Manual on the Global Observing System

Volume I – Global Aspects

2010 edition

Updated in 2013

World Meteorological Organization

WMO-No. 544

Weather • Climate • Water

Manual on the Global Observing System

Volume I

(Annex V to WMO Technical Regulations)

Global Aspects

WMO-No. 544

World Meteorological Organization
Weather • Climate • Water

2010 edition
Updated in 2013

EDITORIAL NOTE

The following typographical practice has been followed: Standard practices and procedures have been printed in semi-bold roman. Recommended practices and procedures have been printed in light face roman. Notes have been printed in smaller type, light face roman, and preceded by the indication Note.

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

WMO-No. 544

Chair, Publications Board
World Meteorological Organization (WMO)
7 bis, avenue de la Paix
P.O. Box 2300
CH-1211 Geneva 2, Switzerland

Tel.: +41 (0) 22 730 84 03
Fax: +41 (0) 22 730 80 40
E-mail: publications@wmo.int

ISBN 978-92-63-10544-8

NOTE

The designations employed in WMO publications and the presentation of material in this publication do not imply the expression of any opinion whatsoever on the part of WMO concerning the legal status of any country, territory, city or area, or of its authorities, or concerning the delimitation of its frontiers or boundaries.

The mention of specific companies or products does not imply that they are endorsed or recommended by WMO in preference to others of a similar nature which are not mentioned or advertised.

PUBLICATION REVISION TRACK RECORD

Date	*Part/chapter/section*	*Purpose of amendment*	*Proposed by*	*Approved by*
May 2013	Volume I, Part IV	Revision of the text on space-based subsystem proposed by the Commission for Basic Systems at its fifteenth session in 2013 and approved by the Executive Council at its sixty-fifth session	CBS-15 Recommendation 3 (CBS-15)	EC-65 (Resolution 10 (EC-65))

CONTENTS

Page

Page

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 Seventh Congress. Since then it has undergone a number of revisions and amendments. These have been consolidated into this new revised edition approved by Resolution 8 (EC-LV).

3. The Manual is composed of Volumes I and II, which contain the regulatory material for the global and regional aspects, respectively. The regulatory material stems from recommendations of the Commission for Basic Systems (CBS) and resolutions of regional associations, as well as from decisions taken by Congress (Cg) and the Executive Council (EC).

4. Volume I of the Manual – Global Aspects – forms part of the WMO Technical Regulations and is referred to as Annex V to the WMO Technical Regulations.

5. Volume II of the Manual – Regional Aspects – does not form part of the WMO Technical Regulations.

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 on 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.

TYPES OF REGULATION

7. Volume I of the Manual comprises *standard* practices and procedures and *recommended* practices and procedures. The definitions of these two types are as follows:

The *standard* practices and procedures:
(a) Are those practices and procedures which it is necessary that Members follow or implement; and therefore
(b) Have the status of requirements in a technical resolution in respect of which Article 9 (b) of the Convention is applicable; and
(c) Are invariably distinguished by the use of the term ***shall*** in the English text and by suitable equivalent terms in the French, Russian and Spanish texts.

The *recommended* practices and procedures:
(a) Are those practices and procedures which it is desirable that Members follow or implement; and therefore
(b) Have the status of recommendations to Members to which Article 9 (b) of the Convention shall not be applied; and
(c) Are distinguished by the use of the term ***should*** in the English text (except where specifically otherwise provided by decision of Congress) and by suitable equivalent terms in the French, Russian and Spanish texts.

8. 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 the provisions of 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 Manual, 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 of the effective date of the change.

9. With regard to the *recommended* practices and procedures, Members are urged to comply with these, but it is not necessary to notify the Secretary-General of non-observance.

10. In order to clarify the status of the various regulatory material, 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.

NOTES, ATTACHMENTS (VOLUME I) AND VOLUME II

11. Certain notes are included in the Manual for explanatory purposes. They do not have the status of the annexes to the WMO Technical Regulations.

12. A number of specifications and formats of observing practices and procedures are included in the Manual. Taking into account the rapid development of observing techniques and the increasing requirements of the WWW and other WMO programmes, these specifications, etc., are given in "attachments" to the Manual and do not have the status of the annexes to the WMO Technical Regulations. This will enable the Commission for Basic Systems to update them as necessary.

13. The words "shall" and "should" in the attachments, notes and Volume II have their dictionary meanings and do not have the regulatory character mentioned in paragraph 7 above.

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 (GOS) shall be to provide, from all parts of the globe and from outer space, high-quality standardized observations of the state of the atmosphere, 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 would not be detrimental to achieving 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 (GDPFS) and the Global Telecommunication System (GTS).**

2.2 **The GOS shall be constituted as 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 coordinating 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 WMO Commission for Basic Systems (CBS) and 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, paragraph 1 (a) to (h) 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 and upper-air and aircraft meteorological stations as detailed in Part III, paragraph 1 (a) to (c) of this Manual.**

2.10 **Other elements of the GOS surface-based subsystem shall consist of aeronautical meteorological stations, climatological stations, agricultural meteorological stations, research and special-purpose vessel stations and special stations as listed in Part III, paragraph 1 (d) to (h) 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 (R&D) satellites.**

3. IMPLEMENTATION OF THE GLOBAL OBSERVING SYSTEM

3.1 All activities connected with the implementation of the GOS on the territories of individual countries should be the responsibility of the countries themselves and should, as far as possible, be met from 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 (VCP);
(b) Other bilateral or multilateral arrangements including the United Nations Development Programme (UNDP) which should be used to the maximum extent possible.

3.3 Implementation of the GOS in regions outside the territories of individual countries (e.g. 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 supply observation of data at cruising levels and during ascent and descent. 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 (within the Automated Shipboard Aerological Programme (ASAP)) 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 the 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 could become operational only after a long-term development effort. The introduction of new technology should be 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) Exploring 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

1. CLASSIFICATION OF REQUIREMENTS

Note: A classification of the scales of meteorological phenomena is given in Attachment II.1.

1.1 Global requirements

Global requirements shall refer to observational data needed by Members for a general description of large-scale and planetary-scale meteorological phenomena and processes.

1.2 Regional requirements

Regional requirements shall be related to the observations needed by two or more Members to describe in greater detail the large- and planetary-scale atmospheric phenomena, as well as to describe the smaller ones on the mesoscale and small scale as may be agreed by regional associations.

1.3 National requirements

National requirements shall be determined by each individual Member in the light of its own interests.

1.4 Application area observational requirements

Observational data requirements for specific application areas such as Global Numerical Weather Prediction, Nowcasting and Very Short Range Forecasting, etc. are defined, reviewed and updated as part of the Rolling Review of Requirements (RRR) Process as described in the *Guide to the Global Observing System* (WMO-No. 488).

1.5 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 require-ments need to be met. They are specified in Attachment II.2. 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)).

1.6 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.3.

2. PROCEDURE FOR ELABORATION OF REQUIREMENTS

2.1 The formulation of observational data requirements is a complicated process which consists of several stages. At various levels this process involves groups of end-users, regional associations, WMO technical commissions and other bodies. In order to rationalize the formulation of the observational data requirements, the following procedures (schematically shown in Figure II.1) are applied. The process is called the Rolling Review of Requirements (RRR) Process and is described in detail in the *Guide to the Global Observing System* (WMO-No. 488).

2.2 Users present to WMO Members their needs for observational data for various application areas (e.g. meteorological services for aviation, marine navigation, industry, agriculture, climate research, etc.). Meteorological data might be used in two ways: directly in the provision of meteorological services, and in the preparation of meteorological products (weather analysis and prognoses) by Global Data-processing and Forecasting System (GDPFS) centres. In the latter case, GDPFS centres are considered as users.

2.3 WMO technical commissions are responsible for the consolidation of data needs presented by Members and for the formulation, on their basis, of a statement on observational data requirements/goals (usually in the form of tables) in various WMO Programmes. This should include explanatory notes and a rationale for the

requirements/goals and, if possible, a statement on the incremental value of partially meeting these goals (in terms of accuracy, density, frequency, etc.). Often this will include a feedback process with users to ensure that enough information and understanding about users' needs are available. If a statement on requirements/goals is addressed to the World Weather Watch, and in particular to its Global Observing System, it should be presented to the Commission for Basic Systems (CBS) for consideration.

