## WORLD METEOROLOGICAL ORGANIZATION

**WMO INTEGRATED GLOBAL OBSERVING SYSTEM
(WIGOS)**

**(20xx edition)**

**MANUAL on WIGOS**

**(Version 0.1)**

**DRAFT**

**VERSION CONTROL**

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**INTRODUCTION**

**PURPOSE AND SCOPE**

1. The Manual is designed:

(a) To facilitate cooperation in observations between Member countries;

(b) To specify obligations of Member countries in the implementation of the WMO Integrated Global Observing System (WIGOS);

(c) To ensure adequate uniformity and standardization in the practices and procedures employed in achieving (a) and (b) above.

2. This is the first edition of the Manual on the WMO Integrated Global Observing System, developed following the decision of Sixteenth Congress to proceed with the implementation of WIGOS, approved by Seventeenth Congress and issued as the 2015 edition.

3. The regulatory material in this manual was developed by Executive Council through its Inter-Commission Coordination Group on WIGOS (ICG-WIGOS), specifically its Task Team on WIGOS Regulatory Material (TT-WRM). This represents a collaborative approach involving all interested Technical Commissions under the technical leadership provided through CBS and CIMO.

4. Eventually all technical regulations for all WMO component observing systems will be included under the identity of WIGOS. For reasons of practicality the Manual on the GOS (WMO-No.544) continues as a companion document, however all the practices will over time be described in this manual.

5. In essence, the Manual specifies what is to be observed where and when, following what practices and procedures, in order to meet the relevant observational requirements of Members. These requirements may arise directly at a national level or collectively through WMO programmes at global or regional levels, and are expressed through the Application Areas of the Rolling Review of Requirements process. A number of other Manuals and Guides provide more detailed information about the operation of observing systems including stations and platforms, instruments and methods of observations, and the reporting and management of observations and observations metadata.

**TYPES OF REGULATION**

6. 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.

7. 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.

8. In the case of hydrological observations, there is not a widely implemented base of global exchange and global standard practices and procedures. Technical Regulations Volume III-Hydrology provides Members with predominately recommended practices and procedures to be followed. In order to help ensure the quality and comparability of observations within WIGOS, Members making their hydrological observations available through the WMO Hydrological Observing System (WHOS) must comply with the provisions set forth within this Manual. For this reason, a number of provisions listed herein which are recommended practices and procedures for hydrology in Technical Regulations Volume III – Hydrology have become standard practices and procedures, similar to efforts made by Members for the other component observing systems of WIGOS. It is recognised that some of the WIGOS standard practices and procedures might not easily be widely and quickly implemented by all Members for their hydrological observations. Nonetheless, Members are urged to make their best efforts to implement the WIGOS standard practices and procedures in the collection and exchange of hydrological observations and to make such observations available through WHOS.

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 AND ATTACHMENTS**

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 may be 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 them to be updated as necessary.

13. The words “shall” and “should” in any notes and attachments have their dictionary meanings and do not have the regulatory character of standard and recommended practices mentioned above.

**DEFINITIONS: WORK IN PROGRESS – SUBJECT TO CHANGE**

**DEFINITIONS**

The following terms, when used in the Manual on the WIGOS, have the meanings given below:

**Note:** Other definitions may be found in the Manual on Codes (WMO-No. 306), Manual on the Global Data Processing and Forecasting System, Vol. 1 (WMO-No. 485), Manual on the Global Tele­ communication System, Vol. 1(WMO-No. 386) and other WMO publications.

**Note:** definitions, terminology, vocabulary and abbreviations used in relation to quality management are those of the IOS 9000 family of standards for quality management systems, in particular those identified within ISO 9000:2005, Quality Management Systems – Fundamentals and vocabulary.

***Accuracy***. The extent to which the results of the readings of an instrument approach the true value of the calculated or measured quantities, supposing that all possible corrections are applied. (IMV)

***Accreditation.*** The formal recognition by an independent body, that the staff has been trained and have mastered the processes to meet the requirements. Accreditation is not mandatory but it adds another level of confidence, as ‘accredited’ means the certification body has been independently checked to make sure it operates according to international standards.

***Acoustic Doppler Current Profiler (ADCP).*** Hydroacoustic current meter to measure the velocity of water over a range of depths in a column using the Doppler Effect, with the overall depth of water usually being measured simultaneously.

 ***Acoustic Velocity Meter.*** System that uses the difference in travel time of acoustic (ultrasonic) pulses between transducers in a stream to determine the mean velocity on the signal path. (IGH)

***Adaptive maintenance:*** to come.

***Bank***. (1) Rising land bordering a river, usually to contain the stream within the wetted perimeter of the channel. (2) Margin of a channel at the left-hand (right-hand) side when facing downstream. (IGH)

***Cableway***. Cable stretched above and across a stream, from which a current meter or other measuring or sampling device is suspended, and moved from one bank to the other, at predetermined depths below the water surface. (IGH)

***Calibration (rating) Tank***. ***(Straight Open Tanks)***  Tank containing still water through which a current meter is moved at a known velocity for calibrating the meter. (IGH)

***Catchment Area***. Area having a common outlet for its surface runoff. (TR Vol III)

***Certification***. The provision by an independent body, generally known as an accreditation body, of written assurance (a certificate) that the product, service or system in question meets specific requirements.

***Compliance.*** May be an internal code of conduct where employees follow the principles of one of the Quality Management Standards series (such as the ISO standards) or other internationally recognized practices and procedures. It may also represent an external stamp of approval by an accreditation firm when customers or partners request documented proof of compliance.

***Confidence Level***. Probability that the confidence interval includes the true value. (IGH)

***Control***. Physical properties of a channel which determine the relationship between stage and discharge at a location in the channel. (IGH)

***Control Structures.*** Artificial structure placed in a stream such as a low weir or flume to stabilize the stage-discharge relation, particularly in the low flow range, where such structures are calibrated by stage and discharge measurements taken in the field.

**Co-sponsored observing system.** An observing system from which some but not all observations are WMO observations

***Cross-section***. Section perpendicular to the main direction of flow bounded by the free surface and wetted perimeter of the stream or channel. (IGH)

***Current meter***. Instrument for measuring water velocity. (IGH)

***Current meter, propeller type.*** A current meter the rotor of which is a propeller rotating around an axis parallel to the flow.

***Data archiving***. Storage of data on a set of catalogued files which are held in some backup storage medium and not necessarily permanently online. (IGH)

***Data processing***. Treatment of observational data until they are in a form ready to be used for a specific purpose. (IGH)

***Data quality objectives***. Define qualitatively and quantitatively the type, quality and quantity required of primary data and derived parameters to yield information that can be used to support decisions.

**Verification:** the process of establishing the truth, accuracy, or validity of something. (dictionary)

***Discharge***. Volume of water flowing through a river (or channel) cross-section per unit time. (IGH)

***Drainage basin***. (See Catchment area)

***Elevation***. Vertical distance of a point or level, on or affixed to the surface of the ground, measured from mean sea level. (IMV)

***Estuary***. Broad portion of a stream near its outlet to a sea, lake or sabkha.(IGH)

***Flood***. (1) Rise, usually brief, in the water level of a stream or water body to a peak from which the water level recedes at a slower rate. (2) Relatively high flow as measured by stage height or discharge. (IGH)

***Flood-proofing***. Techniques for preventing flood damage in a flood-prone area. (IGH)

***Gauge boards (Staff Gauge).*** Graduated vertical scale, fixed to a staff or structure, on which the water level may be read.

***Gauge datum***. Vertical distance between the zero of a gauge and a certain datum level. (IGH)

***Gauging station***. Location on a stream where measurements of water level and/or discharge are made systematically.

***GAW Station Information System (GAWSIS):*** to come.

***Hydrograph***. Graph showing the variation in time of some hydrological data, such as stage, discharge, velocity and sediment load. (IGH)

***Hydrological Forecast****.* Estimation of the magnitude and time of occurrence of future hydrological events for a specified period and for a specified locality. (IGH)

***Hydrological observation***. Direct measurement or evaluation of one or more hydrological elements, such as stage, discharge and water temperature.(IGH)

***Hydrological observing station***. Place where hydrological observations or climatological observations for hydrological purposes are made. (IGH)

***Hydrological warning***. Emergency information on an expected hydrological event which is considered to be dangerous. (IGH)

***Hydrometric station***. Station at which data on water in rivers, lakes or reservoirs are obtained on one or more of the following elements: stage, streamflow, sediment transport and deposition, water temperature and other physical properties of water, characteristics of ice cover and chemical properties of water.

