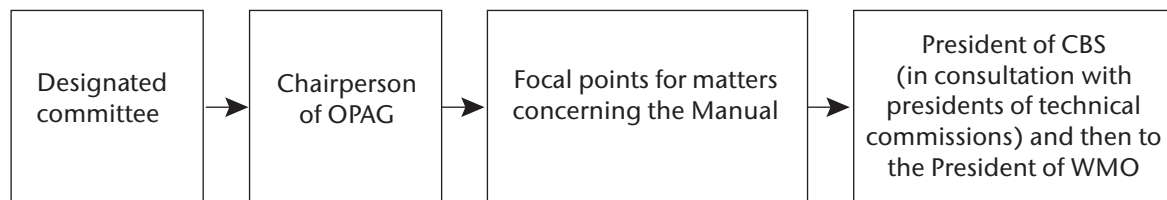


Figure 2. Adoption of amendments to a Manual by simple (fast-track) procedure

4. **STANDARD (ADOPTION OF AMENDMENTS BETWEEN CBS SESSIONS) PROCEDURE**

4.1 **Scope**

The standard (adoption of amendments between CBS sessions) procedure shall be used for changes that have an operational impact on those Members who do not wish to exploit the change, but that have only minor financial impact, or that are required to implement changes in the *Technical Regulations* (WMO-No. 49), Volume II – Meteorological Service for International Air Navigation.

4.2 **Approval of draft recommendations**

For the direct adoption of amendments between CBS sessions, the draft recommendation developed by the designated committee, including a date of implementation of the amendments, shall be submitted to the chairperson of the responsible OPAG and president and vice-president of CBS for approval. The president of CBS shall consult with the presidents of technical commissions affected by the change. In the case of recommendations in response

to changes in the *Technical Regulations* (WMO-No. 49), Volume II – Meteorological Service for International Air Navigation, the president of CBS shall consult with the president of the Commission for Aeronautical Meteorology.

4.3 Circulation to Members

Upon approval of the president of CBS, the Secretariat sends the recommendation to all Members, in the languages in which the Manual is published, including a date of implementation of the amendments, for comments to be submitted within two months following the dispatch of the amendments. If the recommendation is sent to Members via electronic mail, there shall be public announcement of the amendment process including dates, for example by WMO Operational Newsletter on the WMO website, to ensure all relevant Members are informed.

4.4 Agreement

Those Members not having replied within the two months following the dispatch of the amendments are implicitly considered as having agreed with the amendments.

4.5 Coordination

Members are invited to designate a focal point responsible to discuss any comments/ disagreements with the designated committee. If the discussion between the designated committee and the focal point cannot result in an agreement on a specific amendment by a Member, this amendment will be reconsidered by the designated committee. If a Member cannot agree that the financial or operational impact is minor, the redrafted amendment shall be approved by the complex (adoption of amendments during CBS sessions) procedure described in section 5 below.

4.6 Notification

Once amendments are agreed by Members, and after consultation with the chairperson of the responsible OPAG, the vice-president of CBS and the president of CBS (who should consult with presidents of other commissions affected by the change), the Secretariat notifies at the same time the Members and the members of the Executive Council of the approved amendments and of the date of their implementation. See Figure 3.

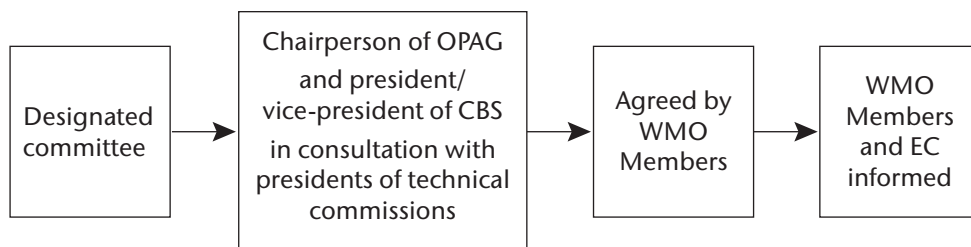


Figure 3. Adoption of amendments between CBS sessions

5. **COMPLEX (ADOPTION OF AMENDMENTS DURING CBS SESSIONS) PROCEDURE**

5.1 **Scope**

The complex (adoption of amendments during CBS sessions) procedure shall be used for changes for which the simple (fast-track) procedure or standard (adoption of amendments between CBS sessions) procedure cannot be applied.

5.2 **Procedure**

For the adoption of amendments during CBS sessions, the designated committee submits its recommendation, including a date of implementation of the amendments, to the Implementation Coordination Team of the responsible Open Programme Area Group. The recommendation is then passed to the presidents of technical commissions affected by the change for consultation, and to a CBS session that shall be invited to consider comments submitted by presidents of technical commissions. The document for the CBS session shall be distributed not later than 45 days before the opening of the session. Following the CBS session, the recommendation shall then be submitted to a session of the Executive Council for decision. See Figure 4.

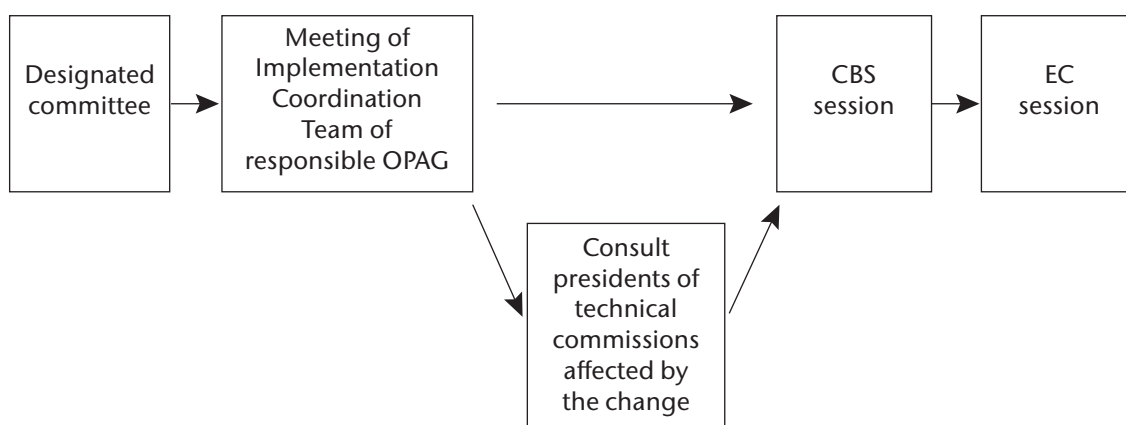


Figure 4. Adoption of amendments during CBS sessions

6. **PROCEDURE FOR THE CORRECTION OF EXISTING MANUAL CONTENTS**

6.1 **Correcting errors in items within Manuals**

Where a minor error in the specification of an item that defines elements within a Manual is found, for example, a typing error or an incomplete definition, the item shall be amended and re-published. Any version numbers associated with items edited as a result of the change should be incremented at their lowest level of significance. If, however, the change has an impact on the meaning of the item, then a new item should be created and the existing (erroneous) item marked as deprecated. This situation is considered a minor adjustment according to 3.3.1 above.

Note: An example of an item for which this type of change applies is a code list entry for the Table Driven Code Forms or WMO Core Metadata Profile, in which the description contains typographical errors that can be corrected without changing the meaning of the description.

6.2 **Correcting an error in the specification of how conformance with the requirements of the Manual can be checked**

If an erroneous specification of a conformance-checking rule is found, the preferred approach is to add a new specification using the simple (fast-track) procedure or standard (adoption of amendments between CBS sessions) procedure. The new conformance-checking rule should be used instead of the old. An appropriate explanation shall be added to the description of the conformance-checking rule to clarify the practice along with the date of the change.

Note: An example of such a change would be correcting a conformance-checking rule in the WMO Core Metadata Profile.

6.3 **Submission of corrections to errors**

Such changes shall be submitted through the simple (fast-track) procedure.

7. **VALIDATION PROCEDURE**

7.1 **Documentation of need and purpose**

The need for, and the purpose of, the proposal for changes should be documented.

7.2 **Documentation of result**

This documentation shall include the results of validation testing of the proposal as described in 7.3 below.

7.3 **Testing with relevant applications**

For changes that have an impact on automated processing systems, the extent of the testing required before validation should be decided by the designated committee on a case-by-case basis, depending on the nature of the change. Changes involving a relatively high risk and/or impact on the systems should be tested by the use of at least two independently developed tool sets and two independent centres. In that case, results should be made available to the designated committee with a view to verifying the technical specifications.

DEFINITIONS

The following terms, when used in this Manual, have the meanings given below. Composite terms have not been defined in this section when their meanings can easily be deduced from those of the elements constituting them. For example, the meaning of the term “synoptic land station” can be constructed logically from the meaning of the terms “synoptic station” and “land station”. Other definitions can be found in the *Manual on Codes* (WMO-No. 306), *Manual on the Global Data-processing and Forecasting System* (WMO-No. 485), *Manual on the Global Telecommunication System* (WMO-No. 386) and other WMO publications.

Many terms used in this Manual are defined in the *Manual on the WMO Integrated Global Observing System* (WMO-No. 1160) and are not repeated here.

A. METEOROLOGICAL OBSERVING FACILITIES AND RELATED SERVICES

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

Agricultural meteorological station: A station that provides meteorological and biological information for agricultural and/or biological applications. Agricultural meteorological stations are classified as follows:

- Principal agricultural meteorological station: A station that provides detailed simultaneous meteorological and biological information and where research in agricultural meteorology is carried out. The instrumental facilities, the range and frequency of observations in both meteorological and biological fields, and the professional personnel are such that fundamental investigations into agricultural meteorological questions of interest to the countries or Regions concerned can be carried out.
- Ordinary agricultural meteorological station: A station that provides, on a routine basis, simultaneous meteorological and biological information and may be equipped to assist in research into specific problems; in general the programme of biological or phenological observations for research will be related to the local climatic regime of the station.
- Auxiliary agricultural meteorological station: A station that provides meteorological and biological information. The meteorological information may include such items as soil temperature, soil moisture, potential evapotranspiration, detailed information on the very lowest layer of the atmosphere; the biological information may cover phenology, onset and spread of plant diseases, etc.
- Agricultural meteorological station for specific purposes: A station set up temporarily or permanently that provides meteorological data for specific agricultural purposes.

Aircraft Communication Addressing and Reporting System (ACARS): Automated aviation meteorological data collection system from aircraft fitted with appropriate software packages. Similar in function to ASDAR.

Aircraft Meteorological Data Relay (AMDAR): The collective name for the automated aviation meteorological data collection systems called ASDAR and ACARS from aircraft fitted with appropriate software packages.

Aircraft to Satellite Data Relay (ASDAR): Automated aviation meteorological data collection system from aircraft fitted with appropriate software packages. Similar in function to ACARS.

Anchored platform station: An observing station on a platform anchored in deep water.

Atmospherics detection station: A station contributing observations to an atmospheric detection system.

Atmospherics detection system: An instrumental system consisting of a number of stations for the detection and location of atmospheric.

Automated aircraft meteorological system: A series of devices integrated into the instrumentation of an aircraft, which records and/or transmits observations automatically.

Automatic weather station (AWS): Meteorological station at which observations are made and transmitted automatically.

Auxiliary ship station: A mobile ship station, normally without certified meteorological instruments, that transmits reports in code form or in plain language, either as routine or on request, in certain areas or under certain conditions.

Climatological station: A station whose observations are used for climatological purposes. Climatological stations are classified as follows:

- Reference climatological station: A climatological station the data of which are intended for the purpose of determining climatic trends. This requires long periods (not less than 30 years) of homogeneous records, where human-induced environmental changes have been and/or are expected to remain at a minimum. Ideally, the records should be of sufficient length to make possible the identification of secular changes of climate.
- Principal climatological station: A climatological station at which hourly readings are taken, or at which observations are made at least three times daily in addition to hourly tabulation from autographic records.
- Ordinary climatological station: A climatological station at which observations are made at least once daily, including daily readings of extreme temperature and of amount of precipitation.
- Climatological station for specific purposes: A climatological station established for the observation of a specific element or elements.

Coastal station: A station on a coast that may be able to make some observations of conditions at sea.

Drifting automatic sea (drifting buoy) station: A floating automatic station that is free to drift under the influence of wind and current.

Environmental data buoy station: A fixed or drifting buoy which records or transmits environmental and/or marine data.

Environmental observation satellite: An artificial Earth satellite providing data on the Earth system which are of benefit to WMO Programmes.

Note: These data support a variety of disciplines including, but not limited to, meteorology, hydrology, climatology, oceanography, climate and global change related disciplines.

Fixed platform station: An observing station on a platform at a fixed site in shallow water.

Fixed sea station: An ocean weather ship or a station situated on a lightship, a fixed or anchored platform, a small island or in certain coastal areas.

Global Climate Observing System Reference Upper-air Network (GRUAN) station: An upper-air station included in the network of stations specially selected and certified to provide long-term high-quality climate records.

Global Climate Observing System Surface Network (GSN) station: A land station included in the specially selected network of stations to monitor daily and large-scale climate variability on a global basis.

Global Climate Observing System Upper-air Network (GUAN) station: An upper-air station included in the specially selected global baseline network of upper-air stations to meet the requirements of the Global Climate Observing System.

Global Data-processing and Forecasting System (GDPFS): The coordinated global system of centres operating under established arrangements for the analysis, forecasting, processing, storage and retrieval of meteorological, climatological, hydrological, oceanographic and environmental-related information.

Global Telecommunication System (GTS): The coordinated global system of telecommunication facilities and arrangements for the rapid collection, exchange and distribution of observational and processed information within the framework of the World Weather Watch.

Ice-floe station: An observing station on an ice floe.

Island station: A station on a small island on which conditions are similar to those in the marine environment and from which some observations of conditions at sea can be made.

Land station: An observing station situated on land.

Lightship station: A surface synoptic station situated aboard a lightship.

Meteorological element: Atmospheric variable or phenomenon which characterizes the state of the weather at a specific place at a particular time (see Section B below).

Meteorological reconnaissance aircraft station: A meteorological station on an aircraft equipped and assigned for the specific purpose of making meteorological observations.

Meteorological reconnaissance flight: An aircraft flight for the specific purpose of making meteorological observations.

Meteorological rocket station: A station equipped to make atmospheric soundings using rockets.

Mobile sea station: A station aboard a mobile ship or an ice floe.

National Meteorological Centre (NMC): A centre responsible for carrying out national functions including those under the World Weather Watch.

Ocean weather station: A station aboard a suitably equipped and staffed ship that should remain at a fixed sea position and that makes and reports surface and upper-air observations, and may also make and report subsurface observations.

Ozone sounding station: A station at which observations of atmospheric ozone are made.

Pilot-balloon observation: A determination of upper winds by optical tracking of a free balloon.

Pilot-balloon station: A station at which upper winds are determined by optical tracking of a free balloon.

Planetary boundary layer: The lowest layer in the atmosphere, usually taken to be up to 1 500 m, in which meteorological conditions are affected significantly by the Earth's surface.

Planetary boundary-layer station: A station equipped to provide detailed meteorological data on the planetary boundary layer.

Precipitation station: A station at which observations of precipitation only are made.

Radar wind profiler observation: A vertical profile of the horizontal wind vector and, under some conditions, the vertical wind component, determined by transmitting radar signals and analysing the reflected information contained in the backscattered electromagnetic wave using system-specific data-processing techniques.

Radar wind profiler station: A surface-based station at which radar wind profiler observations are made.

Radar wind profiler system: A system that makes radar wind profiler observations.

Note: The system includes observational data-processing and telecommunications hardware and software, documentation, monitoring, maintenance and certain facilities and support capabilities such as power supply and air conditioning, together with the human expertise and resources required to operate and manage all of these components.

Radiation station: A station at which observations of radiation are made.

- Principal radiation station: A radiation station the observing programme of which includes at least the continuous recording of global solar radiation and of sky radiation and regular measurements of direct solar radiation.
- Ordinary radiation station: A radiation station whose observing programme includes at least the continuous recording of the global solar radiation.

Note: The terminology of radiation quantities and measuring instruments is given in the *Guide to Meteorological Instruments and Methods of Observation* (WMO-No. 8).

Radiosonde observation: An observation of meteorological elements in the upper air, usually atmospheric pressure, temperature and humidity, by means of a radiosonde.

Note: The radiosonde may be attached to a balloon, or it may be dropped (dropsonde) from an aircraft or a rocket.

Radiosonde station: A station at which observations of atmospheric pressure, temperature and humidity in the upper air are made by electronic means.

Radiowind observation: A determination of upper winds by tracking of a free balloon by electronic means.

Radiowind station: A station at which upper winds are determined by the tracking of a free balloon by electronic means.

Rawinsonde observation: A combined radiosonde and radiowind observation.

Rawinsonde station: A combined radiosonde and radiowind station.

Reference level data: Data for a specified level, normally 1 000 hPa, which enable absolute heights to be ascribed to satellite temperature-sounding data.

Regional Basic Climatological Network (RBCN): A network composed of climatological stations within a WMO Region with a specified observational programme, which is a minimum regional requirement to permit Members to fulfil their World Weather Watch responsibilities, and also serves as a target list for WWW monitoring of climatological data.

Regional Basic Synoptic Network (RBSN): A network composed of synoptic stations within a WMO Region with a specified observational programme, which is a minimum regional requirement to permit Members to fulfil their World Weather Watch responsibilities and in the application of meteorology.

Regional Meteorological Centre (RMC): A centre of the Global Data-Processing and Forecasting System which has the primary purpose of issuing meteorological analyses and prognoses on a regional scale.

Regional Specialized Meteorological Centre (RSMC): A centre of the Global Data-processing and Forecasting System that has the primary purpose of issuing meteorological analyses and prognoses on a regional scale for a specified geographical area or of providing products and related information in a designated field of activity specialization.

Research and special-purpose vessel station: A vessel making voyages for research or other purposes, which is recruited to make meteorological observations during the voyages.

Sea station: An observing station situated at sea.

Selected ship station: A mobile ship station that is equipped with sufficient certified meteorological instruments for making observations and that transmits the required observations in the appropriate code form for ships.

Special report: A report made at a non-standard time of observation when specified conditions or changes of conditions occur.

Special station: A station for a special purpose as specified in Part III, paragraph 1, of this Manual.

Standard time of observation: A time specified in this Manual for making meteorological observations.

Note: The term Coordinated Universal Time (UTC) is used in this Manual.

Supplementary ship station: A mobile ship station that is equipped with a limited number of certified meteorological instruments for making observations and that transmits the required observations in an abbreviated code form for ships.

Surface observation: A meteorological observation, other than an upper-air observation, made from the Earth's surface.

Surface station: A surface location from which surface observations are made.

Synoptic observation: A surface or upper-air observation made at a standard time.

Synoptic station: A station at which synoptic observations are made.

Tide-gauge station: A station at which tidal measurements are made.

Upper-air observation: A meteorological observation made in the free atmosphere either directly or indirectly.

Upper-air report: A report of an upper-air observation.

Upper-air station: A surface location from which upper-air observations are made.