2.4 The Commission for Basic Systems:

(a) Evaluates the feasibility of stated requirements/goals. The evaluation of technical and instrumental feasibility should be conducted in collaboration with the Commission for Instruments and Methods of Observation (CIMO), the WMO body responsible for the Instruments and Methods of Observation Programme (IMOP). The evaluation process will result in the formulation (in the form of tables) of what portion of the statement of requirements/goals is feasible and can be achieved. As part of the RRR Process, a Statement of Guidance will be prepared to indicate the feasibility of achieving the stated requirements;

(b) Formulates system requirements to provide observational data to meet the requirements/goals defined by the technical commissions;

(c) Develops any amendments to the WMO regulatory and guidance publications on the basis of system requirements and submits them (in case of regulatory publications) to the Executive Council.

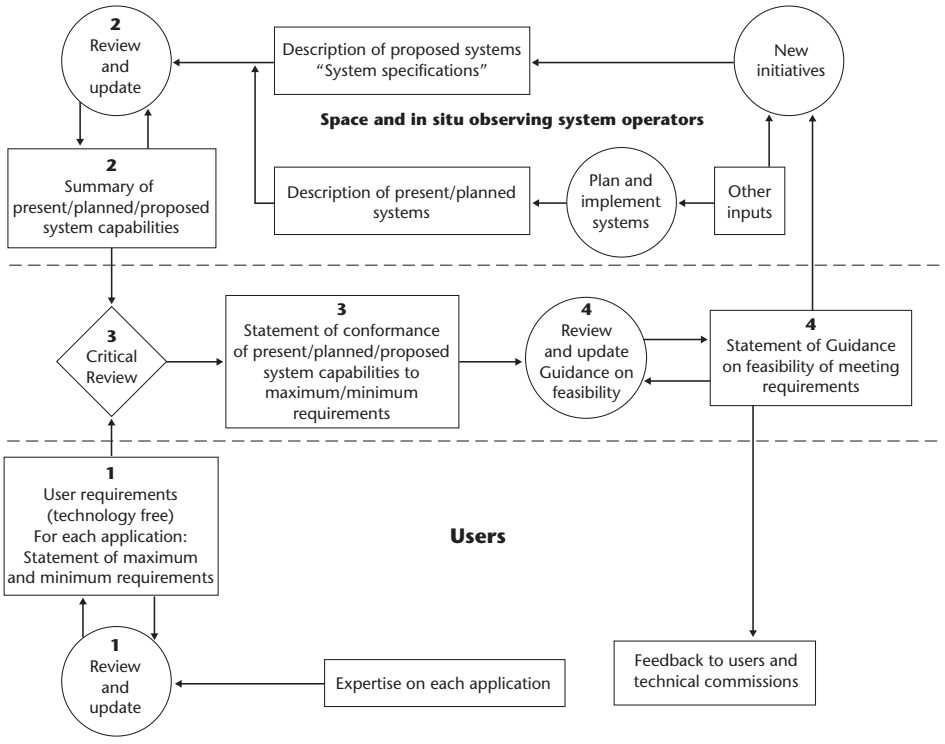
Note: The primary responsibility for the evaluation of the feasibility of meeting stated observational data requirements related to the Global Atmosphere Watch, and for the development of associated guidance material, rests with the Commission for Atmospheric Sciences.

2.5 The Executive Council approves the amendments and requests the Secretary-General to incorporate them in appropriate WMO Manuals.

2.6 The Members will be advised on the performance of observing systems and programmes through updated WMO Manuals and Guides to meet users' needs for observational data.

3. SYSTEMS FOR MEETING REQUIREMENTS

The surface-based subsystem and the space-based subsystem shall complement each other in providing the observational data required.



Note: The four stages of the Rolling Requirements Review process are 1, 2, 3 and 4.

Figure II.1. Rolling Review of Requirements Process

ATTACHMENT II.1

CLASSIFICATION OF SCALES OF METEOROLOGICAL PHENOMENA

The horizontal scales of meteorological phenomena can be classified as follows:

(a) Microscale (less than 100 m for agricultural meteorology; for example, evaporation);
(b) Toposcale or local scale (100 m–3 km), for example air pollution, tornadoes;
(c) Mesoscale (3 km–100 km; for example, thunderstorms, sea and mountain breezes);
(d) Large scale (100–3 000 km, for example, fronts, various cyclones, cloud clusters);
(e) Planetary scale (larger than 3 000 km, for example long upper tropospheric waves).

Note: The requirements for observational data shall be determined in part by these scales of meteorological phenomena. Many phenomena overlap between two of the classes indicated, and there is also dynamic interaction between the phenomena in different scales.

Scale (d) should be considered as roughly corresponding to the regional level within the World Weather Watch (WWW), and (d) and (e) can be combined within the global level.

ATTACHMENT II.2

SPECIAL OBSERVATIONAL REQUIREMENTS FOR ENVIRONMENTAL EMERGENCY RESPONSE ACTIVITIES

A. METEOROLOGICAL DATA REQUIREMENTS

1. Data needed to run transport models are the same as specified for the production of weather forecasts based on numerical weather prediction (NWP) models and are given in the *Manual on the Global Data-processing and Forecasting System* (WMO-No. 485), Volume I – Global Aspects, Appendix II.2 and the *Guide to the Global Observing System* (WMO-No. 488), Appendix II.1.

2. Additional data[1] are desirable from the accident site[2] and potentially affected area[3] and should be available to the designated Regional Specialized Meteorological Centre (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 data needed from the accident site may be provided by the following systems 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 be representative of conditions at or near the accident site;
(b) In an emergency situation, at two or three stations closest to the site of the accident (within 500 km) frequency 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 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:

(a) All upper-air stations within the potentially-affected area should make observations every six hours of the emergency;
(b) Where possible, one or more additional observing systems, including 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 which are not normally exchanged data internationally on a routine basis should provide observational data to designated RSMCs. Platforms and buoys should also provide observational data to ensure adequate coverage over 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;

---

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

[2] Due to the highly variable 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 occurred and the immediate surrounding zone within a range of a few kilometres.

[3] The potentially affected area 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. It should be understood as the area where, using 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 in this area may be obtained from the RSMC concerned.

(c) Radionuclide species;
(d) Total release quantity or pollutant release rate;
(e) Effective height of release.

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

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 required 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 one hour to 10 minutes during the accident (routine frequency of observations varies from one to 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 WMO 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 (containment radiation reading, on-site radiation levels, etc.) which assist in characterizing the nuclear accident, should be provided by national authorities to the International Atomic Energy Agency (IAEA) as soon as practicable via the most reliable communication means. 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 Global Telecommunication System (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 assure system performance.

ATTACHMENT II.3

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 the occurrence of pre-eruption volcanic activity,[1] volcanic eruptions and volcanic ash clouds.

A. METEOROLOGICAL DATA REQUIREMENTS

The data needed to run transport models are the same as specified for the production of weather forecasts based on numerical weather prediction (NWP) models and are given in the *Manual on the Global Data-Processing and Forecasting System* (WMO-No. 485), Volume I – Global Aspects, Appendix II.2 and the *Guide to the Global Observing System* (WMO-No. 488), Appendix II.I.

1. Additional data[2] 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.2 of this Manual.

2. 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 (vertical and horizontal) [Reference: 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 tracking volcanic ash for transport model validation) [Reference: *Handbook on the International Airways Volcano Watch* (*IAVW*), Section 4.4.1 (c), Section 4.5.1 (d) and (e)];
(e) Be processed and delivered to the VAAC with a minimal delay.

3. 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. This may include satellite data that can be used to detect volcanic hot-spots or sulphur dioxide emissions.

4. 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.

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:

---

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 (VAACs) are designated by the International Civil Aviation Organization (ICAO) and WMO to issue advisories on the presence and forecasted trajectory of volcanic ash.