***Intercomparison:*** to come.

***Interoperability***

***Lake***. Inland body of surface water of significant extent. (IGH)

***Metadata:*** to come.

***Moving-Boat Method***. Method of measuring discharge which uses a boat to traverse the stream along the measuring section and continuously measure velocity, depth and distance travelled (IGH)

***Observational data***

***Observational metadata***

***Observing station***

***Observation systems:*** to come.

***Observing system:*** to come.

***Observing Systems Capabilities Analysis and Review (OSCAR):*** to come

***Quality***. The degree to which a set of inherent characteristics fulfils requirements. (ISO 9000:2005)

***Quality Assurance***. That part of quality management focused on providing confidence that quality requirements will be fulfilled. (ISO 9000:2005)

***Quality Control.*** That part of quality management focused on fulfilling quality requirements. (ISO 9000:2005)

***Quality Management***. The coordinated activities to direct and control an organization with respect to quality. (ISO 9000:2005)

***Rating curve***. Curve showing the relation between stage and discharge of a stream at a hydrometric station. (IGH)

***Recession***. Period of decreasing discharge as indicated by the falling limb of a hydrograph starting from the peak. (IGH)

***Registration***. Certification is very often referred to as registration in North America.

***Reservoir***. Body of water, either natural or man-made, used for storage, regulation and control of water resources. (IGH)

***River***. Large stream which serves as the natural drainage for a basin. (IGH)

***Rolling Requirements Review (RRR):*** to come.

***Stage***. See water level. (IGH)

***Stage-discharge relation***. Relationship between water level and discharge for a river cross-section, which may be expressed as a curve, a table or an equation. (IGH)

***Streamflow***. General term for water flowing in a watercourse. (IGH).

***Uncertainty***. Estimate of the range of values within which the true value of a variable lies. (IGH)

***Upstream***. Direction from which a fluid is moving.

***Water level***. Elevation of the free water surface of a water body relative to a datum level. (IGH)

***WIGOS Operational Information Resource (WIR):*** A network platform and tool designed to provide WIGOS stakeholders with information on WIGOS and its observing components, as well as requirements of WMO application areas.

**1.** **INTRODUCTION TO WIGOS**

1.1 **Purpose of WIGOS**

1.1.1 The WMO Integrated Global Observing System (WIGOS) shall be a framework for all WMO observing systems and the contributions of WMO to co-sponsored observing systems. These systems will continue to be owned, managed and operated by a diverse array of organizations and programmes. The promulgation of WIGOS will advance the state of observing systems and data exchange world-wide, with additional benefits emerging as the concept is adopted by entities beyond WMO itself and its partner organizations.

1.1.2 The interoperability (including data compatibility) of WIGOS component observing systems shall be achieved through their in-common utilization and application of internationally accepted standards and recommendations. Data compatibility shall also be supported through the use of data representation standards.

1.2 **WIGOS component observing systems**

The component observing systems of WIGOS comprise the Global Observing System (GOS) of the World Weather Watch (WWW), the observing component of the Global Atmosphere Watch (GAW), the WMO Hydrological Observing Systems (including the World Hydrological Cycle Observing System (WHYCOS)) and the observing component of the Global Cryosphere Watch (GCW), including their surface-based and space-based components. The above component systems include all WMO contributions to the co-sponsored systems, as well as the WMO contributions to GFCS and GEOSS.

Note: the co-sponsored observing systems are the Global Climate Observing System (GCOS), the Global Ocean Observing System (GOOS) and the Global Terrestrial Observing System (GTOS).

1.2.2 **Global Observing System (GOS) of the WWW**

1.2.2.1 The Global Observing System shall be constituted as a coordinated system of networks of observing stations, methods, techniques, facilities and arrangements for making observations on a world-wide scale and defined as one of the main components of the World Weather Watch.

1.2.2.2 The purpose of the Global Observing System shall be to provide the meteorological observations from all parts of the globe that are required by Member countries for operational and research purposes through all WMO and co-sponsored Programmes.

1.2.2.3 The Global Observing System shall consist of a surface-based sub-system composed of regional basic networks of stations and platforms, and other networks of stations and platforms, and a space-based sub-system composed of (a) an Earth observation space segment, (b) a space-based intercalibration system, (c) an associated ground system for data reception, dissemination and stewardship, and (d) a user segment.

1.2.2.4 The Global Observing System shall be operated in accordance with the procedures and practices set out in the following sections (2, 3, 4 and 7).

1.2.3 **Global Atmosphere Watch (observing component of GAW)**

1.2.3.1 The Global Atmosphere Watch shall be a coordinated system of networks of observing stations, methods, techniques, facilities and arrangements encompassing the many monitoring and related scientific assessment activities devoted to the investigation of the changing chemical composition and related physical characteristics of the global atmosphere.

1.2.3.2 The purpose and long-term goal of the Global Atmosphere Watch (GAW) Programme shall be to provide data and other information on the atmospheric chemical composition and related physical characteristics of the background, unpolluted atmosphere, as defined in section 5, from all parts of the globe, required to reduce environmental risks to society and meet the requirements of environmental conventions, strengthen capabilities to predict the state of climate, weather and air quality, and contribute to scientific assessments in support of environmental policy.

1.2.3.3 The observing component of GAW shall consist of a surface-based system composed of networks for observation of specified variables, complemented by a space-based observations.

1.2.3.4 The Global Atmosphere Watch Programme shall be operated in accordance with the procedures and practices set out in the following sections (2, 3, 4 and 5).

1.2.4 **WMO Hydrological Observing System**

1.2.4.1 The WMO Hydrological Observing System (WHOS) comprises hydrological observations, initially focusing on water level and discharge. The composition of hydrological observations is provided in Volume III – Hydrology, Chapter D.1.2. It is expected to expand to include other elements as identified through the application of the Rolling Review of Requirements (RRR) process (specified in section 2 of this Manual) at the national, regional and global levels.

1.2.4.2 The purpose of the WHOS shall be to provide near real-time streamflow data (both water level and discharge) from as many National Hydrological Services as possible.

1.2.4.3 The WMO Hydrological Observing System shall be operated in accordance with the procedures and practices set out in the following sections (2, 3, 4 and 8).

Note: Volume III – Hydrology, the Guide to Hydrological Practices (WMO-No. 168), and the Manual on Stream Gauging (WMO-No. 1044) and other relevant manuals provide the necessary information to operate hydrological stations to prescribed standards.

1.2.5 **Global Cryosphere Watch (observing component of GCW)**

Note: The Cryosphere describes collectively the elements of the Earth System containing water in its frozen state. It shall include solid precipitation, snow cover, sea ice, lake and river ice, glaciers, ice caps, ice sheets, permafrost, and seasonally frozen ground.

1.2.5.1 The Global Cryosphere Watch (GCW) shall be a coordinated system of networks of observing stations, methods, techniques, facilities and arrangements encompassing monitoring and related scientific assessment activities devoted to the investigation of the changing Cryosphere. The Cryosphere Observing Network (CryoNet) shall build on existing Cryosphere observing programmes and promote the addition of standardized cryospheric observations to existing facilities.

1.2.5.2 The purpose and long-term goal of the Global Cryosphere Watch shall be to provide data and other information on the global Cryosphere to improve understanding of its behaviour, interactions with other components of the climate system, and impacts on society.

1.2.5.3 The Global Cryosphere Watch shall be operated in accordance with the procedures and practices set out in the following sections (2, 3, 4 and 6).

1.3 **Governance and management**

Note: WIGOS implementation is an integrating activity for all WMO and co-sponsored observing systems: it supports all WMO Programmes and activities. The Executive Council and Regional Associations, supported by their respective working bodies, have a governing role in the implementation of WIGOS. Technical aspects of WIGOS implementation are guided by the Technical Commissions, with leadership provided through CBS and CIMO. The Sixteenth WMO Congress (Cg-XVI) recorded decisions for the governance and management of WIGOS.

1.3.1 **Implementation and Operation of WIGOS**

1.3.1.1 All activities connected with the implementation and operation of WIGOS 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.

The implementation and operation of WIGOS 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.

1.3.1.2 Implementation and operation of WIGOS 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 the previous paragraph may also be used.

1.3.2 **WIGOS Quality Management**

Note: provisions relating to the WMO Quality Management Framework, WMO QMF, are provided in Volume IV (Technical Regulations, Volume IV – Quality Management (WMO-No.49, 2011 edition)). Detailed guidance on how to develop and implement a quality management system is provided in the Guide to the Implementation of a Quality Management System for National Meteorological and Hydrological Services (WMO-No.1100, 2013 edition).