Upper-wind observation: An observation at a given height or the result of a complete sounding of wind direction and speed in the atmosphere.

Weather radar observation: Evaluation of atmospheric characteristics obtained by transmitting electromagnetic waves (radar signals) and analysing the reflected information from the targets in the sample volume.

Note: Such evaluation is typically repeated over a sequence of samples, as determined by the scan strategy, and reported as a spatially continuous dataset.

Weather radar station: A surface-based station at which weather radar observations are made.

Weather radar system: A system that makes weather radar observations.

Note: The system includes observational data-processing and telecommunications hardware and software, documentation, monitoring, maintenance and certain facilities and support capabilities such as power supply and climate control, together with the human expertise and resources required to operate and manage all of these components.

World Meteorological Centre (WMC): A centre of the Global Data-Processing and Forecasting System which has the primary purpose of issuing meteorological analyses and prognoses on a global scale.

World Weather Watch (WWW): The worldwide, coordinated, developing system of meteorological facilities and services provided by Members for the purpose of ensuring that all Members obtain the meteorological and other environmental information they require both for operational work and for research. The essential elements of the World Weather Watch are the:

- Global Observing System (GOS);
- Global Data-Processing and Forecasting System (GDPFS);
- Global Telecommunication System (GTS).

B. METEOROLOGICAL ELEMENTS AND OTHER OBSERVED VARIABLES

Aerosol: Substances, divided into solid particles or liquid droplets, held in suspension in the atmosphere.

Air temperature: The temperature indicated by a thermometer exposed to the air in a place sheltered from direct solar radiation.

Aircraft icing: Formation of ice, rime or hoar frost on an aircraft.

Atmospheric pressure: Pressure (force per unit area) exerted by the atmosphere on any surface by virtue of its weight; it is equivalent to the weight of a vertical column of air extending above a surface of unit area to the outer limit of the atmosphere.

- Pressure tendency: Character and amount of a station pressure change over three hours (over 24 hours in tropical regions).
- Characteristic of pressure tendency: Shape of the curve recorded by a barograph during the three-hour period preceding an observation.

Cloud: A hydrometeor consisting of minute particles of liquid water or ice, or of both, suspended in free air and usually not touching the ground.

- Cloud amount: The fraction of the sky covered by the clouds of a certain genus, species, variety or layer; or by a combination of clouds.

- Height of cloud base: Height above the surface of the Earth of the base of the lower cloud layer, when its amount exceeds a specific value.
- Direction and speed of cloud movement: Direction from which the cloud is coming and the horizontal component of its speed.
- Cloud type (classification): Type or variety of cloud as described and classified in the *International Cloud Atlas*.

Contrail: Cloud which forms in a wake of an aircraft when the air at flight level is sufficiently cold and moist.

Dew point: Temperature to which a volume of air must be cooled at constant pressure and constant moisture in order to reach saturation.

Humidity: Water vapour content of the air.

Precipitation: Hydrometeor consisting of a fall of an ensemble of particles. The forms of precipitation are: rain, drizzle, snow, snow grains, snow pellets, diamond dust, hail and ice pellets.

Precipitation chemistry: Nature and amount of the impurities dissolved or suspended in the precipitation.

Sea ice: Any form of ice found at sea which has originated from the freezing of sea water.

Sea-surface temperature: Temperature of the surface layer of the sea.

Soil moisture: Moisture contained in that portion of the soil which lies above the water table, including the water vapour contained in the soil pores.

Soil temperature: Temperature observed at different depths in the soil.

Solar radiation: Radiation emitted by the sun, sometimes called short-wave radiation, with wavelengths between 290 nm and about 4 000 nm.

State of ground: The characteristics of the surface of the ground, especially resulting from the effect of rain, snow and temperatures near freezing point.

Sunshine duration: The sum of the time, during a given period, for which the direct solar irradiance exceeds 120 W m^{-2} .

Turbidity: Reduced transparency of the atmosphere to radiation (especially visible) caused by absorption and scattering by solid or liquid particles other than clouds.

Turbulence: Random and continuously changing air motions which are superposed on the mean motion of the air.

Upper wind: The wind speed and direction at various levels in the atmosphere, above the domain of surface weather.

Visibility: Greatest distance at which a black object of suitable dimensions can be seen and recognized against the horizon sky during daylight or could be seen and recognized during the night if the general illumination were raised to the normal daylight level.

Wave height: The vertical distance between the trough and crest of the wave.

Wave period: Time between the passage of two successive wave crests past a fixed point.

Waves, direction of movement of: Direction from which the waves arrive at a given point.

Weather: State of the atmosphere at a particular time, as defined by the various meteorological elements.

- Present weather: Weather existing at a station at a time of observation.
- Past weather: Predominant characteristic of the weather which existed at an observing station during a given period of time.

Wind direction: Direction from which the wind blows.

Wind speed: Ratio of the distance covered by the air to the time taken to cover it.

Note: A more detailed list of geophysical parameters used to state observational data requirements and their associated definitions is contained in the *Guide to the Global Observing System* (WMO-488).

PART I. GENERAL PRINCIPLES REGARDING THE ORGANIZATION AND IMPLEMENTATION OF THE GLOBAL OBSERVING SYSTEM

1. PURPOSE OF THE GLOBAL OBSERVING SYSTEM

1.1 The purpose of the Global Observing System shall be to provide, from all parts of the globe and from outer space, high-quality standardized observations of the state of the atmosphere and of land and ocean surface for the preparation of weather analyses, forecasts and warnings, and for other applications in support of WMO programmes and related environmental programmes of other organizations.

1.2 The GOS should provide supplementary observations required internationally for special purposes, provided this does not obstruct the achievement of the primary purposes of the World Weather Watch (WWW).

2. ORGANIZATION AND DESIGN OF THE GLOBAL OBSERVING SYSTEM

2.1 The GOS shall be organized as part of the WWW, in conjunction with the Global Data-processing and Forecasting System and the Global Telecommunication System (GTS).

2.2 The GOS shall be a coordinated system of methods, techniques and facilities for making observations on a worldwide scale and as one of the main components of the WWW, taking into account to the extent feasible the requirements of other international programmes.

2.3 The GOS shall consist of facilities and arrangements for making observations at stations on land and at sea, from aircraft, from environmental observation satellites and other platforms.

2.4 For convenience in the planning and coordination of the system, taking into account various criteria for observational data requirements, the GOS shall be considered as composed of three levels: global, regional and national.

2.5 The GOS shall be designed as a flexible and developing system capable of continuous improvement, on the basis of the latest achievements of technological and scientific progress and in accordance with changing requirements for observational data.

2.6 The planning and coordination of the GOS shall be realized through recommendations of the Commission for Basic Systems, approved by the Executive Council, in consultation and coordination with Members, regional associations and other technical commissions concerned.

2.7 The GOS shall consist of two subsystems: the surface-based subsystem and the space-based subsystem.

2.8 The GOS surface-based subsystem shall be composed of surface synoptic land and sea stations, upper-air synoptic stations, climatological stations, agricultural meteorological stations, aircraft meteorological stations, aeronautical meteorological stations, research and special-purpose vessel stations and special stations as detailed in Part III, 1, paragraphs (a) to (l) of this Manual.

2.9 The main elements of the GOS surface-based subsystem shall consist of networks of surface synoptic stations on land and at sea, upper-air stations, aircraft meteorological stations, radar wind profiler stations and weather radar stations, as detailed in Part III, 1, paragraphs (a) to (e) of this Manual.

2.10 Other elements of the GOS surface-based subsystem shall consist of aeronautical meteorological stations, research and special-purpose vessel stations, climatological stations, Global Climate Observing System Surface Network stations, Global Climate Observing System upper-air stations, agricultural meteorological stations and special stations, as listed in Part III, 1, paragraphs (f) to (l) of this Manual.

2.11 The GOS space-based subsystem shall comprise satellites of three types: operational low Earth orbit and operational geostationary satellites, and research and development satellites.

3. IMPLEMENTATION OF THE GLOBAL OBSERVING SYSTEM

3.1 Countries themselves are responsible for all activities connected with the implementation of the GOS on their individual territories and should fund them, to the extent possible, using national resources.

3.2 Implementation of the GOS on the territory of developing countries should be based on the principle of the utilization of national resources but, where necessary and so requested, assistance may be provided in part through:

- (a) The WMO Voluntary Cooperation Programme;
- (b) Other bilateral or multilateral arrangements, including the United Nations Development Programme, which should be used to the maximum extent possible.

3.3 Implementation of the GOS in regions outside the territories of individual countries (for example, outer space, oceans, the Antarctic) should be based on the principle of voluntary participation of countries that desire and are able to contribute by providing facilities and services, either individually or jointly from their national resources, or by having recourse to collective financing. The assistance sources described in 3.2 above may also be used.

3.4 In the implementation of the GOS, maximum use should be made of existing arrangements, facilities and personnel.

Notes:

1. The setting up and operation of the new and improved facilities and services require a considerable amount of scientific research, development engineering, coordination of procedures, standardization of methods and implementation coordination.
2. The further development of the GOS is an important feature of the WWW plan that provides for:
 - (a) Continued development of the GOS as a cost-effective composite system comprising operationally reliable surface-based and space-based (satellite) subsystems. It is expected that, within the surface-based subsystem, new systems measuring both large and local scales of atmospheric phenomena will be deployed operationally on a wider scale. Increasing use will be made of the rapidly growing fleet of aircraft with automated observing and reporting systems to observe data at cruising levels and during ascent and descent. Radar wind profilers will play an important role in upper-air networks. International exchange of weather radar observational data will enhance Members' ability to provide services for the good of all. Mobile sea stations will continue to be the main source for surface synoptic observations over the oceans. Through increased use of automatic observing and (satellite) transmission equipment, the quality and quantity of the data will increase. The number of ships equipped with automated upper-air sounding facilities (as part of the Automated Shipboard Aerological Programme) will increase and the deployment of more cost-effective systems will be accelerated. Drifting buoys, deployed outside the main shipping routes, will continue to

supply surface atmospheric and oceanographic parameters from the data-void ocean areas. It is also expected that the operational space-based subsystem will include a new generation of polar-orbiters and geostationary satellites with improved and new sensing systems;

- (b) Coordination, integration and sustainability of composite surface- and space-based subsystems, and development of observing networks that are adaptable to changing requirements. This will include planning for a new composite upper-air observing system making the most effective use of new and emerging technology, in order to develop a cost-effective, truly global system with the density of in situ observations required for operational purposes as well as to complement and calibrate observations from satellites. The new composite system will utilize a range of technologies and techniques, some of which require long-term development efforts to become operational. New technology should be introduced as and when proven and must be consistent with existing systems and supporting structures;
- (c) Development of new strategies to facilitate closer cooperation between Meteorological Services and research programmes so that the available observing systems and programmes can be of use to operational meteorology and the research community;
- (d) Exploration of new ways for Members to contribute to the GOS, including joint funding and innovative arrangements to ensure adequate observations in remote and data-sparse areas.

3.5 Existing elements of the GOS, as defined in Part III, shall not be removed before the reliability of a new element has been proven, and relative accuracy and representativeness of the observational data have been examined and found acceptable.

PART II. REQUIREMENTS FOR OBSERVATIONAL DATA

Note: Regulations regarding the requirements for observational data from the GOS are contained in the *Manual on the WMO Integrated Global Observing System* (WMO-No. 1160).

1. REQUIREMENTS IN SPECIAL CIRCUMSTANCES

1.1 Special requirements for environmental emergency response activities

In order for the designated Regional Specialized Meteorological Centres (RSMCs) to be in a position to provide Members with transport model products for environmental emergency response, meteorological and non-meteorological (radiological) data requirements need to be met. These are specified in Attachment II.1. These data, particularly from the site of an accident, are also needed by Members so that they may take appropriate preventive and remedial action in case of an accidental release of radioactive material into the environment. Data should be made available promptly in accordance with the Convention on Early Notification of a Nuclear Accident (Article 5 (e)).

1.2 Requirements in the event of volcanic activity

Requirements in the event of volcanic activity potentially hazardous to aviation should be related to the observational data needed by Members for taking appropriate action; these data are specified in Attachment II.2.

ATTACHMENT II.1. SPECIAL OBSERVATIONAL REQUIREMENTS FOR ENVIRONMENTAL EMERGENCY RESPONSE ACTIVITIES

A. METEOROLOGICAL DATA REQUIREMENTS

1. Data needed to run transport models are the same as those specified for the production of weather forecasts based on numerical weather prediction models, and are given in the *Manual on the Global Data-processing and Forecasting System* (WMO-No. 485) and the *Guide to the Global Observing System* (WMO-No. 488), Appendix II.1.

2. Additional data¹ from the accident site² and potentially affected area³ are desirable, and should be available to the designated RSMC to improve the quality of information about the transport of pollutants. These should include:

- (a) Wind, temperature and humidity, upper-air data;
- (b) Precipitation data (type and amount);
- (c) Surface air temperature data;
- (d) Atmospheric pressure data;
- (e) Wind direction and speed (surface and stack height) data;
- (f) Humidity data.

3. The following systems should be in place to provide the data needed from the accident site in combination, as necessary and possible:

- (a) At least one radiosonde station should be located at a suitably safe distance, to enable continued operation in an emergency situation and to provide data representative of conditions at or near the accident site;
- (b) In an emergency, at the two or three stations closest to the site of the accident (and within 500 km) frequency of reporting should be increased to every three hours for the duration of the emergency. Stocks of consumables should be stored for use in emergency situations;
- (c) At least one surface station should be located at the accident site or, if this is not possible, at a nearby site. It should be convertible to an hourly automated mode for both operations and telecommunications in case of emergency;
- (d) Additional information should be provided at or near the accident site by instrumented towers or masts (up to 100 m) and conventional or Doppler radars, Sodars and boundary layer sondes with automatic transmission of data.

4. The data needed from the potentially affected area should be provided as follows:

¹ The words "additional data" are used with their usual meaning and not as in Resolution 40 (Cg-XII).

² Due to the wide variety of types of nuclear accidents, a precise definition of "accident site" is not possible. The accident site should be understood as the location where the accident occurs and the immediate surrounding zone within a range of a few kilometres.

³ The area potentially affected is dependent on the state and evolution of the atmosphere over an extended area around the accident site, as well as on the nuclear event itself, and cannot be precisely defined in advance. The "potentially affected area" should be understood, therefore, as the area where (according to all the information available, including the air transport pollution products, if already issued) the nuclear pollutants are likely to be transported in the air or on the ground at a significant level over the natural (background) radioactivity. Advice on the extent of the potentially affected area may be obtained from the RSMC concerned.

- (a) All upper-air stations within the potentially affected area should make observations every six hours for the duration of the emergency;
- (b) Where possible, one or more additional observing systems (including use of wind profilers, mobile radiosounding equipment, and ascent/descent data from aircraft) should be provided;
- (c) All surface stations within the potentially affected area, including those that do not normally exchange data internationally, should provide observational data to designated RSMCs. Platforms and buoys should also provide observational data to ensure adequate coverage of sea areas;
- (d) A series of best estimates of precipitation should be made by combining information from direct measurements (automated or manual) of surface stations, composite radar information extending over the whole WMO Region and satellite-derived data.

B. **NON-METEOROLOGICAL DATA REQUIREMENTS**

1. In case of emergency, non-meteorological data to be provided to designated RSMCs from the accident site should include:

- (a) Start of release (date, time);
- (b) Duration;
- (c) Radionuclide species;
- (d) Total release quantity or pollutant release rate;
- (e) Effective height of release.

Points (a) and (b) are necessary for running transport models, while (c), (d) and (e) are desirable additional data.

2. In order to calibrate and validate the atmospheric transport model forecasts processed, radiological data from potentially affected areas are needed. The most suitable radiological data are:

- (a) Time-integrated air pollutant concentration;
- (b) Total deposition.

3. The required data from the accident site and potentially affected area may be obtained by the following means:

- (a) Fixed radiological monitoring stations;
- (b) Mobile surface units;
- (c) Radiological sounding; or
- (d) Instrumental aircraft.

The frequency of observations should be increased from once per hour to once per 10 minutes during the accident (routine frequency of observations varies from once per hour to once per six hours).

C. EXCHANGE OF METEOROLOGICAL AND NON-METEOROLOGICAL DATA

1. Non-meteorological data and, to some extent, additional meteorological data are likely to be provided by non-meteorological national authorities. The National Meteorological or Hydrometeorological Services (NMSs) should encourage the provision of these data by non-meteorological agencies/operators to National Meteorological Centres (NMCs) for onward transmission to their associated RSMCs.
 2. For the exchange of relevant meteorological and non-meteorological (radiological) data, a complete list of abbreviated heading bulletins, including all the regional meteorological and radiological observations, should be sent by Members to the Secretariat for insertion into *Weather Reporting* (WMO-No. 9), Volume C1 – Catalogue of Meteorological Bulletins.
 3. Radiological data available in the early phase of a nuclear accident that assist in characterizing the nuclear accident (containment radiation reading, on-site radiation levels, etc.) should be provided by national authorities to the International Atomic Energy Agency (IAEA) as soon as is practicable via the most reliable means of communication. The IAEA will verify and assess the information, and then provide these data to the appropriate RSMC, which should distribute them to NMCs via the GTS. In case of environmental emergencies, all relevant observational (meteorological and non-meteorological) data should be transmitted to both RSMCs and NMSs through the GTS as quickly as possible.
 4. End-to-end testing of procedures for data acquisition, quality control, communication use and product dissemination should be carried out periodically to ensure system performance.
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ATTACHMENT II.2. OBSERVATIONAL REQUIREMENTS IN THE EVENT OF VOLCANIC ACTIVITY

The International Airways Volcano Watch (IAVW) is coordinated and developed by the International Civil Aviation Organization (ICAO) Secretariat with the assistance of the Volcanic Ash Warnings Study Group. The *Handbook on the International Airways Volcano Watch (IAVW)* (ICAO Doc 9766) describes the operational procedures and the contact list for the implementation of the IAVW in the event of pre-eruption volcanic activity,¹ volcanic eruptions and volcanic ash clouds.