(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, the 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 [Reference: *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 reported without delay to the designated Area Control Centres, Meteorological Watch Offices and VAAC [Reference: *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 are:

(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:
      – Selected ship stations;
      – Supplementary ship stations;
      – Auxiliary ship stations;
      – Ice-floe stations;
    – Automatic sea stations:*
      – Fixed sea 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;

Other elements of the subsystem are:

(d) Aeronautical meteorological stations;
(e) Research and special-purpose vessel stations;
(f) Climatological stations;
(g) Agricultural meteorological stations;
(h) Special stations, which include:
  (i) Weather radar stations;
  (ii) Radiation stations;
  (iii) Wind profilers;
  (iv) Atmospherics detection stations;
  (v) Meteorological reconnaissance aircraft stations;
  (vi) Meteorological rocket stations;
  (vii) Global Atmosphere Watch stations;
  (viii) Planetary boundary-layer stations;
  (ix) Tide-gauge stations.

* Data may be asynoptic when collected via satellite.

Notes:
1. Definitions of stations listed above will be found in the Appendix to this Manual.
2. Any station may fall under more than one of the above categories.

2. IMPLEMENTATION OF ELEMENTS OF THE SUBSYSTEM

2.1 Networks of observing stations

2.1.1 General

2.1.1.1 **Corresponding to the three levels of requirements for observational data, three types of networks of observing stations – global, regional and national – 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 network forming the global network. Therefore, a station of the global network is part of a regional network and a national network.

2.1.1.3 The frequency and spacing of the 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), 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 which have the necessary accuracy, spatial and temporal resolutions 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 all over the globe, and the observations should be made at the main standard times of observation.

2.1.2.4 Members should implement the Global Climate Observing System (GCOS) Surface Network (GSN) – the global reference 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 the GCOS Upper-air Network (GUAN) – the global baseline network of about 150 selected upper-air stations established with relatively homogenous distribution to meet requirements of GCOS.

2.1.2.6 Members should also establish a network of Global Atmosphere Watch (GAW) stations designed to meet the need for monitoring, on a global and regional basis, the chemical composition and related characteristics of the atmosphere.

Note: For further information on the location of GAW stations, see the *Technical Regulations* (WMO-No. 49), Volume I – General Meteorological Standards and Recommended Practices, Chapter B.2, as well as the appropriate Global Atmosphere Watch technical publications, and the *Guide to the Global Observing System* (WMO-No. 488).

2.1.3 Regional networks

2.1.3.1 Regional networks shall be established in relation to the 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 (CBS).

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 continue to examine their plans to 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 Volume I, Part II, and 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 needs to complete 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

General

2.2.1 The implementation and operation of each of the above elements should be as laid down by 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.

2.2.2 In implementing the Global Observing System (GOS) surface-based subsystem, Members should ensure that the observing system meets the requirements placed on the subsystem.

2.2.3 In implementing the surface-based sub-system, Members should strive to meet the provisions indicated in 2.2.1 above as closely as possible, in particular as regards the main elements of the surface-based subsystem.

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

2.2.5 **In general, observing stations shall be spaced at an interval and with observations taken frequently enough to permit an accurate description of the atmosphere for users of the observations for the purpose intended.**

2.2.6 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 an area when it borders a populated area or is traversed by a regularly used air route.

2.2.7 Asynoptic observations should be taken when necessary to supplement observations from the synoptic networks and in a manner which increases their spatial or temporal frequency.

2.2.8 Observations should be taken in areas where special phenomena are occurring or 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.

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

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.**

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 required for global exchanges.

2.3.1.7 When it is difficult for any reason to provide sufficient staff for 24-hour operations, partially or fully automated stations should supplement 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 **A synoptic station on land shall be identified by a station index number assigned by the Member concerned within the allocations made to that Member, in compliance with the scheme prescribed in the *Manual on Codes* (WMO-No. 306).**

2.3.2.2 **When a Member establishes a synoptic station on land (or a fixed weather station at sea) the Member 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 – Observing Stations.

2.3.2.3 **Members shall send the necessary amendments to the information supplied under 2.3.2.2 (a) – (f) above to the Secretariat as soon as possible.**

2.3.2.4 Any change in index number of synoptic stations included in the international exchanges

should be notified to the Secretariat at least six months before becoming effective.

2.3.2.5 Each Member should publish a description, in sufficient detail to enable departures from the representativeness of observations to be assessed, of each of its synoptic stations whose reports are included in international exchanges.

2.3.2.6 **All changes in the station index number of a synoptic station shall be effective from 1 January or 1 July each year.**

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

Location and composition

2.3.2.8 Surface land stations, including those in the RBSN, should be spaced at intervals not exceeding the minimum horizontal resolution required by applications areas supported by the network and as described in the Rolling Review of Requirements Process. During the first decade of the twenty-first century, the interval, in general, should not exceed 250 km (or 300 km in sparsely populated areas).

2.3.2.9 **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 regional association resolutions:
(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.

2.3.2.10 **A surface synoptic observation at an automatic land station shall consist of observations 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 meteorological elements which should be included if possible:
(f) Amount of precipitation;
(g) Intensity of precipitation;
(h) Visibility;
(i) Optical extinction profile (height of cloud base);*
(j) Special phenomena.

Note: The standard set of metadata elements is presented in Attachment III.1.

Frequency and timing of observations

2.3.2.11 At synoptic land stations the frequency of 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.

2.3.2.12 **At a (manned or automatic) land station, surface synoptic observations shall be made and reported at least at the main standard times.**

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. In this role, these stations are an integral part of regional and national networks.

* Height of cloud base and cloud extent could be derived directly from the optical extinction profile without further measurement, using one-minute time series.

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. A fixed sea station other than an ocean weather station or a moored buoy may be identified by a station index number 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 with amendments to the 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, type of barometer, psychrometer, barograph, radio equipment and other instruments aboard the ship and radio-watch hours.**

2.3.3.5 Members should consider using fixed or mobile automatic sea stations or drifting buoy stations in the data-sparse areas of persistent cloudiness, where remote sounding by satellite is hampered.

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

2.3.3.6 **Environmental data buoy stations shall be identified by the International Identifier System.**

Note: This identifier system is used by the Intergovernmental Oceanographic Commission and WMO universally.

Location and composition

2.3.3.7 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 taken at the main synoptic times. The observations should include as many meteorological elements of a full synoptic report as possible.

2.3.3.8 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 station should be sent to the Secretariat as for synoptic land stations (see paragraph 2.3.2.2).

2.3.3.9 In its recruitment programme, each Member should aim at making the maximum possible contribution from mobile sea stations towards attaining an adequate density of observations in all oceanic areas.

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

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

2.3.3.11 **At ocean weather stations, a surface synoptic observation 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.

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

2.3.3.13 At a supplementary ship station, a surface synoptic observation should consist of observations of elements (a) to (h), (i) and (r) in 2.3.3.11 above.

2.3.3.14 At an auxiliary ship station, a surface synoptic observation should consist of observations of elements (a) to (d), (g), (h) (j) and (r) in 2.3.3.11 above.

2.3.3.15 At a lightship, a manned platform, and coastal and island stations, a surface synoptic observation should consist of observations of elements (a) to (r), with the exception of (m), in 2.3.3.11 above.

2.3.3.16 **At a fixed automatic sea station, surface synoptic observations shall consist of observations 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.

2.3.3.17 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 2.3.3.16 above.

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

2.3.3.18 Members should endeavour to equip mobile ships to make subsurface observations and report them in the BATHY/TESAC code form.

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

2.3.3.19 **At an ocean weather station, surface synoptic observations shall be made and reported at least four times per day and preferably hourly at the main and intermediate standard times.**

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

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

2.3.3.22 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.

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

2.3.3.24 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 time of observation.

Note: For specific instructions relative to the furnishing by ships of special reports, in accordance with the International Convention for Safety of Life at Sea, see *Weather Reporting* (WMO-No. 9).

2.3.3.25 Members should arrange for timely transmission of observations.

Note: Details of observing and reporting programmes are described 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 given in the *Manual on the Global Telecommunication System* (WMO-No. 386), Volume I – Global Aspects, Part I, Attachment I-1, should be followed.

2.4 Upper-air synoptic stations

General

2.4.1 **Upper-air synoptic stations shall be identified as provided under 2.3.2.1 to 2.3.2.7 above.**

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 applications areas supported by the network and as described in the Rolling Review of Requirements Process. During the first decade of the twenty-first century, the interval, in general, should not 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 observations 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 an upper-air synoptic station, the frequency of synoptic observations should be four per day at the standard times of upper-air synoptic observations.