1.3.2.1 Within the WMO Quality Management Framework, WIGOS provides the procedures and practices with regard to the quality of observations and observational metadata that should be adopted by Members in establishing quality management systems for the provision of meteorological, hydrological and related services.

Note: more detailed provisions relating to WIGOS Quality Management are provided in section 2.6 and, to the extent necessary, in subsequent sections.

1.4.3 **WIGOS high level processes**

1.4.3.1 Many of the WIGOS activities may be represented together as a series of high level processes.

1.4.3.2 Figure 1 provides a schematic description of the processes (horizontal bars), the collaborating entities (vertical columns) and those having primary involvement in each process (marked by solid circles). In reality the processes have more complex interrelationships and sequences than shown by the arrows – the most extreme case is the capacity development (including training) process which is not shown as a step in the sequence since it has important inputs to most of the other processes.

All the processes are ultimately carried out by Member countries through one of the following modes of collaboration:

• Data Users in Application Areas: Members collaborate by selectively contributing Application experts and information to provide the capability to undertake the relevant WIGOS process/es,

• WMO Regional Associations: Members collaborate by working together in a geographical grouping, and by selectively contributing experts for Regional teams, to undertake the relevant WIGOS process/es,

• WMO Technical Commissions: Members collaborate by selectively contributing technical experts for global teams to undertake the relevant WIGOS process/es,

• WMO Members: as individual operators and managers of observing systems, Members directly undertake the relevant WIGOS process/es,

• WMO designated Centres for performance monitoring (including Lead Centres, and Monitoring Centres): individual Members or groups of Members operate a WMO centre designated for performance monitoring, including Lead Centres or Monitoring Centres, to undertake the relevant WIGOS process/es.

1.4.3.3 In the case of WIGOS processes being undertaken by the WMO Secretariat or other entities funded by WMO Programmes, the mode of collaboration is through the overall funding and operation of the WMO.

Note: Each section of the WIGOS regulatory material is segmented into sub-sections which are generally based on the WIGOS processes. This is intended to support the implementation of the WMO Quality Management Framework which calls on Members to adopt a process-based approach in which activities are managed as processes, which is one of WMO's eight Principles of Quality Management.

For example, in section 2 the standards and recommended practices relevant to each WIGOS process can be found in the following sub-sections:

• Determination of user requirements: 2.1, 2.2

• Design, planning and evolution of WIGOS: 2.2

• Development and documentation of standards for control and best practice for observing systems: 2.3

• Implementation of systems by owners/operators: 2.3, 2.4

• Observing system operation and maintenance including fault management and audit: 2.4

• Observations quality control: 2.4, 2.6

• Observations and observational metadata delivery: 2.4, 2.5

• Performance monitoring (outputs and systems): 2.4, 2.6

• User feedback and review of requirements: 2.2, 2.6

• Capacity development (including training): 2.7

FIGURE 1: Schematic diagram of WIGOS processes (horizontal bars), the collaborating entities (vertical columns) and those having primary involvement in each process (marked by solid circles). In reality the processes have more complex interrelationships and sequences than shown by the arrows – the most extreme case is the capacity development (including training) process which is not shown as a step in the sequence since it has important inputs to most of the other processes.

**2.** **COMMON ATTRIBUTES OF COMPONENT SYSTEMS**

2.1 **Requirements**

2.1.1 Members shall take steps for collecting, reviewing, recording, and making available their observational user requirements.

Note: The reference to Members includes actions directly and through the participation of their experts in the activities of Regional Associations and Technical Commissions

2.1.2 Members shall convey their observational user requirements, for each of the WMO application areas, to the Rolling Review of Requirements (RRR) process.

Note 1: the WMO Rolling Review of Requirements (RRR) process compiles information on Members evolving requirements for observations in the application areas that directly use observations, the extent to which current and planned WMO observing systems satisfy those requirements, guidance from experts in each application area on priorities for addressing the deficiencies and opportunities in WMO observing systems, and hence plans for the future evolution of WMO observing systems (that is, WIGOS).

The Application Areas are:

• Global numerical weather prediction (GNWP)

• High-resolution numerical weather prediction (HRNWP)

• Nowcasting and very short range forecasting (NVSRF)

• Seasonal and inter-annual forecasting (SIAF)

• Aeronautical meteorology

• Atmospheric chemistry

• Ocean applications

• Agricultural meteorology

• Hydrology

• Climate monitoring (as undertaken through the Global Climate Observing System, GCOS)

• Climate applications

• Space weather

In addition, observational requirements for WMO polar activities and the Global Framework for Climate Services (GFCS) are also to be considered. The observational needs of the former application area "Synoptic meteorology" are now captured and reviewed along with those for NVSRF.

An expert is identified in each Application Area to be the Point of Contact. That expert has a very important role as the conduit to the RRR for input and feedback from the entire stakeholder community for that Application Area.

Compilation of user requirements is just one stage of the RRR process which is actually a planning process for WMO observing systems (that is, WIGOS).

A detailed and up-to-date description of the RRR is available on the WMO web site at http://www.wmo.int/pages/prog/www/OSY/GOS-redesign.html

Note 2: the observational user requirements compiled through the RRR process are stored and made available by the WIGOS Operational Information Resource (WIR) and its tool the Observing System Capability Analysis and Review (OSCAR). Details on the compilation process may be found on the WMO web site at http://www.wmo.int/pages/prog/www/OSY/GOS-RRR.html.

2.2 **Design, planning and evolution**

2.2.1 **General**

2.2.1.1 The WIGOS shall be designed as a flexible and evolving system undergoing continuous improvement.

Note: factors which drive the evolution of WIGOS component observing systems include technological and scientific progress and cost-effectiveness, changes in the needs and requirements of WMO, WMO co-sponsored Programmes and international partner organizations at national, regional and global levels, and changes in the capacity of Members to implement observing systems. It is important to identify the impact on all users before a change is made.

2.2.1.2 The WIGOS shall be constituted as a coordinated system of observing methods, techniques, facilities and arrangements for making observations on a world-wide scale to satisfy the multifaceted requirements of Members.

Note: WIGOS may be considered to consist of two subsystems: the surface-based subsystem and the space-based subsystem. WIGOS may also be considered to consist of four component observing systems: GOS (of the WWW), the observing component of GAW, WHOS and the observing component of GCW. This is explained further in section 1. For the many observing systems which contribute to WIGOS, planning and coordination may most effectively be undertaken at global, or regional or national level, or a combination of levels.

2.2.1.3 The WIGOS surface-based sub-system shall be composed of multi-purpose fixed and mobile observing stations/platforms providing observations and observational metadata for the defined application areas.

2.2.1.4 The WIGOS space-based sub-system shall comprise the following elements: an Earth observation space segment; associated ground segment for data reception, dissemination, and stewardship; and a user segment.

2.2.2 **Some Principles for Observing System Network Design and Planning**

2.2.2.1 **Observing System Network Design Principles**

Note: a set of WIGOS observing system network design (OSND) principles is in development and will be included in future editions of this Manual. The OSND principles will make reference to OSND guidance to be included in a future version of the WIGOS guide.

2.2.2.1.1 Members should conduct network design studies which address national, regional and global scale questions about the optimum affordable mix of components to best satisfy the requirements for observations.

Note: The reference to Members includes actions directly and through the participation of their experts in the activities of Regional Associations and Technical Commissions

2.2.2.2 **Climate Monitoring Principles**

2.2.2.2.1 Members operating observing systems for monitoring climate should adhere to the following principles:

1. The impact of new systems or changes to existing systems should be assessed prior to implementation.
2. A suitable period of overlap for new and old observing systems is required.
3. The details and history of local conditions, instruments, operating procedures, data processing algorithms and other factors pertinent to interpreting data (i.e., metadata) should be documented and treated with the same care as the data themselves.
4. The quality and homogeneity of data should be regularly assessed as a part of routine operations.
5. Consideration of the needs for environmental and climate-monitoring products and assessments, such as IPCC assessments, should be integrated into national, regional and global observing priorities.
6. Operation of historically-uninterrupted stations and observing systems should be maintained.
7. High priority for additional observations should be focused on data-poor regions, poorly observed parameters, regions sensitive to change, and key measurements with inadequate temporal resolution.
8. Long-term requirements, including appropriate sampling frequencies, should be specified to network designers, operators and instrument engineers at the outset of system design and implementation.
9. The conversion of research observing systems to long-term operations in a carefully-planned manner should be promoted.
10. Data management systems that facilitate access, use and interpretation of data and products should be included as essential elements of climate monitoring systems.