A. METEOROLOGICAL DATA REQUIREMENTS

1. The data needed to run transport models are the same as specified for the production of weather forecasts based on numerical weather prediction models, and are given in the *Manual on the Global Data-Processing and Forecasting System* (WMO-No. 485) and the *Guide to the Global Observing System* (WMO-No. 488), Appendix II.I.
2. Additional data² are desirable from the area in the vicinity of the volcano and should be made available to the designated Meteorological Watch Offices and Volcanic Ash Advisory Centre (VAAC)³ to improve the quality of information about the transport of volcanic ash. These data are the same as specified for the special observation requirements for environmental emergency response activities, and are given in Attachment II.1 of this Manual.
3. Imagery data from geostationary and polar-orbiting satellites are required by the designated VAAC to ascertain whether a volcanic ash cloud is identifiable and to determine its extent, both vertical and horizontal (see the *Handbook on the International Airways Volcano Watch (IAVW)*, section 4.1.1 (c) and section 4.5.1 (b)). These data are also required to validate the transport model trajectory forecast and to determine when the volcanic ash has dissipated. The imagery data should:
 - (a) Be multi-spectral, covering visible and infrared wavelengths;
 - (b) Have adequate spatial resolution to detect small volcanic ash clouds (5 km or less);
 - (c) Have global coverage to provide data for all the VAACs;
 - (d) Have a frequent repeat cycle (30 minutes or less for the detection of volcanic ash and at least every six hours for the tracking of volcanic ash for transport model validation) (see *Handbook on the International Airways Volcano Watch (IAVW)*, section 4.4.1 (c) and section 4.5.1 (d) and (e));
 - (e) Be processed and delivered to the VAAC with a minimal delay.
4. Additional satellite data that can assist in the detection of pre-eruption volcanic activity, a volcanic eruption, or a volcanic ash cloud should be made available to the designated VAAC. These may include satellite data that can be used to detect volcanic hot-spots or sulphur dioxide emissions.
5. Data obtained from surface-based radar within range of the volcano should be made available to the designated VAAC. These data can be used to detect the presence of a volcanic ash cloud and measure its height.

¹ Pre-eruption volcanic activity in this context means unusual and/or increasing volcanic activity, which could presage an eruption.

² The words “additional data” are used with their usual meaning and not as in Resolution 40 (Cg-XII).

³ Volcanic Ash Advisory Centres are designated by ICAO and WMO to issue advisories on the presence and forecasted trajectory of volcanic ash.

B. NON-METEOROLOGICAL DATA REQUIREMENTS

1. The occurrence of pre-eruption volcanic activity, volcanic eruptions and volcanic ash clouds, because of the potential hazard to aviation, should be reported without delay to the designated Area Control Centres, Meteorological Watch Offices and VAAC, as described in the *Handbook on the International Airways Volcano Watch (IAVW)*. The report, in plain language, should be made in the form of a volcanic activity report comprising the following information, if available, in the order indicated:

- (a) Message type: VOLCANIC ACTIVITY REPORT;
- (b) Station identifier, location indicator or name of station;
- (c) Date/time of message;
- (d) Location of volcano and name, if known;
- (e) Concise description of event including, as appropriate, level of intensity of volcanic activity, occurrence of an eruption and its date and time, and existence of a volcanic ash cloud in the area (with the direction of ash cloud movement and height, as best estimated).

2. Available geological data that indicates the occurrence of pre-eruptive volcanic activity or a volcanic eruption should be passed immediately to the designated Area Control Centres, Meteorological Watch Offices and VAAC (see *Handbook on the International Airways Volcano Watch (IAVW)*, section 4.1.1 (a)). These data include:

- (a) Vulcanological observations;
- (b) Seismological activity reports.

3. Pilot reports of pre-eruption volcanic activity, volcanic eruptions and volcanic ash clouds should be sent without delay to the designated Area Control Centres, Meteorological Watch Offices and VAAC (see *Handbook on the International Airways Volcano Watch (IAVW)*, section 4.1.1 (a)).

C. EXCHANGE OF METEOROLOGICAL AND NON-METEOROLOGICAL DATA

The exchange of all the above data is described in the *Handbook on the International Airways Volcano Watch (IAVW)*.

PART III. SURFACE-BASED SUBSYSTEM

1. COMPOSITION OF THE SUBSYSTEM

The main elements of the surface-based subsystem shall be:

- (a) Surface synoptic stations:
 - (i) Land stations:
 - Manned surface stations;
 - Automatic surface stations;
 - (ii) Sea stations:
 - Fixed sea stations:
 - Ocean weather stations;
 - Lightship stations;
 - Fixed-platform stations;
 - Anchored-platform stations;
 - Island and coastal stations;
 - Mobile sea stations:
 - Voluntary observing ship (VOS) stations:
 - Selected ship stations;
 - Selected ship stations equipped with automatic weather stations (AWSs);
 - VOSCLim (VOS Climate) ship stations;
 - VOSCLim ship stations equipped with AWSs;
 - Supplementary ship stations;
 - Supplementary ship stations equipped with AWSs;
 - Auxiliary ship stations;
 - Auxiliary ship stations equipped with AWSs;
 - Ice-floe stations;
 - Automatic sea stations:
 - Fixed sea stations;
 - Lightship stations;
 - Mobile sea stations;
 - Drifting-buoy stations;
 - Moored-buoy stations;
 - (b) Upper-air synoptic stations:
 - Rawinsonde stations;
 - Radiosonde stations;
 - Radiowind stations;
 - Pilot-balloon stations;
 - (c) Aircraft meteorological stations;
 - (d) Radar wind profiler stations;
 - (e) Weather radar stations;
- other elements of the subsystem shall be:
- (f) Aeronautical meteorological stations;
 - (g) Research and special-purpose vessel stations;
 - (h) Climatological stations;
 - (i) Global Climate Observing System Surface Network stations;

- (j) **Global Climate Observing System upper-air stations;**
- (k) **Agricultural meteorological stations;**
- (l) **Special stations, which include:**
 - (i) **Radiation stations;**
 - (ii) **Other remote-sensing profiler stations;**
 - (iii) **Lightning location stations;**
 - (iv) **Meteorological reconnaissance aircraft stations;**
 - (v) **Global Atmosphere Watch stations;**
 - (vi) **Planetary boundary-layer stations;**
 - (vii) **Tide-gauge stations.**

Notes:

1. Definitions of stations listed above will be found in the definition section at the beginning of this Manual.
2. Any station may fall under more than one of the above categories.
3. Observations from automatic surface synoptic stations on land or at sea may be asynoptic when collected via satellite.

2. **IMPLEMENTATION OF ELEMENTS OF THE SUBSYSTEM**

2.1 **Networks of observing stations**

2.1.1 **General**

2.1.1.1 **Three types of network of observing stations – global, regional and national – to meet the three levels of requirements for observational data shall be established.**

2.1.1.2 The networks should be interdependent, with selected stations of the national networks within a Region comprising the corresponding regional network, and with selected stations of the regional networks forming the global network. Therefore, a station of the global network should be part of a regional network and a national network.

2.1.1.3 The frequency and spacing of observations should be adjusted to the physical scales of the meteorological phenomena to be described.

Note: See the *Guide to the Global Observing System* (WMO-No. 488), Part II, Figure II.1.

2.1.2 **Global networks**

2.1.2.1 **A global synoptic network shall be established, based upon the Regional Basic Synoptic Networks (RBSNs).**

Note: See 2.1.3 below.

2.1.2.2 The observing programme of the global synoptic network should provide meteorological data that have the necessary accuracy, and spatial and temporal resolution, to describe the state of temporal and spatial changes in the meteorological phenomena and processes occurring on the large and planetary scales.

Note: Guidance as to the determination of requirements for accuracy and time and spatial resolution of the observational data is given in the *Guide to the Global Observing System* (WMO-No. 488).

2.1.2.3 The global synoptic network should be as homogeneous and as uniform as possible, and observations should be made at the main standard times of observation.

2.1.2.4 Members should implement and sustain the Global Climate Observing System (GCOS) Surface Network (GSN) – the global baseline network of some 1 000 selected surface observing stations established to monitor daily global and large-scale climate variability.

2.1.2.5 Members should implement and sustain the GCOS Upper-air Network (GUAN) – the global baseline network of about 170 selected upper-air stations established with relatively homogenous distribution to meet requirements of GCOS.

2.1.2.6 Members should also establish and sustain the GCOS Reference Upper-air Network (GRUAN) of about 30 to 40 selected upper-air stations, to provide long-term high-quality climate records, to constrain and calibrate data from more spatially-comprehensive global observing systems (including satellites and current radiosonde networks), and to fully characterize the properties of the atmospheric column.

2.1.3 **Regional networks**

2.1.3.1 **Regional networks shall be established in relation to regional requirements.**

Note: Regional associations are responsible for the determination and coordination of the composition of these networks within the general framework established by the Commission for Basic Systems.

2.1.3.2 **Regional Basic Synoptic Networks of both surface and upper-air stations and Regional Basic Climatological Networks (RBCNs) of climatological stations shall be established to meet the requirements laid down by the regional associations.**

Notes:

1. The regional associations will review their plans regularly in order to ensure that they meet any new international requirements.
2. Details of known regional requirements are given in Volume II of this Manual.

2.1.3.3 **Together, the RBSNs shall form the main part of the global surface-based synoptic network.**

2.1.3.4 **Members shall implement the RBSNs.**

2.1.3.5 The horizontal spacing of observing stations and the frequency of their reporting should be in accordance with the requirements laid down in Part II above and in Volume II of this Manual.

2.1.4 **National networks**

National networks shall be established by Members to satisfy their own requirements. When implementing these national networks, Members shall take into account the need to participate in, and form part of, the global and regional networks.

Note: A complete list of all surface and upper-air stations in operation which are used for synoptic purposes is given in *Weather Reporting* (WMO-No. 9), Volume A – Observing Stations.

2.2 **Observing stations**

2.2.1 **General**

2.2.1.1 The implementation and operation of each of the above elements should be in accordance with decisions of Congress, the Executive Council, the technical commissions and regional associations concerned.

Note: These decisions are reflected in the *Technical Regulations* (WMO-No. 49) and its annexes, for example, this Manual and the *Manual on Codes* (WMO-No. 306), and in other relevant WMO publications such as the *Guide to the Global Observing System* (WMO-No. 488) and the *Guide to Meteorological Instruments and Methods of Observation* (WMO-No. 8), which set forth the technical and meteorological aspects in detail.

2.2.1.2 In implementing the GOS surface-based subsystem, Members should ensure that the observing system meets the subsystem requirements.

2.2.1.3 In implementing the surface-based subsystem, Members should strive to meet the provisions of the decisions indicated in 2.2.1.1 above as closely as possible, in particular as regards the main elements of the surface-based subsystem.

2.2.1.4 **Each station shall be uniquely identified by a WMO Integrated Global Observing System (WIGOS) station identifier.**

Note: Further regulations and notes relating to WIGOS station identifiers are to be found in the *Manual on the WMO Integrated Global Observing System* (WMO-No. 1160), sections 2.4.1.1 to 2.4.1.4.

2.2.1.5 Each station should be located at a site that permits correct exposure of the instruments and satisfactory non-instrumental observations.

2.2.1.6 **In general, the distance between observing stations and the time between observations shall be close enough to provide an accurate description of the atmosphere for those who use the observations for their intended purpose.**

2.2.1.7 If in certain desert and other sparsely populated areas it is not possible to establish networks with the recommended densities, networks with densities as near as possible to those recommended should be established. Special efforts should be made to establish an adequate network in such areas when they border a populated area or are traversed by a regularly used air route.

2.2.1.8 Asynoptic observations should be taken when necessary to complement observations from the synoptic networks and in a manner that increases the overall observational spatial or temporal density.

2.2.1.9 Observations should be made in areas where special phenomena are occurring or are expected to develop. As many meteorological elements of standard observations as possible should be reported. Information should be communicated in real time.

Note: Drifting buoys and aircraft may also report at asynoptic times.

2.2.1.10 **Members shall ensure that a record of all surface and upper-air observations is made and preserved.**

2.2.2 ***Operation of automatic weather station systems***

Notes:

1. This section contains provisions for the operation of AWS systems in support of the Global Observing System and WIGOS. It is structured so as to anticipate the eventual integration of the material into the *Manual on the WMO Integrated Global Observing System* (WMO-No. 1160).
2. The provisions of this section are specific to AWS systems. They must be read in conjunction with further provisions throughout Part III of this Manual as well as the *Manual on the WMO Integrated Global Observing System* (WMO-No. 1160) with which AWS operated by Members are to comply.
3. The provisions in this section are directed to Members who operate AWSs and provide data to the WMO Information System (WIS).
4. Guidance on making measurements using AWSs can be found in *Guide to Meteorological Instruments and Methods of Observation* (WMO-No. 8), Part II, Chapter 1.
5. Guidance on network planning and site selection in relation to AWSs can be found in the *Guide to the Global Observing System* (WMO-No. 488), Part III, section 3.2.1.4.

General requirements

2.2.2.1 Members shall establish and operate an AWS network to meet national, regional and global requirements for observations.

Notes:

1. General provisions for equipment and methods of observation for meteorological stations, including AWSs, are given in section 3.1 below.
2. Further guidance on the operation of AWS networks in support of the surface-based subsystem of the GOS is provided in *Guide to the Global Observing System* (WMO-No. 488), Part III, section 3.1.4.3.

2.2.2.2 Members should ensure that observations from AWSs, meet at least the minimum requirements for all application areas associated with the station.

Notes:

1. Further discussion of requirements for observations can be found in the *Manual on the WMO Integrated Global Observing System* (WMO-No. 1160), section 2.2.4 and Appendix 2.3. Requirements for observational data are also described in the *Guide to the Global Observing System* (WMO-No. 488), Part II.
2. It is recommended that Members designate an AWS network manager who will be responsible for ensuring that the network addresses user requirements on an ongoing basis, through a review process that takes into consideration WIGOS requirements.
3. The *Guide to the Global Observing System* (WMO-No. 488), Part III, Appendix III.2, offers guidance to Members on variables that should be reported from an AWS so as to meet minimum requirements in several areas.
4. The *Guide to the Global Observing System* (WMO-No. 488), Appendix III.1, provides information on measurement performance requirements for a range of variables associated with various WMO application areas.

2.2.2.3 Members should ensure that staff are trained to the appropriate level of competency for operation and maintenance of their AWSs.

Note: Guidance on the training of instrument specialists is provided in the *Guide to Meteorological Instruments and Methods of Observation* (WMO-No. 8), Part IV, Chapter 5.

2.2.2.4 Members should document the methods and procedures employed in the operation of their AWSs.

Note: Such documentation is necessary to meet the requirements of some application areas for observation traceability, and comprises several aspects including metadata management, quality management, maintenance, change management, incident management, inspection and calibration. Further provisions and guidance on documentation practices are available in the *Manual on the WMO Integrated Global Observing System* (WMO-No. 1160), section 2.6.6, and the *Guide to the Global Observing System* (WMO-No. 488), Part III, section 3.2.1.4.

Observing practices

2.2.2.5 Observation reports shall have a time stamp indicating the time of measurement with a minimum temporal resolution of 1 minute with respect to UTC.

Quality control

Notes:

1. The requirements for quality control procedures to be implemented by Members are given in the *Manual on the WMO Integrated Global Observing System* (WMO-No. 1160), section 2.4.3. Further information on best practice in quality control of AWS observational data is provided in the *Guide to the Global Observing System* (WMO-No. 488), Part VI, and in the *Guide to Meteorological Instruments and Methods of Observation* (WMO-No. 8), Part II, Chapter 1, section 1.3.2.8, and Part IV. For AWS observations, it is important that appropriate quality control procedures are applied at all stages of data processing and message generation.
2. Quality control of AWS systems incorporates aspects of system design and operation including the following core elements as a minimum:
 - (a) Siting and exposure of systems and sensors;

- (b) Calibration and verification of systems and sensors;
- (c) System and network maintenance;
- (d) Incident management;
- (e) Data quality control.

Data and metadata reporting

2.2.2.6 Members shall make and report observations from AWSs a minimum of eight times per day at the main and intermediate times.

Note: WMO standard Table Driven Code Forms (such as BUFR) are to be used for international exchange of surface observations in accordance with the *Manual on Codes* (WMO-No. 306), Volume I.1.

2.2.2.7 Members should make and report observations from AWSs at least hourly.

Notes:

1. Observations generated routinely should be reported at uniform intervals aligned with the UTC hour.
2. It may be necessary to report observations more frequently in order to meet requirements for specific application areas such as high-resolution numerical weather prediction (NWP) and nowcasting. In such cases, it is recommended that Members report these observations to the WIS.

2.2.2.8 Members who report AWS observations to the WIS shall maintain a copy of all reported AWS observations and associated metadata.

Notes:

1. Non-destructive storage of observations is important such that data and metadata quality and information content are not altered.
2. More information on data processing is provided in the *Guide to the Global Observing System* (WMO-No. 488), Part V, and on data sampling in the *Guide to Meteorological Instruments and Methods of Observation* (WMO-No. 8), Part IV, Chapter 2.
3. The *Manual on the WMO Integrated Global Observing System* (WMO-No. 1160), section 2.5, contains provisions for Members to maintain and provide required metadata in relation to all observations including from operational AWSs. Specific requirements for the calculation and reporting of some meteorological observations are given in the present Manual, Part III, section 3.3.

Incident management

Note: The *Manual on the WMO Integrated Global Observing System* (WMO-No. 1160), section 2.4.5, contains provisions for Members in relation to the management of incidents that interrupt the normal operation of their observing systems by reducing availability or quality of observational data.

2.2.2.9 Members who exchange AWS observations shall report any major incidents they detect to international recipients of observational data and inform them of their resolution, in accordance with the incident management systems under WIGOS.

Notes:

1. Some incidents, such as those related to internal factors, may be detected automatically and reported without delay to international recipients of observational data. Other incidents may be detected with delay or through periodic checks and reported accordingly. Automatic incident detection can be performed using either built-in test equipment or external monitoring systems. A centralized system can be used for monitoring the performance and health of AWS systems and networks.
2. It is important to take corrective action in response to incidents as soon as possible; this includes their analysis and recording.

2.2.2.10 Members who exchange AWS observations should include information about incidents in the metadata that they record and make available.

Change management

Note: The *Manual on the WMO Integrated Global Observing System* (WMO-No. 1160), section 2.4.6, contains provisions for Members in relation to change management associated with all observing systems, including AWSs.

2.2.2.11 Members should carefully plan changes to AWSs in order to avoid or minimize impact on observational data availability and quality.

Note: An important aspect of such planning is the definition of clear roles and responsibilities for each given change.

2.2.2.12 When making changes to AWS systems and networks, Members should notify both national and international stakeholders and observational data users in advance, record and document such changes and update relevant metadata records.

Notes:

1. These notifications include information on the expected impacts and the time period over which the change will take place and, importantly, when the period of change is complete. A future standard mechanism and format for such notifications will be useful.
2. The records of changes include the nature and characteristics of the changes, the date and time of implementation and the reason for making the changes.
3. The relevant metadata include both national and international metadata records pertaining to the AWS system and site.

2.2.2.13 In making changes to observing systems, Members should plan and define requirements for periods of overlapping observations.

Note: For climatological stations in particular, there may be a requirement to undertake simultaneous observations for an overlapping period as detailed in the *Guide to the Global Observing System* (WMO-No. 488), Part III, section 3.7.4, and this is particularly pertinent when the establishment of an AWS system replaces manual observations.

Maintenance

Note: The *Manual on the WMO Integrated Global Observing System* (WMO-No. 1160), section 2.4.7, contains provisions for Members in relation to the maintenance of all observing systems, including AWS systems.

2.2.2.14 Members who operate AWSs shall develop, implement and document policies and procedures for routine maintenance of those systems.