2.4.8 **At an upper-air synoptic station, upper-air observations shall be made and reported at least at 0000 UTC 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 (H-45) to H.

Note: The actual time of a pilot-balloon observation may deviate from the range indicated above if, by doing so, wind observations to considerably greater heights can be expected.

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

General

2.5.1 **Each Member shall arrange for observations to be made by aircraft of its registry operating on international air routes and for the recording and reporting of these observations.**

Note: Further information on aircraft observations and reports may be found in the *Technical Regulations* (WMO-No. 49), Volume II – Meteorological Service for International Air Navigation, Part 1, [C.3.1.] 5.

2.5.2 **Members accepting responsibility for collecting aircraft reports for synoptic purposes shall promptly make these available, in agreed code forms, to other Members.**

2.5.3 Members should give special consideration to the use of an automated aircraft meteorological observing and reporting system.

2.5.4 **Aircraft reports shall, at a minimum, satisfy the requirements of International Air Navigation (for details see the *Technical Regulations* (WMO-No. 49), Volume II – Meteorological Service for International Air Navigation, Part 1, [C.3.1.] 5).**

Location and composition

2.5.5 **The following aircraft observations shall be made:**
(a) Routine aircraft observations during en-route and climb-out phases of the flight; and
(b) Special and other non-routine aircraft observations during any phase of the flight.

2.5.6 **Routine air reports shall contain the following meteorological elements:**
(a) Air temperature;
(b) Wind direction and speed;
(c) Turbulence;
(d) Aircraft icing;
(e) Humidity (if available).

In addition, reports of any volcanic activity observed by the flight crew shall be included.

2.5.7 **Special aircraft reports shall be made whenever any of the following conditions are observed:**
(a) Severe turbulence;
(b) Severe icing;
(c) Severe mountain wave;

(d) Thunderstorms, with or without hail, that are obscured, embedded, widespread or in squall lines;
(e) Heavy duststorm or heavy sandstorm;
(f) Volcanic ash cloud;
(g) Pre-eruption volcanic activity or a volcanic eruption;

In addition, in the case of transonic and supersonic flights:
(h) Moderate turbulence;
(i) Hail;
(j) Cumulonimbus clouds.

2.5.8 Routine aircraft observations should be made at the designated air traffic services/meteorological (ATS/MET) reporting points.

Note: Lists of designated ATS/MET reporting points are prepared by and available from International Civil Aviation Organization (ICAO) Regional Offices.

Frequency and timing of observations

2.5.9 When automated observing and reporting systems are available, routine observations should be made every 15 minutes during the en-route phase and every 30 seconds during the first 10 minutes of the flight.

2.5.10 **When voice communications are used, routine observations shall be made during the en-route phase in relation to those air traffic services reporting points or intervals:**
(a) At which the applicable air traffic services procedures require routine position reports; and
(b) Which are those separated by distances corresponding most closely to intervals of one hour of flying time.

2.5.11 **Observations shall be made by all aircraft of meteorological conditions encountered during the take-off or approach phases of flight, not previously reported to the pilot-in-command, which in his opinion are likely to affect the safety of other aircraft operations.**

2.5.12 **Observations shall also be made by aircraft:**
(a) If a meteorological office providing meteorological service for a flight makes a request for specific data; or
(b) By agreement between a Meteorological Authority and an operator.

2.6 Aeronautical meteorological stations

General

2.6.1 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 – Meteorological Service for International Air Navigation, Part 1, [C.3.l.] 4.

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

2.6.3 **An aeronautical meteorological station on land shall be identified by a station index number assigned by the Member concerned in compliance with the scheme prescribed in Annex II of the WMO Technical Regulations – *Manual on Codes* (WMO-No. 306), Volume I.**

2.6.4 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 each year.

Location and composition

2.6.5 **Aeronautical meteorological stations shall be established at aerodromes and other points of significance to international air navigation.**

2.6.6 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 – Meteorological Service for International Air Navigation, Part 1, [C.3.l.] 4.6.8.

Frequency and timing of observations

2.6.7 **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.**

2.7 Research and special-purpose vessel stations

General

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

Location and composition

2.7.2 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.

Frequency and timing of observations

2.7.3 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.

2.8 Climatological stations

General

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

2.8.2 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 (e.g. plains, mountainous regions, plateaux, coasts, islands, etc.).

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

2.8.4 **Each Member shall establish and maintain an up-to-date directory of the climatological stations in its territory, giving the following information, often referred to as metadata, for each station:**

(a) Name and geographical coordinates;
(b) Elevation of station;
(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.

Location and composition

2.8.5 Each climatological station should be located at a place and under an arrangement that will provide for the continued operation of the station for at least 10 years, and for the exposure to remain unchanged over a long period, unless it serves a special purpose that justifies its functioning for a shorter period.

2.8.6 Each reference climatological station should be sited with an adequate and unchanged exposure where the observations can be made in representative conditions. The surroundings of the station should not alter in time to such an extent as to affect the homogeneity of the series of observations.

2.8.7 The data relating to the elevation of a climatological station should be specified at least to the nearest five metres, except that for a station with a barometer the elevation should be specified to the nearest metre.

2.8.8 **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;
(l) Sunshine duration and/or solar radiation;
(m) Soil temperature.

2.8.9 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.

2.8.10 **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 in 2.8.8 above.**

2.8.11 At an automatic climatological station, records should be made of meteorological elements selected from those in 2.8.8 above.

Frequency and timing of observations

2.8.12 Each Member should arrange that observations at any climatological station are made at fixed hours, according to either UTC or Local Mean Time, which remain unchanged throughout the year.

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

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

2.9 Global Climate Observing System Surface Network (GSN) stations

In implementing the observing programme at GCOS Surface Network (GSN) stations, Members should adhere as appropriate 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 the provision of the necessary resources, including well-trained staff, and keeping changes of location to a minimum. In the case of significant changes in sensor-devices or station location, Members should provide for a sufficiently long period of overlap (at least one but preferably two years) with dual operation of old and new systems to enable comparisons to be made and the identification of inhomogeneities and other measurement characteristics;
(b) CLIMAT data should be provided in an accurate and timely manner: CLIMAT reports should be transmitted by the fifth day of the month but not later than the eighth day of the month;
(c) Rigorous quality control should be exercised on the measurements and their message encoding: CLIMAT reports require quality control of the measurements themselves and their message encoding to ensure their accurate transmission to national, regional and world centres for their use. Quality-control checks should be made on site and at a central location designed to detect equipment faults at the earliest stage possible. The *Guide to Meteorological Instruments and Methods of Observation* (WMO-No. 8), Part III, Chapter 3, provides the appropriate recommendations;
(d) The site layout should follow the recommended form: the layout of the site 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 is documented in the *Guide to Meteorological Instruments and Methods of Observation* (WMO-No. 8). The quality of the measured variables should be guaranteed by appropriate inspection of sites, instruments and exposure to be based on the procedures given in the Guide. As part of the maintenance, the necessary calibration practices should be traceable to the standards provided by the Guide;
(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 observational data and metadata pertaining to each climate station. Metadata should include data concerning a station's establishment, subsequent maintenance and changes in exposure, instrumentation and staff. The data and metadata should be in its original form as well as in digital format;
(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.

2.10 Global Climate Observing System Upper-air Network (GUAN) stations

In implementing observing programmes at GCOS Upper-air Network (GUAN) stations, Members should adhere as appropriate 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 GUAN station: this requires the provision of the necessary resources, including well-trained staff, and keeping changes of location to a minimum. Changes of bias caused by changes in instrumentation should be evaluated by a sufficient overlapping period of observation (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 assure 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 so that shifts in the data will not be mistaken for climate change. The metadata should include detailed information about the station, such as location, elevation, operating instruments and their changes over time. Changes to operating and correction procedures should also be recorded. 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.

2.11 Agricultural meteorological stations

General

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

2.11.2 The desirable density of the network of each category of agricultural meteorological stations should be adequate to delineate weather parameters on the scale required for agrometeorological planning and operation, taking into account the agricultural features of the country.