Note: in addition to the above provisions, operators of satellite systems for monitoring climate need to:

(a) Take steps to make radiance calibration, calibration-monitoring and satellite-to-satellite cross-calibration of the full operational constellation a part of the operational satellite system; and

(b) Take steps to sample the Earth system in such a way that climate-relevant (diurnal, seasonal, and long-term inter-annual) changes can be resolved.

These considerations give rise to the specific principles in 2.2.2.2.2.

2.2.2.2.2 Members who operate satellite systems for climate monitoring should adhere to the following specific principles:

1. Constant sampling within the diurnal cycle (minimizing the effects of orbital decay and orbit drift) should be maintained.
2. A suitable period of overlap for new and old satellite systems should be ensured for a period adequate to determine inter-satellite biases and maintain the homogeneity and consistency of time-series observations.
3. Continuity of satellite measurements (i.e. elimination of gaps in the long-term record) through appropriate launch and orbital strategies should be ensured.
4. Rigorous pre-launch instrument characterization and calibration, including radiance confirmation against an international radiance scale provided by a national metrology institute, should be ensured.
5. On-board calibration adequate for climate system observations should be ensured and associated instrument characteristics monitored.
6. Operational production of priority climate products should be sustained and peer-reviewed new products should be introduced as appropriate.
7. Data systems needed to facilitate user access to climate products, metadata and raw data, including key data for delayed-mode analysis, should be established and maintained.
8. Use of functioning baseline instruments that meet the calibration and stability requirements stated above should be maintained for as long as possible, even when these exist on decommissioned satellites.
9. Complementary in situ baseline observations for satellite measurements should be maintained through appropriate activities and cooperation.
10. Random errors and time-dependent biases in satellite observations and derived products should be identified.

2.2.3 **The Rolling Review of Requirements (RRR) Process**

Note: A detailed and up-to-date description of the RRR is available on the WMO web site under http://www.wmo.int/pages/prog/www/OSY/GOS-redesign.html.

2.2.3.1 Members, both individually and also through the participation of their experts in the activities of Regional Associations and Technical Commissions, shall contribute to the Rolling Review of Requirements (RRR) process and assist the designated Points of Contact (PoCs) for each Application Area in performing their roles in the RRR. The RRR process is illustrated schematically in Figure 2.

Figure 2: Schematic representation of the steps included in the Rolling Review of Requirements process

Note 1: the RRR process consists of four stages:

(i) a review of technology-free (that is, not constrained by any particular type of observing technology) users requirements for observations, within each of the WMO Application Areas (see section 2.1);

(ii) a review of the observing capabilities of existing and planned observing systems, both surface- and space-based;

(iii) a Critical Review, providing a gap analysis of the extent to which the capabilities meet the requirements; and

 (iv) for each Application Area, a Statement of Guidance providing recommendations on addressing the gaps.

Note 2: The role of the Points of Contact is to coordinate with their Application Area community (Technical Commission, or Programme or Co-sponsored Programme as appropriate) as needed in order to perform the following tasks:

(1) investigate whether it is appropriate to represent the Application Area in several sub-applications;

(2) submit the quantitative observational user requirements to the OSCAR/Requirements database (see www.wmo.int/oscar), review and keep up-to-date these requirements, and make changes as needed (the PoCs are provided with the required access rights);

(3) produce, review and revise the Statement of Guidance for the Application Area;

(4) review how requirements for cross cutting activities (e.g. Cryosphere, climate services) are taken into account in the user requirements database and in the SoG for the Application Area.

2.2.3.2 **Review of observational user requirements**

Note 1: this stage of the RRR is described in section 2.1.

Note 2: Regional associations examine and provide to PoCs additional detail for the compiled user requirements, taking into account the particular requirements of the Region and transboundary river basin authorities.

2.2.3.3 **Review of current and planned observing systems capabilities**

Members shall take steps for collecting, reviewing, recording, and making available current and planned capabilities of observing systems.

Note: much of the information about observing system capabilities is in the form of metadata and is to be made available for global compilation according to the provisions of section 2.5.

2.2.3.4 **The critical review**

Note: this WMO programme activity proceeds with assistance from the PoCs of the Application Areas. It compares the quantitative observational user requirements of each Application Area with the observing systems capabilities in order to identify gaps.

2.2.3.5 **Observations Impact studies**

Note: Impact studies using Observing System Experiments (OSEs), Observing System Simulation Experiments (OSSEs), Forecast Sensitivity to Observations (FSO) studies and other assessment tools are used to assess the impact of the various observing systems on Numerical Weather Prediction model analyses and predictions, hence their value and relative priority for addition or retention for the Application Areas.

2.2.3.5.1 Members, or groups of members within regions, should conduct impact studies and related scientific evaluations to address WIGOS network design questions.

2.2.3.5.2 Members should make their experts available for participating at WMO workshops for synthesizing the results of impact studies and making recommendations on the best mix of observing systems to address the gaps identified by the RRR process.

2.2.3.6 **Statements of Guidance**

Note 1: The Statement of Guidance identifies priorities for action – the most feasible, beneficial and affordable initiatives to close the identified gaps or shortcomings in WMO observing systems for an Application Area. This draws on the subjective judgement and experience of the PoC and all of the experts and other stakeholders they consult within their Application Area.

Note 2: This stage of the RRR requires the Application Area PoCs to coordinate with their Application Area community and stakeholders as needed in order to produce, review and revise the Statement of Guidance for the Application Area.

2.2.3.7 **Vision for the WIGOS**

Members shall take into account the Vision for the WIGOS when planning the evolution of their WIGOS observing networks.

Note: the Vision for the WIGOS provides high-level goals to guide the evolution of the WMO integrated global observing system in the coming decades. The Vision for the WIGOS is rewritten on a multi-year time scale (typically decadal), taking into account all of the information and guidance brought together through the RRR process, particularly the Statements of Guidance. The Vision for the WIGOS is endorsed by WMO Members through the Executive Council (EC).

2.2.3.8 **Evolution of WIGOS observing systems**

2.2.3.8.1 Members should implement the plans published by WMO for evolution of WIGOS observing systems when planning and managing their WIGOS observing systems.

Note: The planning and coordination of the evolution of WIGOS is steered by the Executive Council and undertaken by Members individually and through Regional Associations, Technical Commissions and relevant steering bodies of WMO co-sponsored observing systems.

The WMO plans for implementing the evolution of WIGOS contain clear and focused guidelines and recommended actions in order to stimulate cost-effective evolution of the observing systems to address in an integrated way the requirements of WMO programmes and co-sponsored programmes.

The WMO plans for implementing the evolution of WIGOS are regularly updated and new versions are published on a multi-year time scale (typically decadal), taking into account the Vision for the WIGOS, and the advice of Technical Commissions and Regional Associations, concerned and relevant WMO co-sponsored observing systems, and international experts in all application areas. The Rolling Review of Requirements process, including the result of impact studies, critical reviews, and the gaps identified in the Statements of Guidance is contributing to this exercise. The WMO plans for implementing the evolution of WIGOS are endorsed by WMO Members through the Executive Council (EC).

The WMO plans for implementing the evolution of WIGOS specify a set of actions to be carried out by various parties including Members, Technical Commissions, Regional Associations, and satellite operators (for example through the CGMS).

2.2.3.8.2 Members shall coordinate the response by agencies within their country, including the NMHS and other relevant agencies, in addressing relevant actions of the WMO plans for evolution of WIGOS.

2.2.3.8.3 In some cases, where member countries cover small areas and are geographically close or already have established multilateral working relationships, Members should consider taking a sub-regional or transboundary river basin, in addition to national, approach to WIGOS observing systems planning.

2.2.3.8.4 In this case, Members concerned should work in close cooperation to prepare sub-regional or transboundary river basin reviews of requirements to be used as a basis for detailed planning at that scale.

2.2.4 **Monitoring the evolution of WIGOS observing systems**

Note: The CBS, in collaboration with other Technical Commissions, Regional Associations, and Co-sponsored Programmes, regularly reviews progress of actions of the plan for evolution of WIGOS observing systems, and provides updated guidance to Members regarding the evolution of global observing systems.

Members should contribute to the monitoring of evolution of WIGOS observing systems by providing national progress reports on a yearly basis through their nominated national focal points.

2.3 **Instrumentation and Methods of Observation**

2.3.1.1 Members should employ properly calibrated instruments and sensors that provide observations satisfying at least measurement uncertainties that meet the specified requirements. Members conducting observations should employ instruments and sensors that provide data satisfying at least the measurement uncertainties described in the column „achievable“ of the Table [The Guide to Meteorological Instruments and Methods of Observation (WMO-No. 8), Part I, Annex 1.D]

Note: A number of operational, financial, environmental and instrumental issues may cause the system to not always satisfy the specified requirements, e. g. The Guide to Meteorological Instruments and Methods of Observation (WMO-No. 8), Part I, Annex 1D in the column „achievable“ provides a list of the achievable and affordable measurement uncertainties which in some cases might not satisfy specified requirements.