Notes:

1. The purpose of these policies and procedures is to ensure that the requirements and standards for operational performance and observational data quality are met.
2. The complete AWS system incorporates hardware, software, telecommunications and ancillary systems. Where possible and practical, the maintenance programme is to be based on relevant manufacturer specifications and guidelines.
3. Routine site maintenance is conducted so as to ensure the ongoing representativeness of the site and the measured variables in accordance with the requirements of the application areas that the AWS observations support.
4. Further guidance on maintenance of AWS networks is in the *Guide to Meteorological Instruments and Methods of Observation* (WMO-No. 8), Part II, Chapter 1, section 1.6.
5. Routine maintenance should be planned so as to minimize any impact on the making and reporting of observations, particularly during critical weather times and situations.

2.2.2.15 Members shall perform corrective maintenance as soon as practically possible after an issue with an AWS system has been detected.

Note: Typically, it is through monitoring or incident management that an issue is detected and responsive maintenance is triggered. The assessment of what is practically possible may take into account the severity of the issue.

2.2.2.16 Members who operate AWSs should, where appropriate, implement and perform maintenance tasks remotely.

Note: Remote maintenance cannot replace on-site maintenance for many tasks, but the ability to perform some tasks remotely can contribute to preventive maintenance practices thus helping to achieve higher overall system uptime and quality of operation.

2.2.2.17 Members who operate AWSs shall ensure that they have enough competent staff to meet all maintenance requirements and responsibilities.

2.2.2.18 Members who exchange AWS observational data should record and report details of corrective and preventive maintenance completed in accordance with the WIGOS metadata standard.

Notes:

1. The requirements to retain and make available metadata are laid out in the *Manual on the WMO Integrated Global Observing System* (WMO-No. 1160), section 2.5 and Appendix 2.4, and the specification of the WIGOS metadata standard can be found in *The WIGOS Metadata Standard* (WMO-No. 1192), with further elaboration in the *Guide to the WMO Integrated Global Observing System* (WMO-No. 1165).
2. Any planned or responsive maintenance which has reduced or is expected to reduce the normal AWS data availability or quality is to be treated in the same manner as an incident, by following provisions under 2.2.2.9 and 2.2.2.10 above.

2.2.2.19 Members should either flag, remove or not report, as appropriate, observational data that is adversely impacted by maintenance activities.

Inspection and supervision

2.2.2.20 Members shall define and establish functions and responsibilities for inspection and supervision of their AWSs.

Notes:

1. The objective of inspection and supervision is to determine whether the AWS and its sensors are functioning correctly (within performance tolerances) and, if not, to understand the deviations and initiate a response.
2. Remote monitoring and diagnostic systems can significantly increase the effectiveness of inspection and supervision activities.
3. The general provisions for inspection and supervision provided in the *Manual on the WMO Integrated Global Observing System* (WMO-No. 1160), section 3.4.8, apply to all surface-based systems, including AWS systems.

2.2.2.21 Members who report AWS observational data to the WIS shall record and report inspection results in accordance with the WIGOS metadata standard.

2.2.2.22 Members who report AWS observations to the WIS shall inspect their AWSs at least once every two years.

Notes:

1. It is recommended that the inspections should be frequent enough to ensure a high probability of detecting issues that might affect the integrity and quality of observational data.
2. For further guidance on inspection processes and standards see the *Guide to the Global Observing System* (WMO-No. 488), Part III, section 3.1.3.8.

Calibration procedures

2.2.2.23 Members shall define and establish functions and responsibilities for the calibration of their AWSs and their sensors, taking into consideration the manufacturer's guidelines.

Notes:

1. The objective of calibration is to constrain AWS components and sensors to operate within performance tolerances given by the supplier and to meet defined user requirements.
2. Recalibration or replacement of sensors is to be undertaken as soon as possible after detecting that tolerances for field verifications are exceeded.

2.2.2.24 Members should ensure that, when possible, AWS field sensors and travelling standards are traceable to the relevant primary international standard.

2.2.2.25 Members who report AWS observations to the WIS should record and report details of calibrations or field verifications in accordance with the WIGOS metadata standard.

Notes:

1. Any calibration or verification activity which has reduced or is expected to reduce availability or quality of AWS observations is to be treated in the same manner as an incident, by following provisions under 2.2.2.9 and 2.2.2.10 above.
2. It is recommended that, for those sensors for which it is possible and appropriate, the periodic comparison of AWS sensors with travelling standards should be performed and recorded in accordance with the *Guide to Meteorological Instruments and Methods of Observation* (WMO-No. 8), Part IV, Chapter 1, section 1.7.

2.3 **Surface synoptic stations**

2.3.1 **General**

2.3.1.1 **Surface synoptic stations may be manned or partly or fully automated and shall include land stations and fixed and mobile sea stations that conduct synoptic observations.**

2.3.1.2 **Each synoptic station shall be located so as to give meteorological data representative of the area in which it is situated.**

2.3.1.3 **The main standard times for surface synoptic observations shall be 0000, 0600, 1200 and 1800 UTC.**

2.3.1.4 **The intermediate standard times for surface synoptic observations shall be 0300, 0900, 1500 and 2100 UTC.**

2.3.1.5 Atmospheric pressure observations should be made at exactly the standard time while the observation of other meteorological elements should be made within the 10 minutes preceding the standard time.

2.3.1.6 Every effort should be made to obtain surface synoptic observations four times daily at the main standard times, with priority being given to the 0000 and 1200 UTC observations, which are required for global exchanges.

2.3.1.7 Additionally, Members should endeavour to obtain surface synoptic observations at the intermediate standard times and, furthermore, at regular hourly intervals.

2.3.1.8 When it is difficult, for any reason, to provide sufficient staff for 24-hour operations, partially or fully automated stations should complement or replace manned surface stations, including those in the basic synoptic network, to provide observations at least at the main standard times.

2.3.2 **Land stations**

General

2.3.2.1 **Each synoptic station on land shall be uniquely identified by a WIGOS station identifier.**

Note: Requirements relating to station identifiers are to be found under 2.2.1.4 above. Some of the now-expired identification requirements for synoptic stations are reproduced below because they may be adopted by an issuer of identifiers as a convention to be followed in defining local identifiers for new stations:

A synoptic station on land shall be identified by a station index number assigned by the Member concerned, from within the allocations made to that Member, in compliance with the scheme prescribed in the *Manual on Codes* (WMO-No. 306). Before issuing a station index number, Members should ensure that the operator of the station or platform has committed to complying with the relevant Technical Regulations.

When a Member establishes a synoptic station on land, it shall send the following information to the Secretariat at least two months before the station becomes operational:

- (a) Name, and where appropriate, station index number (stating whether the station is automatic or manned and, if both, the type of each);
- (b) Geographical coordinates in degrees, minutes and integer seconds of arc and elevation of the station, in metres (up to two decimals) above mean sea level;
- (c) Geopotential of the datum level in whole metres to which the pressure is reduced, or the reference isobaric surface the geopotential of which is reported;
- (d) Times at which synoptic observations are made and reported;
- (e) Topographical situation;
- (f) Any other information required for completion of the entries in *Weather Reporting* (WMO-No. 9), Volume A.

Information on the accurate specification of the geographical coordinates and elevation of a station is provided in the *Guide to Meteorological Instruments and Methods of Observation* (WMO-No. 8), Part I, Chapter 1, 1.3.3.2.

Members shall send any necessary amendments to the information supplied under (a)–(f) above to the Secretariat as soon as possible.

The Secretariat should be notified of any changes of the index numbers of synoptic stations included in the international exchanges at least six months before they take effect.

Each Member should publish a description of each of its synoptic stations in accordance with the provisions of the *Manual on the WMO Integrated Global Observing System* (WMO-No. 1160).

All changes in the station index number of a synoptic station shall take effect on 1 January or 1 July.

Each Member of WMO shall designate a national focal point to communicate with the Secretariat on matters regarding the contents of *Weather Reporting* (WMO-No. 9), Volume A. The national focal point shall be authorized to act in this capacity on behalf of the Permanent Representative concerned.

Location and composition

2.3.2.2 Surface land stations, including those in the RBSN, should be spaced at intervals not exceeding the minimum horizontal resolution required by application areas supported by the network and as described in the Rolling Review of Requirements and the Observing Systems Capability Analysis and Review Tool (OSCAR) database.

Note: As a general rule, during the first decade of the twenty-first century, the interval was not supposed to exceed 250 km (or 300 km in sparsely populated areas).

2.3.2.3 Surface synoptic observations recorded at a manned synoptic land station shall consist of observations of the following meteorological elements:

- (a) Present weather;
- (b) Past weather;
- (c) Wind direction and speed;
- (d) Cloud amount;
- (e) Type of cloud;
- (f) Height of cloud base;
- (g) Visibility;
- (h) Air temperature;
- (i) Humidity;
- (j) Atmospheric pressure;

together with such of the following meteorological elements as are determined by resolutions of regional associations:

- (k) Pressure tendency;
- (l) Characteristic of pressure tendency;
- (m) Extreme temperature;
- (n) Amount of precipitation;
- (o) State of ground;
- (p) Direction of cloud movement;
- (q) Special phenomena.

2.3.2.4 Surface synoptic observations at an automatic land station shall consist of measurements of the following meteorological elements:

- (a) Atmospheric pressure;
- (b) Wind direction and speed;
- (c) Air temperature;
- (d) Humidity;
- (e) Precipitation, yes or no (at least in tropical areas);

together with the following additional meteorological elements, which should be included if possible, or as determined by resolutions of regional associations:

- (f) Amount of precipitation;

- (g) Intensity of precipitation;
- (h) Visibility;
- (i) Optical extinction profile (height of cloud base);
- (j) Special phenomena;
- (k) Snow depth or snow cover.

Notes:

1. The set of automatic weather station metadata required for operational purposes is presented in Attachment III.1.
2. The height of cloud base and cloud extent can be derived directly from the optical extinction profile without further measurement, using one-minute time series.
3. Snow cover and snow depth are reported from stations where snow is experienced and the capabilities to observe and measure these variables exist, as determined by resolutions of regional associations.

Frequency and timing of observations

2.3.2.5 At synoptic land stations, surface synoptic observations should be made and reported eight times per day (at the main and intermediate standard times) in extratropical areas, and four times per day (at the main standard times) in the tropics.

2.3.2.6 **At a (manned or automatic) land station, surface synoptic observations shall be made and reported at least at the main standard times, except for snow depth or snow cover to which 2.3.2.7 and 2.3.2.8 apply.**

2.3.2.7 At a (manned or automatic) land station, snow cover or snow depth observations should be reported four times per day, at the main standard times, namely 0000, 0600, 1200, 1800 UTC.

2.3.2.8 **At a (manned or automatic) land station, snow cover or snow depth shall be reported at least once per day, together with the time of observation.**

2.3.2.9 **Snow depth shall be reported as zero (0 cm) when snow is not present, for the entire period during which snow can be expected but is not present, as determined by resolutions of regional associations.**

2.3.2.10 Snow cover should be reported in the state of ground field, where possible, and zero snow depth (absence of snow) should be reported in the quantitative snow depth field.

2.3.3 ***Sea stations***

General

2.3.3.1 When more economical means are not available, ocean weather stations and some other fixed sea stations should provide essential and detailed meteorological and oceanographic data from critical locations or ocean areas.

Notes:

1. These stations, in fulfilling this role, form an integral part of regional and national networks.
2. Fixed sea stations also provide reference-level data and a basis for calibration of soundings by remote sensing from satellites and are thus important in the analysis of phenomena on a large or planetary scale.
3. The WIGOS station identifier of a fixed sea station, other than an ocean weather station or a moored buoy, may be a station index number following the convention of 2.3.2.1, if considered to be in the same category as a land station.

2.3.3.2 **Members shall recruit as mobile ship stations as many ships as possible that traverse data-sparse areas and regularly follow routes through areas of particular interest.**

2.3.3.3 **Members concerned shall provide the Secretariat, not later than 1 March each year, with a list of their selected and supplementary ship stations in operation at the beginning of the year, or shall provide any necessary amendments to their previous list – giving the name, call sign and route or route designator of each ship.**

2.3.3.4 **Members shall include in the lists of selected and supplementary ship stations information on the method of obtaining sea-surface temperature; on the types of barometer, psychrometer, barograph, radio equipment and other instruments aboard the ship; and radiowatch hours.**

2.3.3.5 **Members should consider using fixed or mobile automatic sea stations or drifting buoy stations in data-sparse areas.**

Note: These stations are located on fixed or mobile ships, fixed or anchored platforms, and drifting platforms and ice floes.

Location and composition

2.3.3.6 **Each fixed sea station should be located so as to provide data which are representative of the marine area. As a minimum, observations should be made at the main synoptic times. The observations should include as many meteorological elements of a full synoptic report as possible.**

2.3.3.7 **Members should establish, either individually or jointly, ocean weather stations or other suitable observing facilities in ocean areas where there are large gaps in the global network.**

Note: Information describing the stations should be sent to the Secretariat, as for synoptic land stations (see paragraph 2.3.2.2).

2.3.3.8 **In its recruitment programme, each Member should aim for its mobile sea stations to contribute as much as possible to the attainment of an adequate density of observations in all oceanic areas.**

Note: An adequate density of surface reports in oceanic areas is one per 250 km.

2.3.3.9 **It shall be possible to determine the position of a fully automated mobile sea station.**

2.3.3.10 **At ocean weather stations, surface synoptic observations shall consist of observations of the following elements:**

- (a) **Present weather;**
- (b) **Past weather;**
- (c) **Wind direction and speed;**
- (d) **Cloud amount;**
- (e) **Type of cloud;**
- (f) **Height of cloud base;**
- (g) **Visibility;**

- (h) **Air temperature;**
- (i) **Humidity;**
- (j) **Atmospheric pressure;**
- (k) **Pressure tendency;**
- (l) **Characteristic of pressure tendency;**
- (m) **Ship's course and speed;**
- (n) **Sea-surface temperature;**
- (o) **Direction of movement of waves;**
- (p) **Wave period;**
- (q) **Wave height;**
- (r) **Sea ice and/or icing of ship superstructure, when appropriate;**
- (s) **Special phenomena.**

2.3.3.11 At a selected ship station, a surface synoptic observation should consist of observations of elements (a) to (r) in 2.3.3.10 above.

2.3.3.12 At a supplementary ship station, a surface synoptic observation should consist of observations of elements (a) to (i) and (r) in 2.3.3.10 above.

2.3.3.13 At an auxiliary ship station, a surface synoptic observation should consist of observations of elements (a) to (d), (g), (h), (j) and (r) in 2.3.3.10 above.

2.3.3.14 At lightships, manned platforms, and coastal and island stations, a surface synoptic observation should consist of observations of elements (a) to (r), with the exception of (m), in 2.3.3.10 above.

2.3.3.15 At a fixed automatic sea station, surface synoptic observations shall consist of measurements of the following elements:

- (a) **Atmospheric pressure;**
- (b) **Wind direction and speed;**
- (c) **Air temperature;**
- (d) **Sea-surface temperature.**

In addition to the elements listed above, a surface synoptic observation made at a fixed automatic sea station should include, if possible, the following elements:

- (e) Precipitation, yes or no (especially in tropical areas);
- (f) Waves.

2.3.3.16 At a drifting automatic sea station (drifting buoy), a surface synoptic observation should consist of as many as possible of elements (a) to (d), and (f), in 2.3.3.15 above.

Note: The position of the drifting buoy shall also have to be determined.

2.3.3.17 Members should endeavour to equip mobile ships to make subsurface observations.

Note: Guidance on steps to be taken while recruiting a selected supplementary or auxiliary observing ship, on the organization needed to collect ships' weather reports, and on the use of marine meteorological logs on board ships is contained in the *Guide to Marine Meteorological Services* (WMO-No. 471).

Frequency and timing of observations

2.3.3.18 **At ocean weather stations, surface synoptic observations shall be made and reported at least four times per day at the main standard times (preferably also at the intermediate standard times and ideally hourly).**

2.3.3.19 **At lightship stations, fixed and anchored platform stations, and automatic sea stations, surface synoptic observations shall be made and reported at least four times per day at the main standard times.**

2.3.3.20 At mobile sea stations, surface synoptic observations should be made and reported at least four times per day at the main standard times.

2.3.3.21 When operational difficulties on board ship make it impracticable to make a surface synoptic observation at a main standard time, the actual time of observation should be as near as possible to the main standard time.

2.3.3.22 Whenever storm conditions threaten or prevail, surface synoptic observations should be made and reported from mobile sea stations more frequently than at the main standard times.

2.3.3.23 When sudden and dangerous weather developments are encountered at sea stations, surface observations should be made and reported as soon as possible without regard to the standard observation times.

Note: For specific instructions relative to the provision by ships of special reports, in accordance with the International Convention for Safety of Life at Sea, see *Weather Reporting*.

2.3.3.24 Members should arrange for timely transmission of observations.

Note: Details of observing and reporting programmes are given in the *Guide to Marine Meteorological Services* (WMO-No. 471), Chapter 5. In case of difficulties resulting from fixed radiowatch hours on board single-operator ships, the procedures set out in the *Manual on the Global Telecommunication System* (WMO-No. 386), Part I, Attachment I-1, should be followed.

2.4 Upper-air synoptic stations

General

2.4.1 **Upper-air synoptic stations shall be uniquely identified by a WIGOS station identifier.**

2.4.2 **The standard times of upper-air synoptic observations shall be 0000, 0600, 1200 and 1800 UTC.**

2.4.3 As upper-air data from the ocean areas are particularly sparse, Members should give consideration to equipping suitable ships to make soundings and, if possible, to measure upper winds.

2.4.4 In the tropics, priority should be given to upper-wind observations.

2.4.5 Upper-air stations making observations of pressure, temperature, humidity and wind should be spaced at intervals not exceeding the minimum horizontal resolution required by application areas supported by the network and as described in the Rolling Review of Requirements and the OSCAR database.

Note: As a general rule, during the first decade of the twenty-first century, the interval was not supposed to exceed 250 km (or 1 000 km in sparsely populated and ocean areas).

Location and composition

2.4.6 **An upper-air synoptic observation shall consist of measurement of one or more of the following meteorological elements:**

- (a) **Atmospheric pressure;**
- (b) **Air temperature;**
- (c) **Humidity;**
- (d) **Wind direction and speed.**

Frequency and timing of observations

2.4.7 At upper-air synoptic stations, the frequency of synoptic observations should be four per day, and these should be made at the standard times of upper-air synoptic observations.

2.4.8 **At upper-air synoptic stations, upper-air observations shall be made and reported at least at 0000 and 1200 UTC.**

2.4.9 At ocean weather stations, upper-air synoptic observations should comprise rawinsonde observations at 0000 and 1200 UTC and/or radiowind observations at 0600 and 1800 UTC.

2.4.10 The actual time of regular upper-air synoptic observations should be as close as possible to H-30 and should not fall outside the time range from H-45 to H.

Note: The actual time of a pilot-balloon observation may deviate from the range indicated above if such deviation is expected to enable wind observations to considerably greater heights.

2.4.11 In areas where it is not possible to meet the frequency requirements mentioned above, every effort should be made to obtain at least the following observations:

- (a) Upper-air observations from the RBSNs and other networks of stations on land and at sea, twice daily, at 0000 and 1200 UTC;
- (b) In the tropics, at stations where two complete radiosonde/radiowind observations are not made, priority should be given to the implementation of one complete radiosonde/radiowind observation and one radiowind observation daily.