2.11.3 Each Member should maintain an up-to-date directory of the agricultural meteorological stations in its territory, giving the following information, often referred to as metadata, for each station:

(a) Name and geographical coordinates;
(b) Elevation of station;
(c) A 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) 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);
(i) The name of the supervising organization or institution.

Location and composition

2.11.4 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.

2.11.5 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 producing 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

2.11.6 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.

2.12 Special stations

2.12.1 General

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

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

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

2.12.1.3 **Special stations shall include:**
(a) Weather radar stations;
(b) Radiation stations;
(c) Wind profiler stations;
(d) Atmospherics detection stations;
(e) Meteorological reconnaissance aircraft stations;
(f) Meteorological rocket stations;
(g) Global Atmosphere Watch (GAW) stations;
(h) Planetary boundary-layer stations;
(i) Tide-gauge stations.

2.12.1.4 A special station should be identified by its name and geographical coordinates, and elevation.

2.12.2 Weather radar stations

General

2.12.2.1 Members should establish an adequate network of weather radar stations, either nationally or in combination with other Members of the Region, in order to secure information about areas of precipitation and associated phenomena and about the vertical structure of cloud systems, for both operational meteorology and research.

Location and composition

2.12.2.2 **Weather radars shall be located in such a manner as to minimize interference from surrounding hills, buildings and electro-magnetic sources, so as to provide good coverage of population centres and geographic features affecting stream and river flows, major thoroughfares and other facilities of importance.**

Frequency and timing of observations

2.12.2.3 As a minimum, observations should be taken and reported at hourly intervals. Observations should be more frequent when heavy convective activity or heavy widespread precipitation is occurring.

2.12.3 Radiation stations

General

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

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

2.12.3.3 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 of station in whole metres;
(c) A 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) 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);
(h) Name of the supervising organization or institution.

Location and composition

2.12.3.4 **Each radiation station shall be sited, as far as possible, with an adequate exposure, where the observations can be made in representative conditions.**

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

2.12.3.5 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 (throughout 24 hours);
(d) Recording of duration of sunshine.

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

2.12.3.6 At ordinary radiation stations, the observing programme should include:
(a) Continuous recording of global solar radiation;
(b) Recording of duration of sunshine.

2.12.3.7 **Pyrheliometric measurements shall be expressed in accordance with the World Radiometric Reference (WRR).**

Frequency and timing of observations

2.12.3.8 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.

2.12.3.9 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.

2.12.4 Wind profiler stations

General

2.12.4.1 Members should consider the establishment of wind profilers.

Location

2.12.4.2 Wind profiler stations should be located so as to measure wind profiles in the troposphere. The spacing of stations should be consistent with the requirements for the observations.

2.12.5 Atmospherics detection stations

General

2.12.5.1 Members should establish atmospherics detection stations.

Note: Methods in use are described in the *Guide to Meteorological Instruments and Methods of Observation* (WMO-No. 8), Part II, Chapter 7.

Location and composition

2.12.5.2 Atmospherics (spherics) detection stations should be located so as to measure this phenomenon in areas of frequent convective activity. The spacing and number of ground stations should be in keeping with the technique used, coverage and accuracy of location desired.

Frequency and timing of observations

2.12.5.3 Continuous monitoring by the station should be maintained, with an indication of direction and distance, at about 10-minute intervals.

2.12.6 Meteorological reconnaissance aircraft stations

General

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

Location and composition

2.12.6.2 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.

2.12.6.3 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.

2.12.6.4 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

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

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

2.12.7 Meteorological rocket stations

General

2.12.7.1 Members are encouraged to establish meteorological rocket stations.

Note: When establishing and operating these stations, appropriate safety precautions are considered necessary and need to be coordinated with the relevant air traffic control authorities.

Location and composition

2.12.7.2 Members establishing rocket stations should coordinate their locations through WMO so that continuous networks can be maintained. Meteorological elements to be measured include:
(a) Wind direction and speed;
(b) Air temperature;
(c) Solar radiation;
(d) Electrical variables;
(e) Minor chemical constituents.

Frequency and timing of observations

2.12.7.3 The frequency and timing of launches should be coordinated, because of cost, among Members concerned to allow simultaneous sampling at rocket network stations. Information on launches should be communicated to the WMO Secretariat.

2.12.8 Global Atmosphere Watch (GAW) stations

General

2.12.8.1 Members should cooperate in the establishment of a minimum of 30 global GAW stations and at least 300 regional GAW stations.

Location and composition

2.12.8.2 Global Atmosphere Watch stations should be established only at sites where direct pollution effects can be avoided.

2.12.8.3 Global Atmosphere Watch stations should be collocated with or located near a surface and/or an upper-air synoptic station.

Note: For further information on the location of GAW stations, see the *Technical Regulations* (WMO-No. 49), Volume I – General Meteorological Standards and Recommended Practices, 2.4.3, Note 3, as well as the appropriate Global Atmosphere Watch technical publications and the *Guide to the Global Observing System* (WMO-No. 488).

2.12.8.4 At each global GAW station, measurements should be carried out on all or most of the following variables:
(a) Greenhouse gases (concentration near the surface, total column density and vertical profile): carbon dioxide; chlorofluorocarbons, their substitutes, intermediates and final products; methane; nitrous oxide; tropospheric ozone;
(b) Ozone (concentration near the surface, total column density and vertical profile) and related precursor gases, e.g. volatile organic compounds ((VOCs) NO_x);
(c) Radiation and the optical depth or transparency of the atmosphere: turbidity, solar radiation, ultraviolet B radiation, visibility, total aerosol load (concentration near the surface, in a marine or continental background and, where possible, vertical profile up to the tropopause);
(d) Chemical composition of precipitation;
(e) Reactive gas species (concentration near the surface, total column density and vertical profile): sulphur dioxide, reduced sulphur species, oxides of nitrogen, reduced nitrogen species, carbon monoxide, VOCs, peroxyacetyl nitrate (PAN), hydrogen peroxide (H_2O_2) and others;
(f) Physical and chemical characteristics of atmospheric particles, including mineral aerosols and their vertical distribution;
(g) Radionuclides, krypton-85, radon, tritium, isotopes of selected substances;
(h) Routine measurements of the classical meteorological elements (in particular wind direction and speed, wet- and dry-bulb air temperature, relative humidity, atmospheric pressure, present weather, aerological soundings);
(i) Chemical composition of water in the soil and plants, in collaboration with other interested organizations;
(j) Integrated air samples for archiving.

2.12.8.5 At regional GAW stations, measurements should be made of as many of the variables listed in 2.12.8.4 (a) to (j) above as possible and others as the needs of the region or country dictate. However, the following variables should constitute the core measurement programme at GAW regional stations, with the highest priority given to the first five:
(a) Ozone concentration near the surface;
(b) Precipitation chemistry;
(c) Carbon black (in precipitation and in aerosols);
(d) Meteorological parameters;
(e) Solar radiation (visible, ultraviolet B);
(f) Methane;
(g) Carbon monoxide;
(h) Total ozone;
(i) Aerosol composition.

Frequency and timing of observations

2.12.8.6 At GAW stations, observations of most parameters should be continuous with reports prepared on an hourly basis.

2.12.9 Planetary boundary-layer stations

General

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

Location and composition

2.12.9.2 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 accuracy of measurements of several variables and the height intervals at which they are required 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).

2.12.10 Tide-gauge stations

General

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

Location and composition

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

Frequency and timing of observations

2.12.10.3 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 of a meteorological station

3.1.1 **All stations shall be equipped with properly calibrated instruments and adequate observational and measuring 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 of 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 not less than 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 not less than once every six months.

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 of instruments

3.2.1 Meteorological instruments should be reliable and accurate.

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) with the earlier 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 the World Meteorological Organization, shall be applied in the GOS. (See *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 An observation 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 indicator of dispersion) can be determined, if required;
(c) All synoptic-scale discontinuities (e.g. fronts) can be identified as soon as possible after the 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 for the purpose of observing 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 of 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 (symbol g_n) shall be regarded as a conventional constant.**

$$g_n = 9.806\ 65\ \text{m/s}$$

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

3.3.2.3 **Atmospheric pressure shall be determined by a suitable pressure measuring device**

of uncertainty specified in the *Guide to Meteorological Instruments and Methods of Observation* (WMO-No. 8), Part I, Chapter 1, Annex 1.B.