2.3.1.2 Members should follow the methods of observation specified in the WMO Technical Regulations and further consider methods of observation provided or referenced in WMO guidance material.

Note: For detailed guidance on instruments and methods of observation, see the Guide to Meteorological Instruments and Methods of Observation (WMO-No. 8), Weather Reporting (WMO-No. 9), Volume D – Information for Shipping, Technical regulations (WMO-No. 49), Volume III: Hydrology and the Guide to Hydrological Practices, Volume I: Hydrology – From Measurement to Hydrological Information.

2.3.1.3 Members should ensure that observations and observational metadata are traceable to International Standards (SI), where these exist.

Note: Traceability to International Standards (SI) is an area where concerted effort is required to increase-improve compliance.

2.3.1.4 Members should describe uncertainty of observations and observational metadata as defined in The Guide to Meteorological Instruments and Methods of Observation (WMO-No. 8), Part I Ch1.6.

Note 1: This will be included as an Appendix in a future edition

Note 2: The definition in The Guide to Meteorological Instruments and Methods of Observation (WMO-No. 8), Part I, Ch1.6 is consistent with approved international standards from CIPM.

2.3.1.5 Members should follow the definitions and specifications for the calculation of derived observations specified in the WMO Technical Regulations and further consider methods provided or referenced by the The Guide to Meteorological Instruments and Methods of Observation (WMO-No. 8), and the Guide to Hydrological Practices, Volume I: Hydrology – From Measurement to Hydrological Information as well as [GCOS Climate Monitoring Principles].

Note 1: Such derivations can take many forms, such a statistical processing of average or smooth values, or multivariate algorithm to determine streamflow discharge.

Note 2: This will be included as an Appendix in a future edition

2.4 **Operations**

2.4.1 **General Requirements**

2.4.1.1 Members shall implement and operate their WIGOS component observing systems in accordance with the practices, procedures and specifications set out in the Technical Regulations (WMO-No. 49), this Annex and the other relevant Manuals.

Note: Members will implement and operate their observing systems in accordance with decisions of Congress, the Executive Council, the technical commissions and regional associations concerned.

2.4.1.2 Members shall equip their observing systems with properly calibrated instruments and adequate observing and measuring techniques.

Note 1: Detailed guidance on observing practices of meteorological observing systems and instruments is given in the Guide to Meteorological Instruments and Methods of Observation (WMO-No. 8).

Note 2: Detailed guidance on observing practices of hydrological observing systems and instruments is given in the Guide to Hydrological Practices (WMO-No. 168); the Manual on Flood Forecasting and Warning (WMO-No. 1072), and the Manual on Stream Gauging (WMO-No. 519).

Note 3: Detailed guidance on observing practices of GAW observing systems and instruments is given in the Guide to Meteorological Instruments and Methods of Observation (WMO-No. 8).

2.4.1.3 Members operating the observing systems should meet the agreed requirements for uncertainty, timeliness, temporal resolution, spatial resolution, and coverage which result from the RRR process as specified in Section 2.1.

2.4.1.4 Each Member shall ensure that proper safety procedures are specified, documented and utilized in all operations of their observing systems.

2.4.1.5 Each Member shall publish a handbook of national safety practices and procedures for operation of the observing systems that stresses precautions and practices specific to the conditions in the country concerned and satisfies country specific requirements regarding legal, health and safety codes.

2.4.2 **Observing Practices**

Note: Observing practices is inclusive of station operations, data processing practices and procedures, applied calculation rules, documentation on calibration practices and associated metadata.

Members should ensure that their observing practices are adequate to comply with the observational user requirements as specified through the Rolling Review of Requirements considering both real-time and archival needs.

2.4.3 **Quality Control**

2.4.3.1 Members shall ensure observations provided through their WIGOS component observing systems are quality controlled.

2.4.3.2 Members shall implement real-time quality control prior to real-time exchange of observations via the WMO Information System.

Notes 1: Quality control on a real-time basis also takes place in the Global Data-Processing and Forecasting System, prior to the use of the meteorological and climatological observational data in data processing (i.e. objective analysis and forecasting).

Note 2: Recommended minimum standards of quality control at the level of the National Meteorological Centre 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.

Note 3: Recommended practices and procedures for quality control of hydrological observations are given in the Manual on Flood Forecasting and Warning (WMO-No. 1072), Chapter 6 and the Guide to Hydrological Practices (WMO-No. 168).

Note 4: Recommended practices and procedures regarding the quality of observations for GAW requirements are formulated in Measurement Guidelines through Data Quality Objectives.

2.4.3.3 Members shall also perform quality control of observations on a non-real-time basis, prior to forwarding the observational data for archiving.

2.4.3.4 Quality Control processes should be developed and implemented by Members as specified in the Manual on WIGOS.

Note:

Quality Control processes include (but not necessarily be limited to) where and as necessary the following processes or activities:

1. Testing of the validity of a data value against a standard reference value;

2. Testing of the validity of a data value against an alternative and representative data value;

3. Testing of the validity of a data value against scientifically derived data sample bounds;

4. Testing of the validity of a data value for temporal and spatial consistency;

5. Testing of the validity of metadata associated with data values;

6. Documentation of the results of tests applied to data values through the use of data flags, metadata parameters or other documentation; or the removal of invalid data from data products or messages.

2.4.4 **Data and Metadata Reporting**

2.4.4.1 Members shall report and make available observations in standard formats specified by Annex II to the Technical Regulations (Manual on Codes (WMO-No. 306)) or as advised by GAW data centres, in accordance with … (the ref. will come here to the Part of the Manual on WIGOS – observation requirements for international exchange).

Note: Members are to report and make available up-to-date WIGOS core metadata as specified in Section 2.5.2.

2.4.5 **Incident Management**

2.4.5.1 Members should implement incident management to detect, identify, record, analyze and respond to any incident for restoring a normal observing system operation as quickly as possible, minimizing the negative impact, and preventing a future re-occurrence.

2.4.5.2 Members shall implement procedures to detect, analyze and respond to system faults and human errors at the earliest stage possible.

2.4.5.3 Members should record and analyze incidents as appropriate.

2.4.6 **Change Management**

2.4.6.1 Members should carefully plan and control changes to ensure continuity and consistency of observations and record any modification related to the observing system.

Note: This requirement relates to any change in the observing system, including an observing station, observing programme, instruments, methods of observation, etc.

2.4.6.2 In the case of significant changes in instruments or methods of observation used or the location in which observations are made, Members should ensure for a sufficiently long period (to capture all expected climatic conditions) of overlap with dual operation of old and new systems to identify biases, inconsistencies and inhomogeneities.

2.4.7 **Maintenance**

2.4.7.1 Members shall ensure that each observing system is rigorously maintained.

2.4.7.2 Members shall perform regular preventive maintenance of their observing systems including their instruments.

Note: Well organized preventive maintenance of all system components is recommended to minimize corrective maintenance and to increase the operational reliability of an observing system.

2.4.7.3 Members shall determine the frequency and timing (schedule) of the preventive maintenance taking into account the type of the observing system, environmental and climate conditions of the observing site, and the instrumentation installed.

2.4.7.4 Members shall perform corrective maintenance in case of observing system component fault as soon as practically possible once the problem has been detected.

2.4.7.5 Members shall employ adaptive maintenance that satisfies the requirements for stability, continuity and consistency of observations through time.

Note: Detailed guidance on maintenance of observing systems and instruments is given in the Guide to Meteorological Instruments and Methods of Observation (WMO-No. 8) including all of the GAW measurement guides as referenced in Chapter 16, the Guide to Hydrological Practices (WMO-No. 168) and the Manual on Stream Gauging (WMO-No. 1044).

2.4.8 **Inspection**

Members shall arrange periodic inspection of their observing systems.

Note: Such inspection could be undertaken directly or remotely as necessary to monitor correct functioning of observing platform and instruments.

2.4.9 **Calibration procedures**

2.4.9.1 Members shall ensure that measurement systems and instruments are calibrated regularly in accordance with adequate procedures to each type of system and instrument, as described in the relevant parts of this Manual.

Note 1: Where international or national standards are not available, the basis for calibration is defined or supplied by the manufacturer or by the Scientific Advisory Groups for GAW observations.

Note 2: Detailed guidance on calibration procedures is given in the Guide to Meteorological Instruments and Methods of Observation (WMO-No. 8), the Guide to Hydrological Practices (WMO-No. 168) and the Manual on Stream Gauging (WMO-No. 1044).