2.5 **Aircraft meteorological stations**

Note: The structure of this section departs from the standard format which consists of subsections: General, Location and composition, and Frequency and timing of observations. This is a transitional step towards the eventual migration to the *Manual on the WMO Integrated Global Observing System* (WMO-No. 1160).

General

Notes:

1. An aircraft meteorological station is defined in *Technical Regulations* (WMO-No. 49), Volume I – General Meteorological Standards and Recommended Practices as a “meteorological station situated on an aircraft”, whereas a meteorological observing station (meteorological station) is defined as a “place where meteorological observations are made with the approval of the WMO Member or Members concerned.”
2. Mandatory requirements for provision of observations from aircraft are to be found in *Technical Regulations* (WMO-No. 49), Volume II – Meteorological Service for International Air Navigation. The following provisions are to be read in conjunction with that material.

2.5.1 Members should arrange for meteorological observations to be made and reported by aircraft of their national registry.

Notes:

1. This provision applies to aircraft operating both on national and international air routes and in all phases of flight.
2. In general, three categories of aircraft-based observations (ABO) are described in the *Guide to Aircraft-based Observations* (in preparation), which Members should consider utilizing:

- (a) WMO aircraft-based observations;
- (b) ICAO aircraft-based observations;
- (c) Other aircraft-based observations.

WMO ABOs are derived from aircraft-based observing systems operated by WMO Members in collaboration with cooperating airlines. In this case, requirements for ABO are specified by WMO and its Members so as to meet meteorological needs.

ICAO ABOs are observations derived from ICAO regulated aircraft observations, which are made available to WMO and its Members under the provisions of ICAO as set out in the *Technical Regulations* (WMO-No. 49), Volume II.

Other ABOs are those derived from aircraft-based observing systems operated by other entities. In this case, while Members do not define specifications for the operation of the observing system, they are urged to ensure that the observations are fit for purpose.

3. It is recommended that Members collaborate with their civil aviation authorities regarding compliance with ICAO requirements for the provision of aircraft reports in support of International Air Navigation, as defined in *Technical Regulations* (WMO-No. 49), Volume II, Part 1, 5.7 and 5.8. Such requirements include the forwarding of aircraft reports by civil aviation authorities to ICAO World Area Forecast Centres (WAFCs) on the Aviation Telecommunications Network so that they can subsequently be made available to WMO Members on the WIS.

2.5.2 Members should participate in the WMO Aircraft Meteorological Data Relay (AMDAR) observing system.

Note: Guidance on AMDAR programme development and operation is provided in the *Guide to Aircraft-based Observations* (in preparation).

Requirements

2.5.3 Members should meet the WIGOS requirements for aircraft-based observations.

Notes:

1. WIGOS requirements for upper-air observations (including those for aircraft-based observations) are to be found in the *Manual on the WMO Integrated Global Observing System* (WMO-No. 1160).
2. It is recommended that aircraft-based observations consist of at least the following variables, with desirable and optional variables as indicated:
 - (a) (Static) Air temperature;
 - (b) Wind speed;
 - (c) Wind direction;
 - (d) Pressure altitude;
 - (e) Latitude;
 - (f) Longitude;
 - (g) Time of observation;
 - (h) Turbulence: mean, peak and event-based Eddy Dissipation Rate (EDR) – desirable;

- (i) Geometric altitude – desirable;
 - (j) Humidity – desirable;
 - (k) Icing – desirable;
 - (l) Turbulence: derived equivalent vertical gust (DEVG) – optional.
3. For more details and further requirements concerning measurement and data processing associated with these and additional optional variables, see *AMDAR Onboard Software Functional Requirements Specification, Instruments and Observing Methods*, Report No. 115, Chapter 3.
 4. For more detailed guidance on the provision of aircraft-based observations in support of requirements for upper-air observations, see *Guide to Aircraft-based Observations* (in preparation).

2.5.4 In the operation of AMDAR observing systems, Members should consult and adhere to WMO specifications and best practice.

Note: Some relevant specifications and guidance on practices include:

- (a) *Guide to Aircraft-based Observations* (in preparation);
- (b) The *AMDAR Onboard Software Functional Requirements Specification*, which provides a standard for the meteorological functionality of AMDAR software applications and air-ground data formats;
- (c) The *ARINC 620-8 Data Link Ground System Standard and Interface Specification (DGSS/IS)*, which provides a specification of the meteorological report;
- (d) *Guide to Meteorological Instruments and Methods of Observation (WMO-No. 8)*, Part II, Chapter 3.

2.5.5 Members who operate AMDAR observing systems shall include in their AMDAR observations air temperature, wind speed, wind direction, pressure altitude, latitude, longitude and time of observation.

2.5.6 Members who operate AMDAR observing systems should include measurement of humidity or water vapour, turbulence and icing as additional components of AMDAR observations.

Observation data management

2.5.7 Members who make aircraft-based observations available to the WIS shall ensure that they have the authority to do so from the observational data owner.

2.5.8 Members who make available aircraft-based observations to the WIS should retain a copy of all such observations.

Note: The purpose of this record is to assist observation management functions. In some cases, retention of raw or high-resolution observational data, from which the reports were derived, may be helpful. Dataset management and services are not regulated in this document.

2.5.9 Members shall make available observational metadata relevant to the aircraft-based observations they report to the WIS.

Notes:

1. More details on data management aspects are to be found in the *Manual on the Global Data-processing and Forecasting System (WMO-No.485)*, Volume 1, Part III.
2. More information on data processing and data levels is provided in the *Guide to the Global Observing System (WMO-No. 488)*, Part V.
3. More detailed guidance on aircraft-based observational data management can be found in the *Guide to Aircraft-based Observations* (in preparation).

Quality management

2.5.10 Members who receive, process and transmit aircraft-based observations to the WIS shall as a minimum comply with the WMO requirements for quality control of these data.

Notes:

1. Requirements for quality control are defined in:
 - (a) The *Manual on the WMO Integrated Global Observing System* (WMO-No. 1160), sections 2.6 and 3.6;
 - (b) The *Manual on the Global Data-processing and Forecasting System* (WMO-No. 485), Volume 1, Part II, Appendix II.1.
2. Further information on quality control of aircraft-based observational data can be found in the *Guide to Aircraft-based Observations* (in preparation).

2.5.11 WMO Members who make available aircraft-based observations to the WIS shall develop and implement policies and procedures for quality monitoring and quality assessment of such observations.

Notes:

1. Further information on quality monitoring of aircraft-based observational data can be found in the *Guide to the Global Observing System* (WMO-No. 488), Chapter 3.4, and the *Guide to Aircraft-based Observations* (in preparation).
2. It is recommended that Members ensure that aircraft-based observing systems operated in collaboration with partner airlines and other operators comply with all practices and guidance related to observational data quality provided in the *Guide to Aircraft-based Observations* (in preparation).

2.5.12 Members who make available aircraft-based observations to the WIS shall develop procedures for the analysis of and response to available monitoring information.

Notes:

1. Responses include taking prompt and appropriate corrective action for systematic observing system defects and issues identified that adversely affect the quality of aircraft-based observations transmitted to the WIS. Such responses can be facilitated by WMO Focal Points on Aircraft-based Observations.
2. Key sources of advice on quality of aircraft-based observational data are the WMO lead centre on aircraft-data and other WMO Members.
3. The WMO lead centre on aircraft data undertakes quality monitoring of aircraft-based observations and makes monitoring information available to Members on the WMO website.
4. More detailed guidance on quality management of aircraft-based observations and observing systems can be found in the *Guide to Aircraft-based Observations* (in preparation).

2.5.13 Members who operate AMDAR observing systems shall ensure that on-board data quality control is applied in accordance with WMO specifications and best practice.

Note: Specifications for on-board data quality control are described in the *AMDAR Onboard Software Functional Requirements Specification*.

Provision of aircraft-based observations to the WIS

2.5.14 Members who receive and process aircraft-based observational data from any source, including AMDAR, ICAO and other aircraft-based observing systems, shall make such data available to the WIS in accordance with WMO regulations.

Notes:

1. Relevant regulations may be found in:
 - (a) *Technical Regulations* (WMO-No. 49), Volume II;
 - (b) *Manual on the Global Telecommunication System* (WMO-No.386);
 - (c) *Manual on Codes* (WMO-No. 306), Volumes I.1 and I.2.
2. Guidance on the encoding and provision of aircraft-based observations to the WIS can be found in the *Guide to Aircraft-based Observations* (in preparation).

2.5.15 Members who make aircraft-based observations available to the WIS shall ensure that they have the capacity to identify and remove poor-quality data from transmission to the WIS until such time as the data quality is restored.

Observational metadata requirements and management

2.5.16 Members who receive, process and make available to the WIS aircraft-based observational data from any source shall maintain a database of related metadata.

Note: Relevant metadata include those relating to the following aspects and elements of the observational data:

- (a) Models and types of aircraft;
- (b) When and where possible, on-board sensors and their siting, calibration and operational issues and faults;
- (c) Specific software and algorithms used to process data to generate the reported variables;
- (d) Metadata related to quality control processes, data communication practices, data processing and delivering centres.

2.5.17 Members who make available aircraft-based observations to the WIS shall maintain and provide the related, internationally required metadata.

Notes:

1. Specific details of relevant metadata can be found in the *Guide to Aircraft-based Observations* (in preparation).
2. General requirements for provision of observational metadata can be found in the *Manual on the WMO Integrated Global Observing System* (WMO-No. 1160), section 2.5.
3. More detailed guidance on management of aircraft-based observational metadata can be found in the *Guide to Aircraft-based Observation*, (in preparation).

Maintenance and management of incidents and changes

Note: General provisions that apply to the management of incidents and changes in Members' aircraft-based observing systems can be found in the *Manual on the WMO Integrated Global Observing System* (WMO-No. 1160), sections 2.4 and 3.4, and in the *Manual on the Global Telecommunication System* (WMO-No. 386), Part II, 5.

2.5.18 Members should ensure that changes to the programme or schedule of reporting of aircraft-based observations to the WIS are planned and notified in advance.

Notes:

1. Recommended practices for reporting and recording of incidents within aircraft-based observational metadata are provided in the *Guide to Aircraft-based Observations* (in preparation).
2. It is recommended that Members establish and document suitable policies and procedures for the management of incidents associated with the operation of aircraft-based observing systems.
3. One aim of such procedures is to ensure that incidents adversely affecting the quality or timeliness of aircraft-based observations are rectified in a timely manner.
4. It is recommended that Members report such incidents to the relevant WMO lead centre on aircraft data and to WMO Focal Points on Aircraft-based Observations through the relevant communications channels.

2.5.19 Members who make aircraft-based observations available to the WIS shall, in collaboration with their operating partners, develop policies and procedures for the detection, communication and timely rectification of issues and errors that adversely affect the quality of observations.

2.5.20 Members who make aircraft-based observations available to the WIS shall develop, implement and document plans, policies and procedures for routine maintenance of their aircraft-based observing systems.

Notes:

1. Such plans will ensure that standards for operational performance are maintained.
2. Plans and procedures for routine maintenance should include provisions for maintenance of all aircraft-based observing system components and sensors, related infrastructure and materials.
3. Maintenance documentation and related metadata should be made available to relevant users and stakeholders.

2.5.21 Members should utilize a centralized system for monitoring the status and health of aircraft-based observing systems as an integrated component of their maintenance regime.

Note: An example of such a centralized system is a computer system designed and established to receive, monitor and report automatically generated information and data pertaining to the operation and performance of the aircraft-based observing system. The functions of such a system might include: (a) automated analysis of reports on quality monitoring and data quality control, and the raising of alarms or flags based on specific criteria; (b) raising alerts on changes in data availability; and (c) monitoring and event-based alerts related to operational performance of computer and communications systems.

2.6 Radar wind profiler stations

Notes:

1. This section departs from the standard structure used to regulate other elements of the surface-based subsystem of the GOS. This is a transitional step towards the eventual migration of this regulatory material to the *Manual on the WMO Integrated Global Observing System* (WMO-No. 1160).
2. Wind profile observations can be determined by a range of systems, such as Doppler lidars, Doppler sodars and Doppler weather radars. A general description of surface-based profiling techniques and systems is given in the *Guide to Meteorological Instruments and Methods of Observation* (WMO-No. 8), Part II, Chapter 5, section 5.2; for radar wind profilers in particular, see section 5.2.2.

2.6.1 General requirements

2.6.1.1 Members should consider the establishment of radar wind profiler (RWP) stations in their network of upper-air stations.

Note: Each RWP station is to be uniquely identified by a WIGOS station identifier, following the provisions laid out in *Manual on the WMO Integrated Global Observing System* (WMO-No. 1160), Chapter 2, Attachment 2.1.

2.6.1.2 Members who operate RWPs shall comply with national regulations for the use of radio frequencies.

Notes:

1. Extensive information about the use of radio frequencies can be found in the *Handbook – Use of Radio Spectrum for Meteorology: Weather, Water and Climate Monitoring and Prediction* (ITU/WMO, 2008), noting that Resolution 217 of the World Radiocommunication Conference 1997 (WRC-97) is the basis for frequency allocation for RWPs. Further information is provided in the *Guide to Participation in Radio-frequency Coordination* (WMO-No. 1159).
2. Physical constraints in selecting systems are described in the *Guide to Meteorological Instruments and Methods of Observation* (WMO-No. 8), Part II, Chapter 5, section 5.2.2. The vertical range of a radar wind profiler is strongly related to the operating frequency.

2.6.1.3 Members who operate RWPs shall make horizontal wind vector observations.

2.6.1.4 Members who operate RWPs should make vertical wind component observations.

Notes:

1. Further information about the observations made by RWPs and accuracy requirements is provided in the *Guide to Meteorological Instruments and Methods of Observation* (WMO-No. 8).
2. RWP operations may pose safety hazards to operators and maintenance personnel, so the requirement to ensure proper safety procedures (see *Manual on the WMO Integrated Global Observing System* (WMO-No. 1160), section 2.4.1.7) is particularly relevant. Typically, safety hazards for RWPs include electric shock, radiofrequency (RF) radiation, high levels of noise (for systems equipped with a Radio-acoustic Sounding System (RASS)), tripping, lifting and electrostatic discharge. Hazards may also include high voltage and radiation exposure.

2.6.2 Observing practices

Note: The *Guide to Meteorological Instruments and Methods of Observation* (WMO-No. 8), Part II, Chapter 5, section 5.2.2, provides guidance on RWP observing practices. Relevant considerations include techniques and system characteristics, and site selection to optimally contribute to the upper-air network.

2.6.2.1 **Members shall operate their RWP continuously so as to acquire and provide horizontal winds at time intervals not exceeding 60 minutes.**

Note: Data acquisition at shorter time intervals, for example every five or ten minutes, may be preferable or required depending on the user requirements and applications that the observations are intended to support. Users must then be cautious about a potential degradation of data quality under certain atmospheric conditions.

2.6.2.2 **Members who operate RWPs should maximize the quality of the acquired observational data.**

Note: Range and velocity aliasing errors can be completely avoided if data sampling is properly set up. Moreover, clutter needs to be filtered, and interference contamination needs to be minimized by suitable data processing techniques. Further information is provided in the *Guide to Meteorological Instruments and Methods of Observation* (WMO-No. 8).

2.6.2.3 **Members should retain a copy of all RWP observations they report to the WIS.**

Note: Non-destructive storage of observations is important such that data and metadata quality and information content are not altered.

2.6.3 **Quality control**

Notes:

1. The importance and requirement for Members to implement quality control procedures are described in the *Manual on the WMO Integrated Global Observing System* (WMO-No. 1160), section 2.4.3. For RWPs, it is important that appropriate quality control procedures are applied at all stages of signal and data processing.
2. The *Guide to Meteorological Instruments and Methods of Observation* (WMO-No. 8), Part II, Chapter 5, section 5.2.2, provides some guidance on quality control for radar wind profiler observations. To the extent possible, the procedures are to operate automatically in real time and enable the characterization of data quality. They are to be part of a quality assurance programme which includes at least system and test equipment calibration, hardware and software maintenance, technical instructions and reporting.

Members who operate RWPs shall implement practices and procedures for frequent routine monitoring of the quality of their RWP observations.

Note: It is recommended that monitoring of RWP observational data quality be based on frequent and ongoing comparison with a reliable reference standard. A commonly used method relies on the use of “observation minus background” statistics from NWP output. Comparison may also be made with co-located upper-air wind measurements from other observing systems if available.

2.6.4 **Data and metadata reporting**

Members who operate RWPs should make RWP observational data available via the WIS.

Notes:

1. WMO standard RWP BUFR codes are to be used for international exchange.
2. The *Manual on the WMO Integrated Global Observing System* (WMO-No. 1160), section 2.4.4, contains provisions for Members to maintain and provide required metadata in relation to all observations including operational RWP. While it is desirable that real-time metadata such as data quality be provided together with the observations to which they apply, the feasibility of reporting codes places a limit on what can be accommodated.

2.6.5 **Incident management**

Note: The *Manual on the WMO Integrated Global Observing System* (WMO-No. 1160), section 2.4.5, contains provisions for Members in relation to the management of incidents that interrupt the normal operation of their observing systems by reducing the availability or quality of observational data.

2.6.5.1 Members who exchange RWP observations shall report any major incidents they detect to international recipients of observational data, and shall state when such incidents have been resolved, in accordance with the incident management systems under WIGOS.

Notes:

1. Some incidents, such as those related to internal factors, may be detected automatically and reported without delay to international recipients of observational data. Other incidents may be detected with delay or through periodic checks and reported accordingly. Automatic incident detection can be performed using either built-in test equipment or external monitoring systems. A centralized system can be used for monitoring the performance and health of RWP systems and networks.
2. It is important to take corrective action in response to incidents, including analysis and recording of the event, as soon as possible.

2.6.5.2 Members who exchange RWP observations should include information about incidents in the metadata that they record and make available

2.6.6 Change management

Note: The *Manual on the WMO Integrated Global Observing System* (WMO-No. 1160), section 2.4.6, contains provisions for Members in relation to change management associated with all observing systems, including RWPs.

2.6.6.1 Members should carefully plan changes to RWP systems in order to avoid or minimize impact on observational data availability and quality.

Note: An important aspect of such careful planning is to define clear roles and responsibilities for each given change.

2.6.6.2 When making changes to RWP systems and networks, Members should notify national and international stakeholders and observational data users in advance, record and document such changes, and update relevant metadata records.

Notes:

1. These notifications include information on the expected impacts and the time period over which the change will take place and, importantly, when the period of change is complete. A future standard mechanism and format for such notifications will be useful.
2. The record of changes includes the nature and characteristics of the change, the date and time of implementation and the reason for making the change.
3. The relevant metadata include both national and international metadata records pertaining to the observing system and site.

2.6.7 Maintenance

Note: The *Manual on the WMO Integrated Global Observing System* (WMO-No. 1160), section 2.4.7, contains provisions for Members in relation to the maintenance of all observing systems, including RWPs.