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.

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 from which measurements made there are derived.**

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. However, 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 keep the correct height above the snow surface.

3.3.3.3 Thermometer screens should be constructed so as 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* (WMO-No. 8), Part I, Chapter 1, Annex 1.B.

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 and 10 m/s.

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 touchdown areas.

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. The direction in this case is not measured for synoptic purposes.

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 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 (WMO-No. 407), Volume I – Manual on the Observation of Clouds and other Meteors – (Annex I to the WMO Technical Regulations), shall be used.**

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

3.3.7 Weather

See *Guide to Meteorological Instruments and Methods of Observation* (WMO-No. 8), Part I, Chapter 14, paragraph 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 recalibrated, if necessary, at least once a year against existing standards.

Note: For details of calibration of other 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.

3.4 UPPER-AIR OBSERVATIONS

3.4.1 **At an upper-air synoptic station, 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 based on the relevant definitions of physical functions and values of constants given in the *Technical Regulations* (WMO-No. 49), Volume I – General Meteorological Standards and Recommended Practices, Appendix A.**

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 (e.g. 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 on any changes of 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

STANDARD SET OF METADATA ELEMENTS FOR AUTOMATIC WEATHER STATION INSTALLATIONS

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

Major database elements include the following:
(a) Network information;
(b) Station information;
(c) Individual instrument information;
(d) Data-processing information;
(e) Data handling information;
(f) Data transmission information.

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 station 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 (AWS), 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)

Relevant metadata 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

1. COMPOSITION OF THE SUBSYSTEM

The main elements of the space-based subsystem are:

(a) An Earth observation space segment:
  (i) Operational satellites on Geostationary Earth Orbit (GEO);
  (ii) Operational satellites on distributed, sun-synchronous, Low Earth Orbits (LEO);
  (iii) Other operational/sustained satellites or instruments on appropriate orbits;
  (iv) Research and development (R&D) satellites;
(b) A space-based intercalibration system;
(c) Associated ground segment for data reception, dissemination and stewardship;
(d) A user segment.

Notes:

1. Information on the detailed characteristics and capabilities of current and planned systems of environmental satellites of the GOS is contained in the database on Observing Systems Capability Analysis and Review Tool (OSCAR), which is available online at http://www.wmo.int/oscar.
2. Information on the principles of remote sensing from space and on the derivation of geophysical variables from space-based measurements will be included in the *Guide to Meteorological Instruments and Methods of Observations* (WMO-No. 8), Part IV.

2. IMPLEMENTATION OF THE SUBSYSTEM

2.1 General

2.1.1 Requirements: Operators of environmental satellites should meet, to the extent possible, the uncertainty, timeliness, temporal resolution, spatial resolution and coverage requirements of the GOS as defined in the Rolling Review of Requirements (RRR) process described in Part II of this Manual, and recorded in the requirements database: http://www.wmo.int/oscar.

2.1.2 Technical coordination: Members operating satellites should ensure the greatest possible compatibility between their different systems, through following recommended Coordination Group for Meteorological Satellites (CGMS) practices, and publish details of the technical characteristics of their instrumentation, data processing and transmissions, as well as the dissemination schedules.

2.1.3 Continuity: A period of overlap of new and old satellite systems should be ensured to determine inter-satellite biases and maintain the homogeneity and consistency of time series observations, unless reliable transfer standards are available.

2.1.4 Contingency arrangements: The satellite operators, working together under the auspices of the CGMS or otherwise, should ensure the continuity of operation, and the data dissemination and distribution services of the operational satellites within the subsystem.

2.1.5 Data collection platforms:

(a) Members operating satellites with a capability to receive data from data collection platforms (DCP) should maintain technical and operational coordination under the auspices of CGMS in order to ensure compatibility;
(b) A number of "international" DCP channels should be identical on all geostationary satellites to allow movement of mobile platforms across their individual footprints;
(c) The satellite operators should publish details of the technical characteristics and operational procedures of their data-collection missions, including the admission and certification procedures.

2.2 Operational satellites on Geostationary Earth Orbit

2.2.1 The following capability should be provided:

(a) Multispectral visible and infrared imagery;
(b) Infrared sounding;
(c) Lightning mapping;
(d) Data collection from in situ observing systems;
(e) Space environment monitoring;
(f) Other capabilities as appropriate, for example, broadband and spectral visible and infrared (for Earth radiation budget estimates), high-0spectral resolution UV sounding (for atmospheric composition), high-spectral resolution visible and infrared imaging (for ocean colour), solar activity monitoring.

2.2.2 The constellation of satellites in geostationary orbit should provide full disc imagery at least every 15 minutes, throughout a field of view between 60°S and 60°N. This implies the availability of at least six operational geostationary satellites located at evenly distributed longitudes, with in-orbit redundancy. On-demand rapid-scan capabilities should be implemented where feasible.

2.2.3 For the imagery mission the availability rate of rectified and calibrated data should be at least 99 per cent as a target. Contingency plans, involving the use of in-orbit standby flight models and rapid call-up of replacement systems and launches, should be in place in order to achieve continuity.

2.3 Operational spacecraft on distributed sun-synchronous Low Earth Orbits

2.3.1 The following capability should be provided on several, distributed orbital planes:
(a) Multispectral visible and infrared imagery;
(b) Infrared sounding;
(c) Microwave imagery;
(d) Microwave sounding;
(e) Scatterometry (for ocean surface winds);
(f) Radar altimetry (for ocean surface topography);
(g) Radio-occultation sounding;
(h) Broadband visible and infrared radiometry for Earth radiation budget measurements;
(i) Passive UV sounding (for atmospheric composition monitoring);
(j) Space environment monitoring including particle detection and magnetic field measurement;
(k) Solar activity monitoring;
(l) Data collection from in situ observing systems;
(m) Direct broadcast;
(n) Other capabilities as appropriate.

2.3.2 The orbital configuration of satellites in sun-synchronous orbits should enable the provision of global coverage for visible, infrared and microwave imagery and infrared and microwave sounding, which represents the core meteorological mission, at least six times per day with a regular temporal sampling. This will require sun-synchronous satellites operated along three orbital planes: one ante-meridian (a.m.) orbit with a descending equatorial crossing around 9:30 Local Solar Time (LST), one post-meridian (p.m.) orbit with an ascending equatorial crossing around 13:30 LST, and one early-morning orbit with an ascending equatorial crossing around 17:30 LST. There should be at least one operational satellite on each of these planes, with redundancy on the a.m. and p.m. orbits.

2.3.3 At least two of these satellites, one in a.m. and one in p.m., should perform infrared sounding with a hyperspectral sensor.

2.3.4 At least two satellites, one in a.m. and one in p.m, should be equipped with radio-occultation receivers.

2.3.5 At least two satellites, on well-separated orbits, should be equipped with wind scatterometers.

2.3.6 At least two satellites, one in a.m. and one in p.m., should perform broadband visible/infrared Earth radiation monitoring.

2.3.7 At least two sun-synchronous satellites, on well-separated orbits, should be equipped with altimeter packages for global ocean surface topography monitoring.

2.3.8 Data from these satellites should be acquired on a global basis, without temporal gaps for blind orbits, and delivered to users to meet timeliness requirements.

2.3.9 The constellation should be designed to achieve a high level of robustness allowing the delivery of imagery and sounding data from at least three polar-orbiting planes, in a.m., p.m. and early morning orbit, on not less than 99 per cent of occasions. This implies provisions for ground segment, instrument and satellite redundancy, and rapid call-up of replacement launches or a.m. and p.m. spares.

2.4 Other operational/sustained spacecraft on appropriate Low Earth Orbits

2.4.1 The following capability should be provided:
(a) High-precision radar altimetry (for ocean surface topography);
(b) Radio-occultation sounding from non-sun-synchronous orbits;
(c) Total solar irradiance;
(d) Dual-angle view infrared imagery (for high-accuracy sea surface temperature measurement);
(e) Narrow-band visible and near infrared imagers for ocean colour, vegetation and aerosol monitoring;
(f) High spatial resolution multispectral visible and infrared imagery.