Note 3: In the GAW Programme, World Calibration Centres perform the audit of the stations and required that every laboratory is traceable to the single network standard.

2.4.9.2 Each Member shall ensure that the measuring devices are:

(a) Calibrated or verified at specified intervals, or prior to use, against measurement standards traceable to international or national measurement standards. Where no such standards exist, the basis used for calibration or verification [shall/should] be recorded.

(b) Adjusted or readjusted as necessary, but at the same time safeguarded from adjustments that would invalidate the measurements;

(c) Identified, enabling the calibration status to be determined; and

(d) Protected from damage and deterioration during handling, maintenance and storage.

Note: Detailed guidance is given in the Guide to Meteorological Instruments and Methods of Observation (WMO-No. 8), WMO Technical Regulations Volume III – Hydrology (WMO-No. 49), the Guide to Hydrological Practices (WMO-No. 168) and the Manual on Stream Gauging (WMO-No. 1044).

2.4.9.3 When the equipment is found not to conform to requirements, the Member shall assess and record the validity of previous measuring results, and take appropriate action on the equipment and the products affected.

2.4.9.4 Each Member shall record and maintain the results of calibration and verification.

**2.5 OBSERVATIONAL METADATA: WORK IN PROGRESS – SUBJECT TO CHANGE**

**2.5. Observational Metadata**

**2.5.1 Purpose and scope**

Note 1: Observational metadata are essential as they enable users of observational data to assess the suitability of the data for the intended application.

Note 2: Discovery metadata, defined in the Manual on WIS (WMO-No 1060), are concerned with discovering and accessing information, including observations and their observational metadata. Requirements for discovery metadata are specified in the Manual on WIS (WMO-No. 1060) and are not considered further here.

2.5.1.1 For all WIGOS observations they provide, Members shall record and retain the observational metadata specified as mandatory in the WIGOS Core Metadata standard in Appendix 2.1 of this Manual

Note: The WIGOS Core Metadata standard defines a common set of requirements for elements to be provided in observational metadata and is specified in the Appendix 2.1 of this Manual. The standard includes a detailed list of mandatory, conditional and optional metadata for each WIGOS component observing system.

2.5.1.2 For all WIGOS observations they provide, Members shall record and retain the observational metadata specified as conditional in the WIGOS Core Metadata standard in Appendix 2.1 of this Manual whenever the related condition is met.

2.5.1.3 For all WIGOS observations they provide, Members should record and retain the observational metadata specified as optional in the WIGOS Core Metadata standard in Appendix 2.1 of this Manual.

Note 1: Any further requirements for observational metadata beyond the Core Metadata standard that apply to observing components of WIGOS are stated in the relevant chapters of this Manual.

Note 2: Further guidance on metadata, and on sound metadata practices, is provided in Guides and guidance documentation associated with the individual observing system components.

**2.5.2 Exchanging and archiving observational metadata**

2.5.2.1 Members shall make available internationally and without restriction, those mandatory observational metadata supporting observations that are made available internationally.

2.5.2.2 Members making observations available internationally shall retain and make available, without restriction, observational metadata for at least as long as they retain the observations described by the observational metadata.

2.5.2.3 Members making available internationally archived observations shall ensure that all WIGOS Core Metadata describing the observations remain available, without restriction, for at least as long as the observations are retained.

2.5.2.4 Members making available internationally archived observations should ensure that any additional observational metadata describing the observations remain available, without restriction, for at least as long as the observations are retained.

**2.5.3 Global compilation of observational metadata**

2.5.3.1 Members shall make available to WMO for global compilation those components of the WIGOS core metadata which are specified in Appendix 2.1

Note: global compilations of WIGOS core metadata are held in several databases. The Observing Systems Capabilities Analysis and Review tool (OSCAR) database of the WIGOS Operational Information Resource (WIR) is the key source of information for WIGOS metadata, providing a record of some current and historical WIGOS metadata and providing a portal to other WIGOS metadata. Other global compilations of specific components of WIGOS metadata include elements of the GAWSIS, the JCOMM Ops database and others. Appendix 2.1 specifies which components of the WIGOS core metadata are to be made available for inclusion in OSCAR. Purposes and management of WIGOS Operational Information Resource (WIR) and OSCAR are described in Attachment 2.1

2.5.3.2 For all WIGOS component observing systems they operate, Members shall keep the relevant WMO observational metadata databases updated with the required WIGOS metadata.

Note: the mechanisms for making metadata available for global compilation will be documented and managed by the WMO Secretariat, including timeliness, content and formatting.

2.5.3.3 Members shall routinely monitor the content of WIGOS metadata databases, and provide feedback to WMO on noted discrepancies, possible errors, and required changes with respect to the WIGOS component observing systems they operate.

2.5.3.4 Members shall designate national focal points responsible for making available metadata and monitoring content of WMO observational metadata databases, and inform the Secretariat accordingly.

2.5.3.5 Members delegating the responsibility of the national focal point for all or part of the observing networks they operate to a global or regional entity, shall inform the Secretariat accordingly.

**Appendix 2.1**

**The WIGOS Core Metadata Standard**

*General*

This Appendix refers to the WIGOS Core Metadata Standard, which consists of the necessary observational set of metadata elements to be provided. They are required for the effective interpretation of observations from all WIGOS observing sub-systems by all data users, allowing them to access important information about why, where, and how an observation was made, and how the raw data were processed and what the quality of the data is.

The tables below present categories (or groups) of metadata, each containing one or more elements. Each element is classified (using the same terminology as is used by ISO) as either mandatory (M), conditional (C), or optional (O). Additional columns are included in the table to show the perspectives of several specific stakeholder groups (WMO Programme or Technical Commission).

The subsequent tables present the condition or conditions that apply to each conditional metadata element.

*“Specifications”*

Mandatory metadata elements shall always be reported. The content of the corresponding fields shall never be empty, either the metadata “value” or the reason for no-value, shall be reported.

Conditional metadata elements shall be reported when the specified condition or conditions are met, in which case the content of the corresponding fields shall never be empty, either the metadata “value” or the reason for no-value, shall be reported.

Optional metadata elements should be reported. They provide useful information that can help to better understand an observation. As is to be expected for a ‘core’ metadata standard, very few elements are considered optional. Optional elements are likely to be important for a particular community, but less so for others.