2.6.7.1 Members who operate RWPs shall develop, implement and document policies and procedures for routine maintenance of the RWP system.

Notes:

1. The purpose of the policies and procedures is to ensure that the requirements and standards for operational performance and observational data quality are met.
2. The complete RWP system includes hardware, software, telecommunications and ancillary systems. Where possible and practical, the maintenance programme should be based on relevant manufacturer specifications and guidelines.

2.6.7.2 Members shall perform responsive maintenance as soon as practically possible after an issue with their RWP system has been detected.

Note: Typically, it is through monitoring or incident management that an issue is detected and responsive maintenance is triggered. The assessment of what is practically possible may take into account the severity of the issue.

2.6.7.3 Members who operate RWPs should, where appropriate, implement and perform maintenance tasks remotely.

Note: Remote maintenance cannot replace on-site maintenance for many tasks, but the ability to perform some tasks remotely can contribute to preventive maintenance practices, thus helping to achieve higher overall system uptime and quality of operation.

2.6.7.4 Members who operate RWPs should maintain their sites to minimize the effect on the system of external factors (for example, blockage by vegetation).

2.6.7.5 **Members who operate RWPs shall ensure that they have sufficient numbers of competent staff to meet all maintenance requirements and responsibilities.**

2.6.7.6 Members who exchange RWP observational data should record and report details of corrective and preventive maintenance completed in accordance with the WIGOS metadata standard.

Notes:

1. The requirements to retain and make available metadata are laid out in the *Manual on the WMO Integrated Global Observing System* (WMO-No. 1160), section 2.5 and Appendix 2.4, and the specification of the WIGOS metadata standard can be found in *The WIGOS Metadata Standard* (WMO-No. 1192), with further elaboration in the *Guide to the WMO Integrated Global Observing System* (WMO-No. 1165).
2. Any planned or responsive maintenance which has reduced or is expected to reduce the normal RWP data availability or quality is to be treated in the same manner as an incident, by following provisions 2.6.5.1 and 2.6.5.2 above.

2.6.8 ***Inspection and supervision***

2.6.8.1 **Members shall define and establish roles and responsibilities for inspection and supervision of their RWPs.**

Notes:

1. The objective of inspection and supervision is to determine whether the RWP is functioning correctly (within performance tolerances) and, if not, to understand the deviations and initiate a response.
2. Remote monitoring and diagnostic systems can significantly increase the effectiveness of inspection and supervision activities.
3. The general provisions for inspection and supervision provided in the *Manual on the WMO Integrated Global Observing System* (WMO-No. 1160), section 3.4.8, apply to all surface-based systems, including RWP systems.

2.6.8.2 **Members who exchange RWP observational data shall record and report inspection results in accordance with the WIGOS metadata standard.**

2.6.9 ***Calibration procedures***

2.6.9.1 **Members shall define and establish roles and responsibilities for the calibration of their RWPs, taking into consideration the manufacturer's guidelines.**

Note: The objective of calibration is to constrain RWPs to operate within performance tolerances given by the supplier and to meet defined user requirements.

2.6.9.2 **Members who exchange RWP observational data shall record and report details of calibrations in accordance with the WIGOS metadata standard.**

Notes:

1. Relevant calibration details, in the case of the spaced antenna method of wind determination, would include the statistical bias correction applied.

2. Any calibration activity which has reduced or is expected to reduce the normal RWP data availability or quality is to be treated in the same manner as an incident, by following provisions 2.6.5.1 and 2.6.5.2 above.

2.7 **Weather radar stations**

Notes:

1. This section departs from the standard structure used to regulate other elements of the surface-based subsystem of the GOS. This is a transitional step towards the eventual migration of this regulatory material to the *Manual on the WMO Integrated Global Observing System* (WMO-No. 1160).
2. A general description of weather radars is given in the *Guide to Meteorological Instruments and Methods of Observation* (WMO-No. 8), Part II, Chapter 7.

2.7.1 **General requirements**

2.7.1.1 Members should establish a network of weather radar stations either nationally or in conjunction with other Members.

Note: Each weather radar station is to be uniquely identified by a WIGOS station identifier (see the *Manual on the WMO Integrated Global Observing System* (WMO-No. 1160), provision 2.4.1.1).

2.7.1.2 **Members who operate weather radars shall comply with national regulations for the use of radio frequencies.**

Note: Extensive information about the use of radio frequencies is provided in the *Handbook – Use of Radio Spectrum for Meteorology: Weather, Water and Climate Monitoring and Prediction* (ITU/WMO, 2008) and also in the *Guide to Participation in Radio-frequency Coordination* (WMO-No. 1159).

2.7.1.3 **Members who operate weather radars shall operate radars capable of transmitting and receiving horizontally polarized signals.**

2.7.1.4 Members who operate weather radars should operate radars capable of transmitting and receiving both horizontally and vertically polarized signals.

Note: Such radars are generally known as dual-polarization or polarimetric radars.

2.7.1.5 **Members shall ensure that their weather radars provide observations of the radar reflectivity factor.**

Note: Radar reflectivity is related to precipitation intensity and may also be generated by non-meteorological phenomena.

2.7.1.6 Members should ensure that their single-polarization weather radars provide the following observations:

- (a) Radial velocity;
- (b) Spectral width.

2.7.1.7 Members should ensure that their weather radars with dual-polarization capability provide the following observations:

- (a) Differential reflectivity;
- (b) Cross-polar correlation;
- (c) Differential phase;
- (d) Specific differential phase.

Notes:

1. Further information about the observations made by weather radars, and accuracy requirements, is provided in the *Guide to Meteorological Instruments and Methods of Observation* (WMO-No. 8), Part II, Chapter 7, Tables 7.1, 7.2 and 7.4.
2. Weather radar operations may pose safety hazards to operators and maintenance personnel as well as the surrounding community, so the requirement to ensure proper safety procedures (see *Manual on the WMO Integrated Global Observing System* (WMO-No. 1160), section 2.4.1.7) is particularly relevant. Typically, on-site safety hazards for weather radars include high voltage, radiation exposure, working in confined spaces, heavy moving components, climbing and working at heights. Further information is available in the *Guide to Meteorological Instruments and Methods of Observation* (WMO-No. 8), Part II, Chapter 7, section 7.8.

2.7.2 **Observing practices**

Note: The *Guide to Meteorological Instruments and Methods of Observation* (WMO-No. 8), Part II, Chapter 7, provides guidance on weather radar observing practices related to site selection (7.8.1), optimizing radar characteristics (7.6.8), understanding error sources (7.9 and Figure 7.2), and meteorological applications (7.10) and products (7.11).

2.7.2.1 Members who operate weather radars should make observations available at least every 15 minutes.

Notes:

1. Acquisition of higher temporal frequency observations, for example every five or ten minutes, may be preferable depending on the user requirements and the applications supporting them.
2. It is recognized that Members may have seasonal differences in the operation of weather radars. The above recommended reporting frequency applies during those periods when the radar is in operation.
3. Requirements to make available metadata related to all observations, including weather radar observations, can be found in the *Manual on the WMO Integrated Global Observing System* (WMO-No. 1160), section 2.5.

2.7.2.2 Members should retain a copy of all weather radar observations they report to the WIS.

Note: Non-destructive storage of observations is important to ensure that data and metadata quality and information content are not altered.

2.7.3 **Quality control**

Notes:

1. The importance and requirement for Members to implement quality control procedures are described in the *Manual on the WMO Integrated Global Observing System* (WMO-No. 1160), section 2.4.3. With regard to weather radars, the procedures will improve both qualitative and quantitative uses of weather radar observations.
2. The *Guide to Meteorological Instruments and Methods of Observation* (WMO-No. 8), Part II, Chapter 7, provides some guidance on quality control of weather radar observations. To the extent possible, the procedures are to include quality control of both internal and external factors in order to enable the characterization of data quality and the inclusion of a record of the quality control methods used with the observations they were applied to.

2.7.4 **Data and metadata reporting**

Note: The *Manual on the WMO Integrated Global Observing System* (WMO-No. 1160), section 2.4.4, contains provisions for Members to maintain and provide required metadata in relation to all observations including those from operational weather radars.

2.7.4.1 Members who operate weather radars should make weather radar observational data available for international exchange.

Note: A standard WMO data format is under development. It will ensure that real-time weather radar observational data and metadata can be represented and exchanged in a way that preserves the required precision, accuracy and information content.

2.7.4.2 Members who exchange observational data shall provide real-time metadata together with the observational data to which they apply.

Notes:

1. Key amongst such metadata is information on quality and it should accompany as closely as possible the observational data to which it applies.
2. It is recommended that such metadata include information on calibration, timing, beam pointing, and other system settings.

2.7.4.3 Members who exchange weather radar observational data shall provide the associated non-real-time metadata to the WMO Radar Database.

Note: Members are strongly urged to provide non-real-time metadata to the WMO Radar Database for all of their weather radars, including those from which observational data are not exchanged.

2.7.5 Incident management

Note: The *Manual on the WMO Integrated Global Observing System* (WMO-No. 1160), section 2.4.5, contains provisions for Members in relation to the management of incidents that interrupt the normal operation of their observing systems by reducing availability or quality of observational data.

2.7.5.1 Members who exchange weather radar observational data shall report any major incidents they detect to international recipients of observational data, and shall state when such incidents have been resolved, in accordance with the incident management systems under WIGOS.

Notes:

1. Some incidents, such as those related to internal factors may be detected automatically and reported without delay to international recipients of observational data. Other incidents may be detected with delay or through periodic checks and reported accordingly. Automatic detection is facilitated through the use of built-in test equipment and/or external monitoring systems.
2. As stated in the *Manual on the WMO Integrated Global Observing System* (WMO-No. 1160), section 2.4.5.2, it is important to take corrective action in response to incidents, including analysis and recording of the event, as soon as possible.

2.7.5.2 Members who exchange weather radar observations should provide incident information within the metadata that they report in real time.

Note: A standard WMO data format is under development. It will ensure that incident information allows identification of observational data that have been adversely impacted, and also any additional quality control that has been applied to the observational data as a result of the incident. This will enhance incident awareness and management.

2.7.6 Change management

2.7.6.1 Members should carefully plan changes to weather radars and systems to avoid or minimize impact on observational data availability and quality.

Note: An important aspect of such planning is the definition of clear roles and responsibilities for each given change.

2.7.6.2 When making changes to weather radar systems and networks, Members should notify both national and international stakeholders and observational data users in advance, record and document such changes and update relevant metadata records.

Notes:

1. These notifications include information on the expected impacts and the time period over which the change will take place and, importantly, when the period of change is complete. A future standard mechanism and format for such notifications will be useful.

2. The record of changes includes the nature and characteristics of the change, the date and time of implementation and the reason for making the change.
3. The relevant metadata includes both national and international metadata records pertaining to the observing system and site.

2.7.7 **Maintenance**

Note: The *Manual on the WMO Integrated Global Observing System* (WMO-No. 1160), section 2.4.7, contains provisions for Members in relation to the maintenance of all observing systems, including weather radars, and the *Guide to Meteorological Instruments and Methods of Observation* (WMO-No. 8), Part II, Chapter 7, section 7.7.1, provides guidance on weather radar maintenance.

2.7.7.1 **Members who operate weather radars shall develop, implement and document policies and procedures for routine maintenance of the weather radar system.**

Note: Such policies and procedures will ensure that requirements and standards for operational performance and observational data quality are met.

2.7.7.2 **With regard to preventive maintenance activities, Members shall pay attention to all components of the complete weather radar system, taking into account the manufacturer's guidelines.**

2.7.7.3 **Members shall perform responsive maintenance as soon as practically possible after an issue with their weather radar system(s) has been detected.**

Note: Typically, it is through monitoring or incident management that an issue is detected and responsive maintenance is triggered. The assessment of what is practically possible may take into account the severity of the issue.

2.7.7.4 **Members who operate weather radars should, where appropriate, implement and perform maintenance tasks remotely.**

Note: Remote maintenance cannot replace on-site maintenance for many tasks, but the ability to perform some tasks remotely can contribute to preventive maintenance practices thus helping to achieve higher overall system uptime and quality of operation.

2.7.7.5 **Members who operate weather radars should maintain their sites to minimize the effect of external factors (for example, blockage by vegetation) on the radar system.**

2.7.7.6 **Members shall ensure that they have enough competent staff to meet all maintenance requirements and responsibilities.**

2.7.7.7 **Members who exchange weather radar observational data shall record and report details of corrective and preventive maintenance completed in accordance with the WIGOS metadata standard.**

Notes:

1. The requirements to retain and make available metadata are laid out in the *Manual on the WMO Integrated Global Observing System* (WMO-No. 1160), section 2.5 and Appendix 2.4, and the specification of the WIGOS metadata standard can be found in *The WIGOS Metadata Standard* (WMO-No. 1192), with further elaboration in *the Guide to the WMO Integrated Global Observing System* (WMO-No. 1165).
2. Any planned or responsive maintenance that has reduced or is expected to reduce the normal availability or quality of weather radar observational data is to be treated in the same manner as an incident, by following provisions 2.7.5.1 and 2.7.5.2.

2.7.8 **Inspection and supervision**

2.7.8.1 **Members shall define and establish roles and responsibilities for inspection and supervision of their weather radars.**

Notes:

1. The objective of inspection and supervision is to determine whether the weather radar system is functioning correctly (within performance tolerances) and, if not, to understand the deviations and initiate a response.
2. Remote monitoring and diagnostic systems can significantly increase the effectiveness of inspection and supervision activities.

2.7.8.2 Members who exchange weather radar observational data shall record and report inspection results in accordance with the WIGOS metadata standard.

2.7.9 Calibration procedures

Note: The *Guide to Meteorological Instruments and Methods of Observation* (WMO-No. 8), Part II, Chapter 7, section 7.7.2, provides guidance on weather radar calibration.

2.7.9.1 Members shall define and establish roles and responsibilities for the calibration of their weather radar systems, taking into consideration the manufacturer's guidelines.

Note: The objective of calibration is to constrain weather radar systems to operate within the performance tolerances given by the supplier and to meet defined user requirements. The *Guide to Meteorological Instruments and Methods of Observation* (WMO-No. 8), Part II, Chapter 7, Table 7.4, contains indicative accuracy requirements.

2.7.9.2 Members shall ensure that they have enough competent staff to meet all calibration requirements and responsibilities.

2.7.9.3 Members who exchange weather radar observational data shall record and report details of calibrations in accordance with the WIGOS metadata standard.

Notes:

1. Relevant details include calibration variables and their settings or levels, and the terms of the weather radar equation along with the calibration constant.
2. Calibrations shall be reported with the observational data to which they apply, in accordance with provision 2.7.4.2 above.
3. Any calibration activity which has reduced or is expected to reduce the normal availability or quality of weather radar observational data is to be treated in the same manner as an incident, by following provisions 2.7.5.1 and 2.7.5.2 above.

2.8 Aeronautical meteorological stations

General

2.8.1 Members should establish an adequate network of aeronautical meteorological stations to meet the requirements of aviation.

Note: Detailed information on aeronautical meteorological stations, observations and reports is given in the *Technical Regulations* (WMO-No. 49), Volume II, Part I, 4.

2.8.2 The data relating to the elevation of an aeronautical meteorological station on land shall be specified in whole metres.

Note: The WIGOS station identifier of an aeronautical meteorological station on land may follow the convention of 2.3.2.1 above.

2.8.3 If a change of index number of an aeronautical meteorological station on land, the reports of which are included in international exchanges, is necessary, such change should be made effective on 1 January or 1 July.

Location and composition

2.8.4 Aeronautical meteorological stations shall be established at aerodromes and other points of significance for international air navigation.

2.8.5 Aeronautical observations should consist of the following meteorological elements:

- (a) Surface wind direction and speed;
- (b) Visibility;
- (c) Runway visual range, when applicable;
- (d) Present weather;
- (e) Cloud amount, type and height of base;
- (f) Air temperature;
- (g) Dew point temperature;
- (h) Atmosphere pressure (QNH and/or QFE);
- (i) Supplementary information.

Note: For further information on what is to be reported under “supplementary information”, see the *Technical Regulations* (WMO-No. 49), Volume II, Part I, 4.6.8.

Frequency and timing of observations

2.8.6 Routine observations shall be made at intervals of one hour or, if so determined by regional air navigation agreement, at intervals of one half-hour. Special observations shall be made in accordance with criteria established by the Meteorological Authority in consultation with the appropriate Air Traffic Services Authority.

2.9 Research and special-purpose vessel stations

General

2.9.1 Members operating research and special-purpose vessels should do their utmost to ensure that all such vessels make meteorological observations.

Location and composition

2.9.2 In addition to as many as possible of the meteorological elements of surface and upper-air observations, subsurface temperature observations, down to the thermocline, should also be made and transmitted (in real time), in accordance with the procedures agreed between WMO and the Intergovernmental Oceanographic Commission of the United Nations Educational, Scientific and Cultural Organization.

Frequency and timing of observations

2.9.3 In addition to meeting requirements for research, special-purpose vessels should, when possible, make surface and upper-air observations that meet and supplement basic synoptic requirements.

2.10 Climatological stations

General

2.10.1 Each Member shall establish in its territory a network of climatological stations.

2.10.2 The network of climatological stations should give a satisfactory representation of the climate characteristics of all types of terrain in the territory of the Member concerned (for example, plains, mountainous regions, plateaux, coasts and islands).

2.10.3 Each Member shall establish and maintain at least one reference climatological station.

2.10.4 Each Member shall establish and maintain an up-to-date directory of the climatological stations in its territory, giving the standard metadata specified in the *Manual on the WMO Integrated Global Observing System* (WMO-No. 1160), including at least the following information for each station:

- (a) Name and geographical coordinates;
- (b) Elevation;
- (c) A brief description of the local topography;
- (d) Category of station and details of observing programmes;
- (e) Exposure of instruments, including height above ground of thermometers, raingauges and anemometers;
- (f) A station history (date of beginning of records, changes of site, closure or interruption of records, changes in the name of the station and important changes in the observing programme);
- (g) The name of the supervising organization or institution;
- (h) The datum level to which atmospheric pressure data of the station refer.

2.10.5 The data relating to the elevation of a climatological station should be specified to the nearest metre.

Note: Information on the accurate specification of the geographical coordinates and elevation of a station is provided in the *Guide to Meteorological Instruments and Methods of Observation* (WMO-No. 8), Part I, Chapter 1, section 1.3.3.2.

Location and composition

2.10.6 Each climatological station should be located and set up so that it will be able to operate continually for at least 10 years, and so that the exposure will remain unchanged over a long period, unless it serves a special purpose that justifies its functioning for a shorter period.

2.10.7 Each reference climatological station should have adequate and unchanging exposure that allows observations to be made in representative conditions. The surroundings of the station should not alter over time to such an extent that they affect the homogeneity of the series of observations.