2.4.2 An altimetry mission on high-precision, inclined orbit should complement the two altimetry missions in sun-synchronous orbits to build a robust ocean surface topography constellation.

2.4.3 A constellation of dedicated spacecraft with radio-occultation sensors on appropriate orbits should complement the radio-occultation missions on sun-synchronous orbits.

2.4.4 At least one satellite should perform downward solar irradiance monitoring, with provisions for overlap between consecutive missions in order to maintain measurement continuity.

2.4.5 A sun-synchronous spacecraft should be maintained on an a.m. orbit with high-accuracy infrared imagery to provide reference measurements of sea surface temperature.

2.4.6 Continuity should be provided for at least one narrow-band visible and near-infrared imager on a sun-synchronous a.m. orbit to monitor ocean colour, vegetation and aerosols.

2.4.7 Several sun-synchronous satellites in a.m. orbit should be equipped with high-resolution (10-m class) multispectral visible/infrared imagers to build a constellation providing sufficient coverage of the land surface.

2.5 Research and development satellites

2.5.1 Purposes: The main purposes of research and development satellites are:

(a) To support scientific investigations on atmospheric, oceanic and other environment related processes;
(b) To test or demonstrate new or improved sensors and satellite systems in preparation for new generations of operational capabilities to meet WMO observational requirements.

2.5.2 Missions: Observing capabilities should be provided to enable, for instance, the following:

(a) Observation of the parameters necessary to understand and model the water cycle, the carbon cycle, the energy budget and the chemical processes of the atmosphere;
(b) Pathfinders for future operational missions should include, for instance: precipitation radars, Doppler lidars, low-frequency microwave radiometers, geostationary microwave imagers and sounders, geostationary narrow-band visible and near-infrared imagers, gravimetric sensors, and imagery missions in high-inclination highly elliptical orbits.

2.5.3 Although neither long-term continuity of service nor a reliable replacement policy is assured, research and development satellites also provide, in many cases, information of great value for operational use. To this purpose, and in order to promote the early use of new types of data in an operational environment, provisions should be made when relevant to enable near-real-time data availability.

2.6 Intercalibration system

2.6.1 Operators of environmental satellites should perform rigorous prelaunch instrument characterization and calibration, including radiance confirmation against an international radiance scale provided by a National Metrology Institute.

2.6.2 After launch, all passive instruments should be intercalibrated on a routine basis against reference instruments or calibration targets, using established and documented methodologies.

2.6.3 Spacecraft with at least one high-quality hyperspectral infrared instrument should be maintained in a LEO orbit to provide reference measurements for intercalibration of operational infrared instruments in geostationary or LEO orbit, respectively. Advantage should be taken of satellite collocation to perform instrument intercalibration.

2.6.4 A range of ground-based calibration targets should be maintained, with precise characterization, in order to support routine visible channel calibration operations.

2.7 Associated ground segments

2.7.1 General provisions

2.7.1.1 Members operating environmental observation satellites should make satellite data available to other Members over the WMO Information System (WIS) in accordance with WIS data management practices, and should inform the Members of the means of obtaining these data through catalogue entries and metadata enabling their meaningful use.

2.7.1.2 Receiving and processing facilities should provide for the reception of remote-sensing and DCP data from operational satellites and for the processing of quality-controlled environmental observation information, with a view of further near-real-time distribution.

2.7.1.3 Satellite data archives should include Level 1B, together with all relevant metadata pertaining to the location, orbit and calibration procedures used. The archiving system should be capable of providing online access to the archive catalogue with a browse facility, and description of data formats, and allowing users to download data.

2.7.2 Data dissemination

2.7.2.1 All operational environmental observation satellite systems should ensure near-real-time data dissemination of the appropriate datasets, per the requirement of Members, either by direct broadcast or re-broadcast via telecommunication satellites.

2.7.2.2 In particular, the operational sun-synchronous satellites providing the core meteorological imagery and sounding mission should have direct broadcast capability as follows:

(a) Direct broadcast frequencies, modulations and formats should allow a particular user to acquire data from either satellite by a single antenna and signal processing hardware. To the extent possible, the frequency bands allocated to meteorological satellites should be used;
(b) Direct broadcast should be provided through a high data rate stream, such as the high resolution picture transmission or its evolution, to provide meteorological centres with all the data required for numerical weather prediction, nowcasting, and other real-time applications;
(c) If possible, a low data rate stream should also be provided, such as the low rate picture transmission, to convey an essential volume of data to users with lower connectivity or low-cost receiving stations.

2.7.2.3 Re-broadcast via telecommunication satellites[1] should complement and supplement direct broadcast services, to facilitate access to integrated data streams including data from different satellites, non-satellite data and geophysical products.

2.7.3 Data stewardship

It is essential to preserve long-term, raw data records and ancillary data required for their calibration, reprocessing them as appropriate, with the necessary traceability information to achieve consistent fundamental climate data records. Operators of environmental satellites should provide full description of all steps taken in the generation of satellite products, including algorithms used, specific satellite datasets used, and characteristics and outcomes of validation activities.

2.8 User segment

2.8.1 Users' stations

2.8.1.1 All Members should endeavour to install and maintain in their territory at least one system enabling access to digital data from both LEO and geostationary operational satellite constellations, either a receiver of re-broadcast service providing the required information in an integrated way, or a combination of dedicated direct readout stations.

2.8.1.2 Members requiring access to data from R&D satellites will need to download these data from the appropriate servers, or install a relevant re-broadcast service providing the required information, or install an appropriate direct broadcast user station, if the R&D satellite has such direct broadcast capability.

2.8.1.3 Data collection platforms: In order to extend the GOS by the use of the data-collection and relay capability of the environmental observation satellites, Members should establish fixed or moving DCP systems, in particular to cover data-sparse areas.

2.8.2 Education and training

2.8.2.1 *Centres of Excellence*

Support should be provided to education and training of instructors in the use of satellite data and capabilities, for example, at specialized Regional Training Centres or other training institutes designated as Centres of Excellence in satellite meteorology, in order to build up expertise and facilities at a number of regional growth points.

2.8.2.2 *Training strategy*

Individual environmental satellite operators should focus their assistance, to the extent possible, on one or more of these Centres of Excellence within their service areas and contribute to the Virtual Laboratory for Education and Training in Satellite Meteorology (VLab). The aim of the education and

[1] Formerly referred to as advanced dissemination methods (ADM), this technique generally uses digital video broadcast (DVB) standard or its evolution.

training strategy implemented through the VLab is to systematically improve the use of satellite data for meteorology, operational hydrology and climate applications, with a focus on meeting the needs of developing countries.

2.8.2.3 *User preparation to new systems*

For smooth transition to new satellite capabilities, provisions should be made for appropriate preparation of the users through training, guidance to upgrade receiving equipment and processing software, and information and tools to facilitate the development and testing of applications. In addition to working through the VLab, Members should, as appropriate, exploit partnerships with organizations providing education and training in environmental satellite applications, depending on their specific needs.

2.8.3 Engagement between users and providers

To achieve the most effective utilization of satellite data, the close engagement between users and providers should be pursued, particularly at a regional level. To this end, each regional association is encouraged to follow systematic steps to document the regional requirements for satellite data access and exchange.

3. OBSERVATIONS FROM SPACE

Satellite systems should provide quantitative data and qualitative information enabling, independently, as a constellation, or in conjunction with surface-based observations, the determination of:

(a) Three-dimension fields of atmospheric temperature and humidity;
(b) Temperature of sea and land surfaces;
(c) Wind fields at the ocean surface and aloft;
(d) Cloud properties (amount, type, top height, top temperature and water content);
(e) Radiation balance;
(f) Precipitation;
(g) Lightning detection;
(h) Ozone concentration (total column and vertical profile);
(i) Greenhouse gases;
(j) Aerosol concentration and properties;
(k) Volcanic ash cloud monitoring;
(l) Vegetation characterization;
(m) Flood and forest fire monitoring;
(n) Snow and ice cover;
(o) Ocean colour;
(p) Wave height, direction and spectra;
(q) Sea level and surface currents;
(r) Sea-ice monitoring;
(s) Solar activity;
(t) Space environment (electric and magnetic fields, particle flows, electron content).