| **Classification of metadata elements as either (M) Mandatory, (C) Conditional, or (O) Optional** | **Perspective of several specific stakeholder groups (WMO programme or Technical Commission)** |
| --- | --- |
| **GAW** | **CIMO** | **CHy** | **JCOMM** |  |  |  |  |
| **1** | **Observed Quantity**The specification of a measurand requires knowledge of the kind of quantity, description of the state of the phenomenon, body, or substance carrying the quantity, including any relevant component, and the chemical entities involved. [VIM3, 2.3]. |
| 1-01 | Name of observed quantity, **measurand** | **M** | M | M | M | M |  |  |  |  |
| 1-02 | **measurement unit,** unit of measurement | **M** | M | M | M | M |  |  |  |  |
| 1-03 | **temporal extent** of observed quantity | **M** | M | O | M | M |  |  |  |  |
| 1-04 | **spatial extent** of observed quantity | **M** | M | M | M | M |  |  |  |  |
| 1-05 | Volume/Area/catchment represented by observed value | **M** | M | M | M | M |  |  |  |  |
| 1-06 | observed medium | **M** | M | M | M | M |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  |
| **2** | **Purpose of observation**Specifies the main application area of an observation and the observation program an observation is affiliated to. |
| 2-01 | Application area(s) | **M** | M | M | M | M |  |  |  |  |
| 2-02 | Network affiliation | **M** | M | M | M | M |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  |
| **3** | **Data quality**Specifies the data quality and traceability of an observation or dataset |
| 3-01 | uncertainty of measurement | **C** | C | O | C | C |  |  |  |  |
| 3-02 | Reference to procedures used | **C** | C | O | C | C |  |  |  |  |
| 3-03 | quality flags | **C** | C | O | C | M |  |  |  |  |
| 3-04 | quality flagging system | **C** | C | O | C | M |  |  |  |  |
| 3-05 | traceability chain | **M** | M | O | O | M |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  |
| 4 | **Environment** - Specifies the geographical setting within which an observation was made |
| 4-01 | land cover | **C** | M | M | O | C |  |  |  |  |
| 4-02 | land cover classification scheme | **C** | M | C | O | C |  |  |  |  |
| 4-03 | topography | **C** | M | O | O | C |  |  |  |  |
| 4-04 | Factors affecting discharge | **C** | n/a | N/A | M | C |  |  |  |  |
| 4-05 | Site information | **O** | O | O | O | O |  |  |  |  |
| **5** | **Data processing**Specifies how raw data are transferred into the reported physical quantities |
| 5-01 | data processing methods and algorithms | **C** | M | C | C | C |  |  |  |  |
| 5-02 | Processing/analysis centre (eg chemical analysis, transform to physical variables) | **C** | M | C | C | C |  |  |  |  |
| 5-03 | Reporting interval (time/space) | **M** | M | M | M | M |  |  |  |  |
| 5-04 | software/processor and version | **C** | O | C | C | C/O |  |  |  |  |
| 5-05 | level of data | **C/O** | O | O | O | C/O |  |  |  |  |
| 5-06 | data format  | **M** | M | M | M | M |  |  |  |  |
| 5-07 | version of data format | **M** | M | M | M | M |  |  |  |  |
| 5-08 | Definition of time stamp | **M** | M | M | M | M |  |  |  |  |
| 5-09 | Aggregation interval | **M** | M | M | M | M |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  |
| 6 | **Sampling and analysis**Specifies how the observation was made or a specimen collected |
| 6-01 | Sampling procedures | **O** | O | O | O | O |  |  |  |  |
| 6-02 | Sample treatment | **O** | O | O | O | O |  |  |  |  |
| 6-03 | Sampling strategy | **M** | M | O | M | M |  |  |  |  |
| 6-04 | Sampling time period | **M** | M | O | M | M |  |  |  |  |
| 6-05 | Meaning of the time stamp | **M** | M | O | M | M |  |  |  |  |
| 6-06 | Spatial sampling resolution | **C** | C | C | O | C |  |  |  |  |
| 6-07 | Analytical procedures | **O** | O | O | O | O |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  |
| 7 | **station/platform**Environmental monitoring facilities, including fixed stations, moving equipment or remote sensing platforms, at which an observed quantity is measured using an instrument. |
| 7-01 | Region of origin of data | **C** | M | C | C | C |  |  |  |  |
| 7-02 | Country of origin of data | **C** | M | C | C | C |  |  |  |  |
| 7-03 | Platform/station type | **M** | M | M | M | M |  |  |  |  |
| 7-04 | Platform/station model | **O** | O | O | O | O |  |  |  |  |
| 7-05 | Station unique identifier | **M** | M | M | M | M |  |  |  |  |
| 7-06 | geospatial location (cf. 1-04) | **C** | M | O | C | C |  |  |  |  |
| 7-07 | Data Communication Method | **O** | O | O | O | O |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  |
| 8 | **Instrument**Specifies characteristics of the instrument used to make the observation |
| 8-01 | Measurement principle | **M** | M | M | M | M |  |  |  |  |
| 8-02 | Instrument performance characteristics | **M** | M | M | O | M |  |  |  |  |
| 8-03 | Vertical distance of instrument above/below reference surface and type of surface | **C** | C | M | O | C |  |  |  |  |
| 8-04 | Exposure of instruments | **C** | M | C | O | C |  |  |  |  |
| 8-05 | environment of instrument | **C** | M | C | O | C |  |  |  |  |
| 8-06 | Instrument lab calibration date and time | **M** | M | C | M | M |  |  |  |  |
| 8-07 | instrument model and serial number | **M** | M | M | M | M |  |  |  |  |
| 8-08 | instrument field maintenance  | **M** | M | C | M | M |  |  |  |  |
| 8-09 | instrument field verification with date/time | **M** | M | O | M | M |  |  |  |  |
| 8-10 | geospatial location of instrument/sensor when different to the station/platform | **C** | C | C | C | C |  |  |  |  |
|  | **Ownership and data policy**Specifies who is responsible for the observation and owns it |
| 9-01 | supervising organization | **M** | M | M | M | M |  |  |  |  |
| 9-02 | data policy/use constraints | **M** | M | M | M | M |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  |
| 10 | **Contact**Specifies where information about an observation or dataset can be obtained |
| 10-01 | Contact (Nominated Focal Point) | **M** | M | M | M | M |  |  |  |  |

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**Attachment 2.1**

**The WIGOS Operational Information Resource (WIR)**

 **Purpose of the WIR**

The WMO Integrated Global Observing System (WIGOS) Operational Information Resource (WIR) is a tool designed to provide WIGOS players/ stakeholders (observing network decision makers / managers / supervisors, implementation coordination groups, observational data users) with all relevant information on the operational status and evolution of WIGOS and its observing components, the operational requirements of WIGOS, including standards / best practices used in the WIGOS framework, and their capabilities to meet observational user requirements of the WMO Application Areas. The WIR serves a number of purposes, and brings the following benefits to WMO Members:

(i) To provide general information on WIGOS, its benefits to Members, and the impacts on Members of addressing WIGOS requirements;

(ii) To provide an overall description of the WIGOS component observing systems that are currently in place (list of observing networks / stations, their characteristics/metadata including information on observational products they deliver);

(iii) To monitor the evolution of the observing systems and compare this with the plans, to ascertain progress;

(iv) To outline existing national and regional plans for evolution of WIGOS component observing systems;

(v) To assist Members and those in charge of observing network design and implementation to understand the requirements for the relevant observing systems, including standards and recommended practices and procedures, and observational user requirements, in order for them to make appropriate decisions;

(vi) To assist Members to identify observational gaps through critical review and to conduct network design studies, in order for them to address those gaps;

(vii) To assist Members to understand the full potential of the current observing systems with regard to the WMO Application Areas, including those systems operated by partner organizations, to enhance (a) the scope and availability of observations made by specific observing stations, (b) collaborations, (c) data sharing, and (d) data exchange;

(viii) To provide data users with immediate access to the list of WIGOS component observing systems, with a basic set of observational metadata for each (specified by WMO Technical Regulations), and with links to the appropriate national databases where more detailed information is available in those cases where such databases exist;

(ix) To provide developing countries with guidance on observing network implementation, and tools they can readily use to document their own observing systems (e.g. by using the OSCAR tool of the WIR, they could avoid the need to develop a database nationally); and

(x) To provide a mechanism for matching specific needs (capacity building, gaps, etc) with resources (via knowledge sharing, donor contributions etc).

Note 1: Observing stations refer to all types of observing sites, stations, and platforms relevant to WIGOS, whether they are surface-based, or space-based, on land, at sea/lake/river, or in the air, fixed, or mobile (incl. in the air), and making in-situ or remote observations.

 Note 2: Gaps are expressed in terms of required space/time resolution, observing cycle, timeliness, and uncertainty for the WMO Application Areas

 **The Observing Systems Capabilities Analysis and Review tool (OSCAR)**

The Observing Systems Capabilities Analysis and Review tool (OSCAR) of the WIR is a key source of information for WIGOS metadata. The surface- and space-based capabilities components of the OSCAR is intended to record observing platform metadata according to the WIGOS core metadata profile described in the WIGOS Manual, and to retain a record of the current and historical WIGOS metadata.

 **Management of OSCAR**

The management of OSCAR (i.e. functional specifications and their evolution, and information content management) and its components is overseen by the WMO Secretariat in liaison with relevant expert groups and bodies, and in accordance with the WIGOS agreed upon standards and procedures.

 **OSCAR content management**

The OSCAR will be managed to provide the availability needed to address its purpose. WIGOS metadata is maintained under the authority of the observing systems owners, and of the Permanent Representatives for WMO owned component observing systems.

The operator of OSCAR will collect feedback from Members on noted discrepancies, possible errors, and required changes, so that the OSCAR information content reflects the reality of the Surface and space-based capabilities of the observing platforms they operate, including instrument/platform metadata.

The WMO Secretariat is responsible to coordinate management of the information content of OSCAR, with assistance from designated experts and focal points.

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**2.6. Quality Management**

Note 1: This section defines provisions for WIGOS quality management as a component of and in compliance with the WMO Quality Management Framework (QMF), Technical Regulations, Volume IV – Quality Management, WMO-No.49, 2011 edition).

Note 2: The provisions of section 2.6 are common to all component observing systems of WIGOS. Further provisions for quality management specific to a WIGOS sub-system or a WIGOS component observing system appear in sections 3, 4, 5, 6, 7 and 8.

Note 3: Provisions relating to the WMO Quality Management Framework, WMO QMF, are provided in Volume IV (Technical Regulations, Volume IV – Quality Management (WMO-No.49, 2011 edition)). Detailed guidance on how to develop and implement a quality management system (QMS) is provided in the Guide to the Implementation of a Quality Management System for National Meteorological and Hydrological Services (WMO-No.1100, 2013 edition).