2.10.8 At a principal climatological station, observations shall be made of all or most of the following meteorological elements, where appropriate:

- (a) Weather;

- (b) **Wind direction and speed;**
- (c) **Cloud amount;**
- (d) **Type of cloud;**
- (e) **Height of cloud base;**
- (f) **Visibility;**
- (g) **Air temperature (including extreme temperatures);**
- (h) **Humidity;**
- (i) **Atmospheric pressure;**
- (j) **Precipitation amount;**
- (k) **Snow cover and/or snow depth;**
- (l) **Sunshine duration and/or solar radiation;**
- (m) **Soil temperature.**

2.10.9 At a principal climatological station, soil temperature should be measured at some or all of the following depths: 5, 10, 20, 50, 100, 150 and 300 cm.

2.10.10 **At an ordinary climatological station, observations shall be made of extreme temperatures and amount of precipitation and, if possible, of some of the other meteorological elements listed under 2.10.8 above.**

2.10.11 At an automatic climatological station, records should be made of meteorological elements selected from those under 2.10.8 above.

Frequency and timing of observations

2.10.12 Each Member should arrange for observations at all climatological stations to be made at fixed times, according to either UTC or Local Mean Time, which remain unchanged throughout the year.

2.10.13 When two or more observations are made at a climatological station, they should be made at times that reflect the significant diurnal variations of the climatic meteorological elements.

2.10.14 When changes are made to the times of climatological observations in a network, simultaneous observations should be carried out at a skeleton network of representative stations at the old times of observation and at the new ones, for a period covering the major climatic seasons of the area.

2.11 Global Climate Observing System Surface Network stations

In implementing the observing programme at GCOS Surface Network (GSN) stations, Members should adhere to the GCOS Climate Monitoring Principles adopted by Resolution 9 (Cg-XIV). In particular, they should comply with the following best practices:

- (a) Long-term continuity should be provided for each GSN station: this requires resources, including well-trained staff, and minimal changes in location. Any significant changes in instrumentation or station location should be managed so as to avoid the introduction

- of inhomogeneities into the measurement record. This may require that old and new instruments be operated simultaneously for a sufficient period of overlap (at least one, but preferably two years) to enable systematic biases between old and new measurement systems to be derived;
- (b) CLIMAT data should be accurate and provided in a timely manner: CLIMAT reports should be transmitted by the fifth day of the month (and no later than the eighth day of the month);
 - (c) Rigorous quality control of the measurements and their message encoding should be exercised: CLIMAT reports require quality control not only of the measurements themselves, but also of their message encoding to ensure their accurate transmission to national, regional and world centres. Quality-control checks should be made on site and at a central facility designed to detect equipment faults at the earliest stage possible. The *Guide to Meteorological Instruments and Methods of Observation* (WMO-No. 8), Part IV, Chapter 3, provides the appropriate recommendations;
 - (d) The site layout should follow the recommendations in the *Guide to the Global Observing System* (WMO-No. 488);
 - (e) The site and instruments should be inspected regularly and maintained according to WMO recommended practices. To obtain homogeneous datasets, maintenance should be carried out as documented in the *Guide to Meteorological Instruments and Methods of Observation* (WMO-No. 8);
 - (f) A national plan should be developed to archive daily data from GSN stations for climate and climate research purposes: the archive should include both observations and observational metadata pertaining to each climate station, as specified in the *Manual on the WMO Integrated Global Observing System* (WMO-No. 1160);
 - (g) Detailed metadata and historical climate data for each GSN station should be provided: a GSN Data Centre should have an up-to-date digital copy of the historical climate data and all types of metadata for GSN stations. A current copy of the long-term series of data and metadata from GSN stations should be made available.

2.12 **Global Climate Observing System upper-air stations**

2.12.1 **Global Climate Observing System Upper-air Network stations**

In implementing observing programmes at GCOS Upper-air Network (GUAN) stations, Members should adhere to the GCOS Climate Monitoring Principles adopted by Resolution 9 (Cg-XIV). In particular, they should comply with the following best practices:

- (a) Long-term continuity should be ensured at each GUAN station: this requires resources, including well-trained staff, and minimal changes in location. Changes in instrumentation must be managed in such a way that no systematic bias is introduced into the measurement time series. This may be accomplished by ensuring a sufficient period of overlap, with observations being made using both old and new measurement systems (perhaps as much as a year), or by making use of the results of instrument intercomparisons made at designated test sites;
- (b) Soundings should preferably be made at least twice per day and should reach as high as possible, noting the GCOS requirements for ascents up to a minimum height of 30 hPa. Since climate data are needed in the stratosphere to monitor changes in the atmospheric circulation and to study the interaction between stratospheric circulation, composition and chemistry, every effort should be made to maintain soundings regularly up to a level as high as 5 hPa where feasible, noting the above GCOS requirements;

- (c) Rigorous quality control should be exercised at each GUAN site: periodic calibration, validation and maintenance of the equipment should be carried out to maintain the quality of the observations;
- (d) Basic checks should be made before each sounding to ensure accurate data: the accuracy of a radiosonde's sensors should be checked in a controlled environment immediately before the flight. Checks should also be made during and/or at the end of each sounding to ensure that incomplete soundings or soundings containing errors are corrected before transmission;
- (e) Back-up radiosondes should be released in cases of failure: in the event of failure of a sounding instrument or incomplete sounding resulting from difficult weather conditions, a second release should be made to maintain the record from the GUAN station;
- (f) Detailed metadata for each GUAN station should be provided: the batch identifier on the radiosondes should be logged for each flight, so that faulty batches can be identified and the data amended or eliminated from the climate records, if necessary. Up-to-date records of metadata in a standard format should be provided to the GUAN Data Centre. Both the corrected and uncorrected upper-air observation should be archived. Climate change studies require extremely high stability in the systematic errors of the radiosonde measurements;
- (g) To achieve suitable global coverage, Members should consider operating stations outside of national boundaries.

2.12.2 ***Global Climate Observing System Reference Upper-air Network stations***

Observing programmes contributing to the GCOS Reference Upper-air Network (GRUAN) must undergo the GRUAN site assessment and certification process. In particular, GRUAN sites shall comply with the following best practices:

- (a) To ensure that GRUAN measurements meet their design criteria and serve the needs of the climate-monitoring community, long-term continuity of measurement series should be ensured at each GRUAN site: this requires resources including well-trained staff, long-term funding and support for replacement of aging measurement systems;
- (b) Robust change management protocols shall be implemented to ensure the long-term homogeneity of the measurement series at GRUAN sites. Changes to measurement systems shall not be made without advanced notification to the GRUAN Lead Centre;
- (c) Sufficient raw data and metadata shall be collected at contributing sites to permit the processing of measurements, at a centralized processing facility, into a reference measurement. This requires, at least, that the uncertainty of the measurement (including corrections) has been determined, the entire measurement procedure and set of processing algorithms are properly documented and accessible, and that every effort has been made to tie the observations to an internationally accepted traceable standard. Sufficient metadata must also be collected and archived to allow reprocessing of the data at any future date;
- (d) In addition to ensuring long-term homogeneity of measurement series at each site within the network, sites shall also be operated in such a way that homogeneity of measurements across the network will ensure that significant site-specific differences between GRUAN data and co-located measurements do not result from the GRUAN data products;
- (e) GRUAN sites shall perform regular traceable pre-launch ground checks for balloon-borne systems and record the results. Other instruments that provide vertical profiles extending from the surface require regular checks to assure correct operation;

- (f) **GRUAN sites shall provide redundant reference observations of the essential climate variables selected for measurement at the site at intervals sufficient to validate the derivation of the uncertainty in the primary measurement;**
- (g) **To achieve suitable global coverage, Members should consider operating stations outside of national boundaries.**

Note: The mandatory practices required of GRUAN sites, as detailed in the *GCOS Reference Upper-Air Network (GRUAN) Manual* (GCOS-170, WIGOS Technical Report No. 2013-02), reflect GRUAN's primary goal of providing reference-quality observations of the atmospheric column while accommodating the diverse capabilities of sites within the network. However, certification of measurement programmes at a GRUAN site goes beyond considering the extent to which the site adheres to the mandatory practices outlined in the GRUAN Manual and considers the added value that the site brings to the network. The added value is assessed by experts forming the Working Group on the GCOS Reference Upper-air Network, whose judgement is guided by considerations 8.17 to 8.26 in the GRUAN Manual. The GRUAN Manual is supplemented by a more detailed *GCOS Reference Upper-Air Network (GRUAN) Guide* (GCOS-171, WIGOS Technical Report No. 2013-03) which provides guidelines on how the protocols detailed in the GRUAN Manual might be achieved, and by a series of technical documents available from the GRUAN website at <http://www.gruan.org>.

2.13 **Agricultural meteorological stations**

General

2.13.1 Each Member should establish in its territory a network of agricultural meteorological stations.

2.13.2 The density of the network of each category of agricultural meteorological station should permit the delineation of weather parameters on the scale required for agrometeorological planning and operation, taking into account the agricultural features of the country.

2.13.3 Each Member should maintain an up-to-date directory of the agricultural meteorological stations in its territory, giving the standard metadata specified in the *Manual on the WMO Integrated Global Observing System* (WMO-No. 1160), including at least the following information for each station:

- (a) Name and geographical coordinates;
- (b) Elevation;
- (c) Brief description of the local topography;
- (d) Natural biomass, main agrosystems and crops of the area;
- (e) Types of soil, physical constants and profile of soil;
- (f) Category of station, details of observing programme and reporting schedule;
- (g) Exposure of instruments, including height above ground of thermometers, raingauges and anemometers;
- (h) Station history (date of beginning of records, changes of site, closure or interruption of records, changes in the name of the station and important changes in the observing programme);
- (i) Name of the supervising organization or institution.

Location and composition

2.13.4 Each agricultural meteorological station should be located at a place that is representative of agricultural and natural conditions in the area concerned, preferably:

- (a) At experimental stations or research institutes for agriculture, horticulture, animal husbandry, forestry, hydrobiology and soil sciences;
- (b) At agricultural and allied colleges;
- (c) In areas of present or future importance for agricultural and animal husbandry;
- (d) In forest areas;
- (e) In national parks and reserves.

2.13.5 At an agricultural meteorological station, the observing programme should, in addition to the standard climatological observations, include some or all of the following:

- (a) Observations of physical environment:
 - (i) Temperature and humidity of the air at different levels in the layer adjacent to the ground (from ground level up to about 10 metres above the upper limit of prevailing vegetation), including extreme values of these meteorological elements;
 - (ii) Soil temperature at depths of 5, 10, 20, 50 and 100 cm and at additional depths for special purposes and in forest areas;
 - (iii) Soil water (volumetric content) at various depths, with at least three replications when the gravimetric method is used;
 - (iv) Turbulence and mixing of air in the lower layer (including wind measurements at different levels);
 - (v) Hydrometeors and water-balance components (including hail, dew, fog, evaporation from soil and from open water, transpiration from crops or plants, rainfall interception, runoff and water table);
 - (vi) Sunshine, global and net radiation as well as the radiation balance over natural vegetation, and crops and soils (over 24 hours);
 - (vii) Observations of weather conditions causing direct damage to crops, such as frost, hail, drought, floods, gales and extremely hot, dry winds;
 - (viii) Observations of damage caused by sandstorms and duststorms, atmospheric pollution and acid deposition as well as forest, bush and grassland fires;
- (b) Observations of a biological nature:
 - (i) Phenological observations;
 - (ii) Observations on growth (as required for the establishment of bioclimatic relationships);
 - (iii) Observations on qualitative and quantitative yield of plant and animal products;
 - (iv) Observations of direct weather damage on crops and animals (adverse effects of frost, hail, drought, floods, gales);
 - (v) Observations of damage caused by diseases and pests;

- (vi) Observations of damage caused by sandstorms and duststorms and atmospheric pollution, as well as forest, bush and grassland fires.

Frequency and timing of observations

2.13.6 Observations of a physical nature should be made at the main synoptic times. Observations of a biological nature should be made regularly or as frequently as significant changes occur, and should be accompanied by meteorological observations.

2.14 **Special stations**

2.14.1 **General**

2.14.1.1 In addition to the stations discussed previously, Members should establish special stations.

Note: In some cases, these special stations are co-located with surface or upper-air stations of the RBSNs.

2.14.1.2 Members should cooperate in the establishment of special stations for particular purposes.

2.14.1.3 **Special stations shall include:**

- (a) **Radiation stations;**
- (b) **Other remote-sensing profiler stations;**
- (c) **Lightning location stations;**
- (d) **Meteorological reconnaissance aircraft stations;**
- (e) **Global Atmosphere Watch stations;**
- (f) **Planetary boundary-layer stations;**
- (g) **Tide-gauge stations.**

2.14.2 **Radiation stations**

General

2.14.2.1 Members should establish at least one principal radiation station in each climatic zone of their territory.

2.14.2.2 Members should maintain a network of radiation stations of sufficient density for the study of radiation climatology.

2.14.2.3 Each Member should maintain an up-to-date directory of the radiation stations in its territory, including ordinary and principal stations, giving the following information for each station:

- (a) Name and geographical coordinates in degrees and minutes of arc;
- (b) Elevation, in whole metres;
- (c) Brief description of local topography;

- (d) Category of station and details of the observing programme;
- (e) Details of radiometers in use (type and serial number of each instrument, calibration factors, dates of any significant changes);
- (f) Exposure of radiometers, including height above ground, details of the horizon of each instrument and nature of the surface of the ground;
- (g) Station history (date of beginning of records, changes of site, closure or interruption of records, changes in the name of the station and important changes in the observing programme);
- (h) Name of the supervising organization or institution.

Location and composition

2.14.2.4 Each radiation station shall be located, to the extent possible, where it can benefit from adequate exposure that permits observations to be made in representative conditions.

Note: The exposure and surroundings of the stations should not alter over time to such an extent as to affect the homogeneity of the series of observations.

2.14.2.5 At principal radiation stations, the observing programme should include:

- (a) Continuous recording of global solar radiation and sky radiation, using pyranometers of the first or second class;
- (b) Regular measurements of direct solar radiation;
- (c) Regular measurements of net radiation (radiation balance) over natural and crop soil cover (made over a 24-hour period);
- (d) Recording of duration of sunshine.

Note: The terminology of radiation qualities and measuring instruments and the classification of pyranometers are given in the *Guide to Meteorological Instruments and Methods of Observation* (WMO-No. 8), Part 1, Chapter 7.

2.14.2.6 At ordinary radiation stations, the observing programme should include:

- (a) Continuous recording of global solar radiation;
- (b) Recording of duration of sunshine.

2.14.2.7 Pyrheliometric measurements shall be expressed in accordance with the World Radiometric Reference.

Frequency and timing of observations

2.14.2.8 When automatic recording is not available, measurements of direct solar radiation should be made at least three times a day, provided the sun and the sky in the vicinity are free from cloud, corresponding to three different solar heights, one of them being near the maximum.

2.14.2.9 During clear-sky conditions, measurements of long-wave effective radiation should be made every night, one of them being made soon after the end of the evening civil twilight.

2.14.3 **Other remote-sensing profiler stations**

General

2.14.3.1 Members should consider the establishment of other remote-sensing profilers.

Note: In addition to radar wind profilers, addressed in section 2.6, a range of other remote-sensing technologies are being used to collect wind and thermal profiles of the atmosphere. The *Guide to Meteorological Instruments and Methods of Observation* (WMO-No. 8), Part II, Chapter 5, section 5.2, provides further information about acoustic sounders (sodars), radio-acoustic sounding systems, microwave radiometers, laser radars (lidars) and the Global Navigation Satellite System. Doppler weather radars may also be used to derive wind profiles.

Location

2.14.3.2 The location and spacing of stations should be consistent with the requirements for the observations.

2.14.4 **Lightning location stations**

General

2.14.4.1 Members should consider acquiring observations from lightning location systems.

Note: A detailed description of methods in use is provided in the *Guide to Meteorological Instruments and Methods of Observation* (WMO-No. 8), Part II, Chapter 6. A surface-based sensor at a single station can detect the occurrence of lightning, but cannot be used to locate it on an individual flash basis. A network of stations is needed for accurate lightning location.

Location and composition

2.14.4.2 The spacing and number of stations should be consistent with the technique used and the desired coverage, detection efficiency and accuracy of location.

Frequency and timing of observations

2.14.4.3 Continuous monitoring by the station should be maintained.

2.14.5 **Meteorological reconnaissance aircraft stations**

General

2.14.5.1 Members are encouraged to organize and communicate, either individually or jointly, routine and special aircraft weather reconnaissance flights.

Location and composition

2.14.5.2 Aircraft reconnaissance facilities should be located near prevalent storm tracks in data-sparse areas. Reconnaissance flights should be initiated in locations where additional observational information is required for the investigation and prediction of developing or threatening storms.

2.14.5.3 Meteorological reconnaissance flight observations should include:

(a) Altitude and position of aircraft;

- (b) Observations made at frequent intervals during a horizontal flight at low level;
- (c) Observations made during flights at higher levels, as near as possible to standard isobaric surfaces;
- (d) Vertical soundings, either by aircraft or by dropsonde.

2.14.5.4 The meteorological elements to be observed during meteorological reconnaissance flights should include:

- (a) Atmospheric pressure at which the aircraft is flying;
- (b) Air temperature;
- (c) Humidity;
- (d) Wind (type of wind, wind direction and speed);
- (e) Present and past weather;
- (f) Turbulence;
- (g) Flight conditions (cloud amount);
- (h) Significant weather changes;
- (i) Icing and contrails.

Notes:

1. For detailed guidance regarding observations made during meteorological reconnaissance flights, see the *Guide to Meteorological Instruments and Methods of Observation* (WMO-No. 8).
2. Type of wind refers to how the wind was determined and whether it was a mean or a spot wind.

Frequency and timing of observations

2.14.5.5 Reconnaissance flights should be scheduled in response to requirements for data from data-sparse areas, or in response to special phenomena.

2.14.5.6 Flight times and frequency should be selected so that reconnaissance information supplements upper-air information.

2.14.6 **Global Atmosphere Watch stations**

Note: Technical regulations relating to the observing component of the Global Atmosphere Watch (GAW) are contained in the *Technical Regulations* (WMO-No. 49), Volume I, Part I, and in the *Manual on the WMO Integrated Global Observing System* (WMO-No. 1160). Further information on GAW stations is contained in the GAW Station Information System at <http://gaw.empa.ch/gawsis/> as well as the appropriate GAW technical publications, and in the *Guide to the Global Observing System* (WMO-No. 488).

2.14.7 **Planetary boundary-layer stations**

General

2.14.7.1 Members should establish an adequate network of stations for making measurements in the planetary boundary layer.

Location and composition

2.14.7.2 Members should, whenever possible, provide a capability to obtain detailed knowledge of the profiles of temperature, humidity, pressure and wind in the lowest 1 500 m of the atmosphere.

Notes:

1. This information is required in the study of diffusion of atmospheric pollution, the transmission of electromagnetic signals, the relation between free-air variables and boundary-layer variables, severe storms, cloud physics, convective dynamics, etc.
2. The required accuracy and height intervals of measurements of several variables depend upon the nature of the problems under study.
3. Some of the vertical and horizontal sounding systems which could be applied to specific problems for limited periods in a variety of locations are described in the *Guide to the Global Observing System* (WMO-No. 488).