Notes:

1. Information on the principles of Earth observation from space and on the different types of space-based instruments will be included in the *Guide to Meteorological Instruments and Methods of Observations* (WMO-No. 8), Part IV.
2. The database on Observing Systems Capability Analysis and Review Tool (OSCAR) provides an indication of the main instruments that are relevant for each specific variable observable from space, as well as the potential performance of each instrument technique for the relevant variables.

PART V

QUALITY CONTROL

1. BASIC CHARACTERISTICS OF QUALITY CONTROL

NOTE: The *Guide on the Global Data-processing System* (WMO-No. 305) is the authoritative reference on all matters related to quality control issues. It should be consulted for more detailed descriptions.

1.1 Quality control of observational data consists of examination of data at stations and at data centres to detect errors so that data may be either corrected or flagged. A quality control system should include procedures for returning to the source of data to verify them and to prevent recurrence of errors. Quality control is applied in real time, but it also operates in non-real time, as delayed quality control. Data quality depends on the quality control procedures applied during data acquisition and processing and during preparation of messages, in order to eliminate the main sources of errors and ensure the highest possible standard of accuracy for the optimum use of these data by all possible users.

1.1.1 **Within the framework of the Global Observing System (GOS), quality control shall be a real-time activity which has to be performed prior to the transmission of the observational data on the Global Telecommunication System (GTS).**

Note: See the *Guide to Meteorological Instruments and Methods of Observations* (WMO-No. 8), Part III.

1.1.2 **Quality control shall also be performed on a non-real-time basis, prior to forwarding the observational data for archiving.**

Notes:

1. Quality control on a real-time basis shall also take place in the Global Data-processing and Forecasting System, prior to the use of the observational data in data processing (i.e. objective analysis and forecasting).
2. See the *Manual on the Global Data-processing and Forecasting System* (WMO-No. 485), Volume I – Global Aspects.

1.2 **Quality control shall be applied to all observational data obtained from either the surface-based or the space-based subsystem.**

2. GENERAL PRINCIPLES

2.1 Responsibility

2.1.1 **The primary responsibility for quality control of all observational data shall rest with the Members from whose Services the observations originated.**

Note: Members should pay due attention to the quality control of observational data at the national level, aiming at the prevention of errors at the observational site, as well as the National Meteorological Centres (NMCs).

2.1.2 **Members shall inform the Secretary-General (for general dissemination) of any special features of their observing systems which may be important in the correct interpretation of the data provided.**

2.2 Relay of data

Quality control of observational data needed for operational use shall not cause any significant delay in onward transmission on the GTS.

2.3 Minimum standards

2.3.1 **Members shall implement minimum standards of quality control at all levels for which they are responsible (e.g. observing stations, NMCs, Regional Meteorological Centres (RMCs) and World Meteorological Centres (WMCs).**

Note: Recommended minimum standards of quality control at the level of the observing station and at that of the NMC are given in the *Manual on the Global Data-processing and Forecasting System* (WMO-No. 485), Volume I – Global Aspects, Appendix II-1, Table I.

2.3.2 Members not capable of implementing these standards should establish agreements with an appropriate RMC or WMC to perform the necessary quality control.

APPENDIX

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.

A. METEOROLOGICAL OBSERVING FACILITIES AND RELATED SERVICES

Advanced Dissemination Method (ADM): Dissemination services other than through direct broadcast for satellite sensor, data and products. These advanced methods include: the use of data relay between satellite systems, the use of commercially provided higher data rate services, and the use of services such as the Internet. ADM should complement or supplement direct broadcast 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 meteorological station: A meteorological station situated on an aircraft.

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 atmospherics.

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.

Data collection platform (DCP): A fixed or moving platform on land, sea or in the air that transmits data via satellite to a collection centre.

Direct broadcast service: A broadcast service, provided by some operational environmental observation satellites, that transmits satellite sensor data and products in real-time for reception by ground stations within radio range of the satellite.

Drifting automatic sea (drifting buoy) station: A floating automatic surface synoptic 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, or a small island, or in certain coastal areas.

Geostationary satellite: A type of meteorological satellite orbiting the Earth at an altitude of approximately 36 000 km with the angular velocity of the Earth and within the equatorial plane, thus providing nearly continuous information in an area within a range of about 60° geocentric angle from a fixed subsatellite point located at the Equator.

Global Atmosphere Watch (GAW) station: A station that provides observational data and other information on the chemical composition and physical characteristics of the background atmosphere.

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 meteorological centres and arrangements for the processing, storage and retrieval of meteorological information within the framework of the World Weather Watch.

Global Observing System (GOS): The coordinated system of methods and facilities for making meteorological and other environmental observations on a global scale in support of all WMO Programmes, particularly the World Weather Watch and the World Climate Programme; the system is comprised of operationally reliable surface-based and space-based subsystems. The objective is to assure continuity of service.

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 observation (Observation): The evaluation or measurement of one or more meteorological elements.

Meteorological observing network: A group of observing stations spread over a given area for a specific purpose.

Meteorological observing station (Station): A place where meteorological observations are made with the approval of the Member or Members concerned.

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 report (Report): A statement of observed meteorological conditions related to a specified time and location.

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

Meteorological satellite: An artificial Earth satellite making meteorological observations and transmitting these observations to Earth.

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.

Observing station: Any station making meteorological and related environmental observations.

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

Operational satellite: One of a series of environmental observation satellites with the primary purpose to routinely provide observations and services of a consistent standard over a long period. Resources are committed to ensure continuity of services thus permitting the establishment of a reliable satellite replacement policy.

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.

Polar-orbiting satellite: A type of environmental observation satellite with nearly circular, nearly polar orbit. The combination of satellite motion and the Earth's rotation beneath the orbit enables the collection of overlapping strips of satellite data (swaths up to 3 000 km wide) from pole to pole. The satellite's altitude or inclination defining the orbit may be selected in such a way to be sun-synchronous and provide global coverage. Sun-synchronous implies that the satellite will pass over a given geographic position at the same local sun-time each day.

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

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 with a specified observational programme within a WMO Region, which is a minimum regional requirement to permit Members to fulfil their responsibilities within the World Weather Watch and also serve as a target list for WWW monitoring of climatological data.

Regional Basic Synoptic Network (RBSN): A network composed of synoptic stations with a specified observational programme within a WMO Region, which is a minimum regional requirement to permit Members to fulfil their responsibilities within the World Weather Watch 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 development satellite: An environmental observation satellite with the primary purpose of acquiring a defined set of research data; testing new instrumentation and/or improving existing sensors and satellite systems; and/or it may provide information for operational use, but has limitations due to the lack of a commitment to ensure continuity of service or a reliable satellite replacement policy; and also due to non-consistent modes of operations.

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

Satellite communication services requirements: Requirements for services using environmental observation satellites including, but not limited to, direct broadcast of data, radio relay of environmental data collected by automatic sensor platforms, and search and rescue transmissions.

Satellite data requirements: Those data specified as performance goals for an operational environmental observation satellite system. At a minimum, environmental observation satellite data requirements are defined in terms of spatial, spectral and temporal resolution, geographic extent, timeliness, and measurement and location accuracy.

Note: These data requirements are routinely reviewed to identify common needs in order to consolidate the design of the satellite's instrument payload, and to identify requirements that could be met more effectively either by surface or space-based observing systems.

Satellite operator: An entity (Member of WMO or international organization) that manages, and/or operates environmental observation satellites which are of benefit to WMO Programmes.

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.

Space-based subsystem: One of the two major components of the Global Observing System composed primarily of environmental observation satellites in polar and geostationary orbits.

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-based subsystem: One of the two major components of the Global Observing System composed of all non-spaced-based observing stations.

Surface observation: A meteorological observation, other than an upper-air observation, made on 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 station: A station making observations by weather radar.

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 of 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, layer, or combination of clouds.

- ***Height of cloud base:*** Height above the Earth surface of the base of the lower cloud layer whose 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: Energy emitted by the sun considered as short-wave radiation with wavelengths between 0.29 and 4μm.

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 had 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-No. 488).

JN 131702

www.wmo.int