2.14.8 **Tide-gauge stations**

General

2.14.8.1 Members should establish an adequate network of tide-gauge stations along coasts subject to storm surges.

Location and composition

2.14.8.2 Gauges should be placed in a manner that allows determination of the full range of water heights.

Frequency and timing of observations

2.14.8.3 Observations of tide height should be made at the main synoptic times: 0000, 0600, 1200 and 1800 UTC. In coastal storm situations, hourly observations should be made.

3. **EQUIPMENT AND METHODS OF OBSERVATION**

Note: The *Guide to Meteorological Instruments and Methods of Observation* (WMO-No. 8) is the authoritative reference for all matters related to methods of observations. It should be consulted for more detailed descriptions.

3.1 **General requirements for meteorological stations**

3.1.1 **All stations shall be equipped with properly calibrated instruments to allow for observations and measurements to be made using sufficiently advanced techniques so that the measurements and observations of the various meteorological elements are accurate enough to meet the needs of synoptic meteorology, aeronautical meteorology, climatology and other meteorological disciplines.**

Note: For detailed guidance on instruments and methods of observation, see the *Guide to Meteorological Instruments and Methods of Observation* (WMO-No. 8) and *Weather Reporting* (WMO-No. 9), Volume D – Information for Shipping.

3.1.2 **To satisfy data requirements, primary data from surface-based instruments and observing systems shall be converted into meteorological variables.**

3.1.3 **The exposure of instruments for the same type of observation at different stations shall be similar in order that observations may be compatible.**

- 3.1.4 **A reference height shall be established at each meteorological station.**
- 3.1.5 **In order to ensure maintenance of a high standard of observations and the correct functioning of instruments, stations shall be inspected periodically.**
- 3.1.6 Station inspections should be carried out by experienced personnel and should ensure that:
- (a) The siting and exposure of instruments are known, recorded and acceptable;
 - (b) Instruments have approved characteristics, are in good order and regularly verified against relevant standards;
 - (c) There is uniformity in the methods of observation and in the procedure for reduction of observations;
 - (d) The observers are competent to carry out their duties.
- 3.1.7 All synoptic land stations should be inspected at least once every two years.
- 3.1.8 Agricultural meteorological and special stations should be inspected at least once every year.
- 3.1.9 Principal climatological stations should be inspected at least once every year; ordinary climatological and precipitation stations should be inspected at least once every three years. If possible, relevant inspections should occasionally be carried out during the winter season.
- 3.1.10 Automatic weather stations should be inspected at least once every two years.
- 3.1.11 At sea stations, barometers should be checked at least twice a year with reference to a standard barometer.

3.2 **General requirements for instruments**

- 3.2.1 Meteorological instruments should be reliable and accurate.

Note: It is mandatory for Members to avoid the use of mercury in their instruments or, where mercury is still in use, to obey safety precautions (see the *Manual on the WMO Integrated Global Observing System* (WMO-No. 1160), section 3.3.2.1 and the *Guide to Meteorological Instruments and Methods of Observation* (WMO-No. 8), Part I, Chapter 3, section 3.2.7).

- 3.2.2 **Instruments in operational use shall be periodically compared directly or indirectly with the relevant national standards.**
- 3.2.3 **Where automated instrument systems are employed, reference (or check) values of variables shall also be measured, taking into consideration criteria for the allowed difference between the reference and compared instruments as well as the appropriate minimum time interval between comparisons.**
- 3.2.4 At reference climatological stations, any change in instrumentation should be such as not to decrease the degree of accuracy of any observations as compared with the earlier observations, and any such change should be preceded by an adequate overlap (at least two years) of older and newer instrumentation.
- 3.2.5 Unless otherwise specified, instruments designated as regional and national standards should be compared by means of travelling standards at least once every five years.

3.2.6 In order to control effectively the standardization of meteorological instruments on a national and international scale, a system of national and regional standards, as adopted by WMO, shall be applied in the GOS.

Note: Further information is provided in the *Guide to Meteorological Instruments and Methods of Observation* (WMO-No. 8), Part I, Chapter 1.

3.3 **Surface observations**

3.3.1 **General**

3.3.1.1 Observations should be made in such a way that:

- (a) A representative temporally smoothed value of the variable can be found in the vicinity of the station;
- (b) All representative extreme values (or other indicators of dispersion) can be determined, if required;
- (c) All synoptic-scale discontinuities (such as fronts) can be identified as soon as possible after an observation is made.

3.3.1.2 To satisfy these requirements, observational methods should be selected so as to achieve:

- (a) Suitable temporal and/or spatial samples of each variable;
- (b) A justifiable accuracy for the measurement of each variable;
- (c) A representative observation height above the ground.

3.3.1.3 To avoid the effect of small-scale fluctuations, the meteorological variable should be sampled continuously or repeatedly over a suitable time in order to obtain both representative mean and extreme values. Alternatively, instruments with a suitable lag or damping effect should be used to eliminate or substantially reduce high-frequency noise.

3.3.1.4 The averaging time should be short compared with the temporal scale of such discontinuities as fronts or squall lines, which usually delineate air masses with different characteristics whilst removing the effects of small-scale disturbance. For example, for synoptic purposes, an average taken over 1 to 10 minutes will suffice for the measurement of atmospheric pressure, air temperature, humidity, wind, sea-surface temperature and visibility.

3.3.1.5 **Instrumental readings shall be corrected and reduced as appropriate.**

3.3.2 **Atmospheric pressure**

3.3.2.1 **Barometric readings shall be reduced from local acceleration of gravity to standard (normal) gravity. The value of standard (normal) gravity (gn) shall be regarded as a conventional constant:**

$$g_n = 9.806\ 65\ \text{m s}^{-2}$$

3.3.2.2 **The hectopascal (hPa), equal to 100 pascals (Pa), shall be the unit in which pressures are reported for meteorological purposes.**

Note: One hPa is physically equivalent to one millibar (mb) and thus no changes are required to scales or graduations made in mb in order to read them in hPa.

3.3.2.3 **Atmospheric pressure shall be determined by a suitable pressure measuring device. The uncertainty of such a device is specified in the *Guide to Meteorological Instruments and Methods of Observation* (WMO-No. 8), Part I, Chapter 1, Annex 1.E.**

3.3.2.4 In order for mercury barometer readings made at different times and at different places to be comparable, the following corrections should be made:

- (a) Correction for index error;
- (b) Correction for gravity;
- (c) Correction for temperature.

Note: It is mandatory for Members to avoid the use of mercury in their instruments or, where mercury is still in use, to obey safety precautions (see the *Manual on the WMO Integrated Global Observing System* (WMO-No. 1160), section 3.3.2.1 and the *Guide to Meteorological Instruments and Methods of Observation* (WMO-No. 8), Part I, Chapter 3, section 3.2.7).

3.3.2.5 **Whenever it is necessary to compute the theoretical local value of the acceleration due to gravity, each Member shall follow the procedure given in the *Guide to Meteorological Instruments and Methods of Observation* (WMO-No. 8), Part I, Chapter 3, Annex 3.A.**

3.3.2.6 **Atmospheric pressure at a station shall be reduced to mean sea level, except at those stations where regional association resolutions prescribe otherwise.**

3.3.2.7 **The results of comparisons of national and regional reference standard barometers shall be reported to the Secretariat for communication to all Members concerned.**

3.3.2.8 **Regional comparisons of national standard barometers with a regional standard barometer shall be arranged at least once every 10 years.**

3.3.2.9 Reference standards for comparison purposes may be provided by a suitable pressure measuring device that, generally, **shall be of the highest metrological quality available at a given location (or in a given organization), and to which measurements made there are traceable.**

3.3.2.10 In calibration against a standard barometer whose index errors are known and allowed for, tolerances for a station barometer stated in the *Guide to Meteorological Instruments and Methods of Observation* (WMO-No. 8), Part I, Chapter 3, should not be exceeded.

3.3.3 ***Air temperature***

3.3.3.1 **One of the following three main types of thermometer shall be used:**

- (a) Liquid-in-glass thermometer;
- (b) Resistance thermometer;
- (c) Thermocouples.

All temperature shall be reported in degrees Celsius.

3.3.3.2 An instrument height of between 1.25 and 2.0 m above ground is considered satisfactory to obtain representative air temperature measurements.

Note: At a station where considerable snow cover may occur, a greater height is permissible or, alternatively, a moveable support can be used allowing the thermometer housing to be raised or lowered in order to maintain the correct height above the snow surface.

3.3.3.3 Thermometer screens should be constructed to minimize radiation effects and at the same time allow free influx and circulation of air.

3.3.3.4 Thermometers should be checked against a reference standard instrument every two years.

Note: The required uncertainties are given in the *Guide to Meteorological Instruments and Methods of Observation*, Part I, Chapter 1, Annex 1.E.

3.3.3.5 **For psychrometric purposes, thermometers shall be read to at least 0.1 °C.**

3.3.4 **Humidity**

Note: Definitions and specifications of water vapour in the atmosphere are given in the *Guide to Meteorological Instruments and Methods of Observation* (WMO-No. 8), Part I, Chapter 4, Annex 4.A.

3.3.4.1 In surface observations, at temperatures above 0 °C, values of humidity should be derived from the readings of a psychrometer or other instrument of equal or better accuracy.

3.3.4.2 If forced ventilation of psychrometers is used, the airflow past the thermometer bulbs should be between 2.5 m s⁻¹ and 10 m s⁻¹.

3.3.4.3 **In surface observations, the height requirements for humidity measurements shall be the same as for air temperature measurements.**

3.3.5 **Surface wind**

3.3.5.1 **The exposure of wind instruments over level, open terrain shall be 10 metres above the ground.**

Note: Open terrain is defined as an area where the distance between the anemometer and any obstruction is at least 10 times, but preferably 20 times, the height of the obstruction.

3.3.5.2 At aeronautical stations the wind sensors should be exposed to provide measurements representative of conditions 6 to 10 metres above the runway at the average take-off and touch-down points.

3.3.5.3 Wind speed should be measured to the nearest unit (metres per second, kilometres per hour or knots), and should represent, for synoptic reports, an average over 10 minutes or, if the wind changes significantly in the 10-minute period, an average over the period after the change.

Note: In observations used at an aerodrome for aircraft taking off and landing, the averaging period is two minutes and the speed is reported in metres per second, kilometres per hour or knots (with an indication of the unit used).

3.3.5.4 Wind direction should be measured in degrees and reported to the nearest 10 degrees and should represent a scalar average over 10 minutes or, if the wind changes significantly in the 10-minute period, an average over the period after the change.

3.3.5.5 "Calm" should be indicated when the average wind speed is less than 0.5 m s⁻¹. The direction is not measured for synoptic purposes in this case.

3.3.5.6 In the absence of an anemometer, the wind speed may be estimated using the Beaufort scale.

Note: The Beaufort scale is given in the *Guide to Meteorological Instruments and Methods of Observation* (WMO-No. 8), Part I, Chapter 5.

3.3.5.7 At sea stations, in the absence of an appropriate instrument, the wind speed may be estimated by reference to the Beaufort scale and the wind direction by observing the motion of sea waves.

3.3.6 **Clouds**

3.3.6.1 For all cloud observations, the tables of classification, definitions and descriptions of general species and varieties of clouds as given in the *International Cloud Atlas – Manual on the Observation of Clouds and other Meteors* (WMO-No. 407) (Annex I to the *Technical Regulations* (WMO-No. 49)), shall be used.

3.3.6.2 Height of cloud base should preferably be determined by measurement.

3.3.7 **Weather**

Note: See the *Guide to Meteorological Instruments and Methods of Observation* (WMO-No. 8), Part I, Chapter 14, section 14.2.

3.3.8 **Precipitation**

3.3.8.1 The amount of precipitation shall be the sum of the amounts of liquid precipitation and the liquid equivalent of solid precipitation.

3.3.8.2 Daily amounts of precipitation should be measured to the nearest 0.2 mm and, if feasible, to the nearest 0.1 mm. Daily measurements of precipitation should be made at fixed times.

3.3.8.3 The design and exposure of a raingauge should be such as to minimize the effects of wind, evaporation and splashing, these being the most frequent sources of error.

Note: In general, objects should not be closer to the gauge than a distance twice their height above the gauge orifice.

3.3.9 **Sea-surface temperature**

The method used at manned sea stations for measuring sea-surface temperature shall be entered in the relevant meteorological logbook.

3.3.10 **Waves**

When separate wave systems are clearly distinguishable, each of them should be recorded.

3.3.11 **Radiation**

The comparison of radiation instruments on a regional or a global level should be performed at least once every five years. The calibration of radiation instruments should be checked and these should be recalibrated, if necessary, at least once a year against existing standards.

Note: For details of calibration of radiation sensors, refer to the *Guide to Meteorological Instruments and Methods of Observation* (WMO-No. 8), Part I, Chapter 7.

3.3.12 **Soil temperature**

3.3.12.1 Measurements should be made to detect diurnal variations of soil temperature at depths of 5, 10, 20 and, in some cases, 50 cm.

3.3.12.2 Soil surface temperature measurements are recommended for special purposes.

3.3.13 **Soil moisture**

3.3.13.1 Gravimetric estimation of soil moisture should be taken as the average of at least three samples from each depth.

3.3.13.2 Gravimetric water content should be expressed as the grams of soil moisture contained in a gram of dry soil.

3.3.14 **Evapotranspiration**

Observations of evapotranspiration should be representative of the plant cover and moisture conditions of the general surroundings of the station. Separate statements of evapotranspiration from irrigated areas should be provided.

3.3.15 **Evaporation**

3.3.15.1 Evaporation should be measured by means of evaporation tanks. The design and exposure of the evaporation tanks should ensure the required comparability of observations.

3.3.15.2 Water temperature and wind run records should be taken at each observation.

3.3.15.3 The amount of evaporation should be read in millimetres.

3.3.16 **Sunshine duration**

The threshold value for bright sunshine should be 120 W m^{-2} of direct solar irradiance.

3.3.17 **Snow depth and snow cover**

The measurement and observation of snow depth and snow cover shall be made according to the description provided in the *Guide to Meteorological Instruments and Methods of Observation* (WMO-No.8), Part I.

3.4 **Upper-air observations**

3.4.1 At upper-air synoptic stations, atmospheric pressure, temperature and humidity (PTU) observations shall be made by means of a radiosonde attached to a fast-ascending free balloon.

Note: For detailed guidance on the radiosonde and balloon techniques, see the *Guide to Meteorological Instruments and Methods of Observation* (WMO-No. 8), Part I, Chapters 12 and 13.

3.4.2 Computations of upper-air observations shall be in accordance with the *Technical Regulations* (WMO-No. 49), Volume I, Part III, 1.2.1 - 1.2.3, based on the description provided in the *Guide to Meteorological Instruments and Methods of Observation* (WMO-No.8), Part I, 1, 12, particularly 12.9.1, and the relevant definitions of physical functions and values of constants given in ISO 2533.

3.4.3 At an upper-air synoptic station, upper-wind observations should be made by tracking of the fast-ascending free balloon by electronic means (such as radio theodolite, radar or NAVAID).

Note: At stations where the skies are generally clear, upper winds may be determined by optical tracking of a balloon.

3.4.4 Each upper-air station should have an appropriate manual of instructions.

3.4.5 **Each upper-air synoptic station shall promptly report any changes in the types of radiosonde and windfinding systems in operational use to the Secretariat for communication to all Members, at least on a quarterly basis.**

3.4.6 **International comparisons of widely used radiosonde types shall be made at least once every four years.**

3.4.7 New radiosonde types should be compared with sondes accepted as having the most stable and accurate performance before adoption for operational use.

3.4.8 At a meteorological reconnaissance aircraft station, electronic means (NAVAID) should be used when a vertical profile of upper winds is to be determined by means of a dropsonde.

ATTACHMENT III.1. AUTOMATIC WEATHER STATION METADATA REQUIRED FOR OPERATIONAL PURPOSES

Note: The *Manual on the WMO Integrated Global Observing System* (WMO-No. 1160) specifies the WIGOS metadata standard, defined in its Appendix 2.4 and detailed in *The WIGOS Metadata Standard* (WMO-No. 1192), for all WIGOS observations. This attachment provides further details relevant only to automatic weather stations.

A metadata database should provide detailed information to enable users to gain adequate background knowledge about the station and observational data, together with updates due to changes that occur.

Major database elements include information on the following:

- (a) Network;
- (b) Station;
- (c) Individual instrument;
- (d) Data processing;
- (e) Data handling;
- (f) Data transmission.

Station information

There is a great deal of information related to a station's location, local topography, etc. Basic station metadata include:

- (a) Station name and index number(s);
- (b) Geographical coordinates;
- (c) Elevation above mean sea level;
- (d) Types of soil, physical constants and profile of soil;
- (e) Types of vegetation and condition;
- (f) Local topography description;
- (g) Type of automatic weather station, manufacturer, model, serial number;
- (h) Observing programme of the station: parameters measured, reference time, times at which observations/measurements are made and reported;
- (i) The datum level to which atmospheric pressure data of the station refer.

Individual instrument information

Information related to sensors installed at the station, including recommended, scheduled and performed maintenance and calibration.

Metadata provided should be:

- (a) Sensor type, manufacturer, model, serial number;
- (b) Principle of operation, method of measurement/observation, type of detection system;
- (c) Performance characteristics;
- (d) Unit of measurement, measuring range;
- (e) Resolution, accuracy (uncertainty), time constant, time resolution, output averaging time;
- (f) Siting and exposure: location, shielding, height above ground (or level of depth);
- (g) Data acquisition: sampling interval, averaging interval and type;
- (h) Correction procedures;
- (i) Calibration data and time of calibration;
- (j) Preventive and corrective maintenance: recommended/scheduled maintenance and calibration procedures, including frequency, procedure description;
- (k) Results of comparison with travelling standard.

Data-processing information

For each individual meteorological element, metadata related to processing procedures include:

- (a) Measuring/observing programme: time of observations, reporting frequency, data output;
- (b) Data-processing method/procedure/algorithm;
- (c) Formula to calculate the element;
- (d) Mode of observation/measurement;
- (e) Processing interval;
- (f) Reported resolution;
- (g) Input source (instrument, element, etc.);
- (h) Constants and parameter values.

Data handling information

Metadata elements of interest include:

- (a) Quality control procedures/algorithms;
- (b) Quality control flags definition;
- (c) Constants and parameter values;
- (d) Processing and storage procedures.

Data transmission information

The transmission-related metadata of interest are:

- (a) Method of transmission;
 - (b) Data format;
 - (c) Transmission time;
 - (d) Transmission frequency.
-

PART IV. SPACE-BASED SUBSYSTEM

Note: Regulations applicable to the space-based subsystem of the GOS are contained in the *Manual on the WMO Integrated Global Observing System* (WMO-No. 1160).

PART V. QUALITY CONTROL

Note: Provisions for quality control of all WIGOS observations, including GOS observations, are contained in the *Manual on the WMO Integrated Global Observing System* (WMO-No. 1160).

For more information, please contact:

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