Note 4: A QMS can only be implemented by the body which has the resources and the mandate to manage the observing system. While for consistency with the WMO QMF, it is Members who are urged to follow the recommended practices associated with implementation of a QMS, in practice it is one or more organisations within the Member’s country that own and operate observing systems and provide observations and observational metadata, most notably the NMHS. In practice, then, implementation of the WMO QMF relies on the Member making arrangements for such organisations to implement a QMS.

Note 5: definitions, terminology, vocabulary and abbreviations used in relation to quality management are those of the ISO 9000 family of standards for quality management systems, in particular those identified within ISO 9000:2005, Quality Management Systems – Fundamentals and vocabulary.

**2.6.1 Scope and Purpose of WIGOS Quality Management**

WIGOS procedures and practices with regard to the quality of observations and observational metadata shall be a component of the WMO Quality Management Framework (QMF) (Technical Regulations, Volume IV – Quality Management (WMO-No.49, 2011 edition), which provides a comprehensive system of recommended procedures and practices, with regard to the quality of data, products and services.

**2.6.2 WIGOS Component of the WMO Quality Management Framework**

Members should comply with the WMO QMF for applying a Quality Management System (QMS) to their observing systems.

Note 1: The WMO QMF provides guidance for QMS implementation based on the requirements of the ISO Standard ISO 9001: Quality Management System – Requirements.

Note 2: A Quality Management System (QMS) is defined in the Guide to the Implementation of a Quality Management System for National Meteorological and Hydrological Services (WMO-No.1100, 2013 edition) as the organizational structure, procedures, processes and resources needed to develop and successfully implement management for the delivery of its products and services.

**2.6.2.1 Quality Policy**

2.6.2.1.1 In the establishment and maintenance of WIGOS observing systems, Members should adopt a policy of ensuring optimum affordable quality for all observations and observational metadata.

2.6.2.1.2 Members should adopt a policy to endeavour, through a process of continual improvement, to pursue effective and efficient management and governance of observing systems in order to best meet user requirements for observational data.

**2.6.2.2 Application of the eight Principles of Quality Management**

Members should apply the eight Principles of Quality Management of the WMO QMF to the implementation of WIGOS as follows:

1. User/client focus: Members should identify, document and understand the current and future needs of their users and clients for meteorological, climatological, hydrological, marine and related environmental observations and observational metadata. The means to achieve this includes participation in and the application of the WMO Rolling Review of Requirements (RRR) process (see section 2.2);

2. Leadership: The relevant WMO Technical Commissions provide technical guidance and leadership for the implementation of WIGOS. They provide information on WIGOS goals and directions, and stimulate the active involvement of technical experts from Member countries. In turn, Members should clearly define the goals and directions of their observing systems and create an environment in which staff are encouraged to work in that direction;

3. Involvement of people: Members of Technical Commissions and Regional Associations, and experts from Member countries, should be fully involved in the implementation of regulations pertaining to WIGOS quality management, as a component of the WMO QMF and the quality management systems of Members;

4. Process approach: the desired results are achieved more efficiently when a process-based approach to management of observing systems is adopted;

5. System approach to management: Operators and managers of WIGOS observing systems should identify, understand and manage such systems as sets of processes that may be operational, scientific or administrative, with the overall objective of producing the required observations and observational metadata outputs;

6. Continual improvement: Continual improvement, resulting in the outcome of improving either the quality of observations or the efficiency of observing systems, should be an integral and permanent component of WIGOS observing systems and should be implemented through a range of processes and activities that include: active participation in the WMO RRR; auditing of observing systems and sites; data quality monitoring and evaluation, and ensuring routine consultation with, and review of feedback from, WIGOS users and Application Areas, primarily through the WMO Rolling Review of Requirements;

7. Factual approach to decision making: Decisions, requirements and regulations associated with the design, development, implementation, operation, maintenance and evolution of WIGOS observing systems should be based on scientifically, factually and analytically derived information that will be available to Members through tools such as the WMO RRR, the WIGOS Information Resource (WIR), the Observing Systems Capability Analysis and Review (OSCAR) tool, and through WMO endorsed planning documents such as the Implementation Plan for Evolution of Global Observing Systems and others;

8. Mutually beneficial supplier relationships: All WMO constituents and working bodies associated with WIGOS should be encouraged to participate in, and share with each other and with suppliers information and results on tests, trials and inter-comparisons of instruments and systems, for the mutual benefit of both WIGOS and suppliers. Suppliers of instruments, systems and related products should be evaluated and selected on the basis of their ability to meet requirements and on the past performance of their products and services.

**2.6.3 WIGOS Quality Management Processes**

Note: The processes and roles of various entities depicted in the process map shown in section 1, Figure 1 provide the context for WIGOS quality management.

2.6.3.1 **Determination and Maintenance of User Requirements**

Note: WMO RRR process for compiling observation user requirements are described in sections 2.1 and 2.2. The contribution of Members to this process provide support for WIGOS Quality Management.

2.6.3.2 **Development and Documentation of Standards for Control and Best Practice for Observing Systems**

Members should participate in the development of standards and recommendations for the operation and maintenance of WIGOS observing systems.

Note: According with the provisions of the Basic Documents No. 1 (WMO No. 15, Annex III,) WMO Technical Commissions are responsible for coordinating with Regional Associations and Members, the development, maintenance and documentation of WMO recommended standards for methods, procedures, techniques and practices. These are documented in the Technical Regulations and its Annexes, as well as other manuals, guides and technical documents.

2.6.3.3 **Training of Personnel and Capacity Development**

Note 1: Training and capacity development are key elements of WIGOS quality management. Relevant provisions are specified in 2.7.

Note 2: According with the provisions of the Basic Documents No. 1 (WMO No. 15, Annex III), WMO Technical Commissions, Regional Associations and Members have the role of coordinating the development and provision of training materials and activities for Members.

Members, individually and through TCs and RAs should ensure that training material and courses include topics for WIGOS and application of the WMO Quality Management Framework.

2.6.3.4 **Performance Monitoring**

Note: According with the provisions of the (Basic Documents No. 1 (WMO No. 15, Annex III DL) WMO Technical Commissions may be responsible for the development of standards and practices for international monitoring of observations quality and observing system performance. Members, regional centers or other organizations may be designated and agree to serve as a centre for performance monitoring of WIGOS observations or systems.

Members should use the results, advice and reports of designated monitoring centers and any subsequent advice of expert groups as an integrated component of their quality management practices.

2.6.3.5 **Feedback, Change Management and Improvement**

2.6.3.5.1 Members should be aware of requirements for continuity of observations and endeavour to ensure that systems are designed, implemented and maintained so as to optimally comply with such requirements.

Note: Many users of WIGOS observational data will either specifically or implicitly define requirements for continuity of the making, provision and retention of observations.

2.6.3.5.2 Members should ensure that systematic issues identified by WIGOS Lead and Monitoring Centers that impact adversely on the quality of WIGOS observations and observing systems are rectified in a timely manner and that a process for documentation of such issues and their rectification is implemented and maintained.

2.6.3.5.3 Members should, upon identification or notification of systematic issues that impact adversely on the quality of WIGOS observations, undertake analysis of the nature of such issues and implement necessary improvements to operational practices and procedures so as to eliminate or reduce the frequency of occurrence of such issues.

2.6.3.5.4 Members should ensure that changes to operational practices and procedures are documented.

**2.6.4 WIGOS aspects of the Development and Implementation of the QMS of Members**

Note 1: This section specifies requirements for the integration of WIGOS standards, practices and procedures into the QMS of Members. The requirements are based on the eight clauses of the ISO 9001 standard, which have the following headings:

1. Introduction

2. Scope

3. Normative Reference

4. Terms and Definitions

5. Quality Management System

6. Management Responsibility

7. Resource Management

8. Product Realization

9. Measurement, Analysis and Improvement

Note 2: the Guide to the Implementation of a Quality Management System for National Meteorological and Hydrological Services (WMO-No.1100, 2013 edition) provides extensive explanatory notes about the eight clauses of the ISO 9001 standard. The eight clauses define the quality management requirements which need to be reflected in the structure and content of the quality management system.

Note 3: in order to fully implement a QMS, Members need to follow the provisions of the Technical Regulations, Volume IV – Quality Management (WMO-No.49, 2011 edition)) and the detailed guidance on how to develop and implement a quality management system which is provided in the Guide to the Implementation of a Quality Management System for National Meteorological and Hydrological Services (WMO-No.1100, 2013 edition).

**2.6.4.1 General requirements for the content of a QMS**

Members should identify at a high level their processes and their interactions which together lead to the provision of observations and observational metadata, for example by composing a diagram of process flows from start to finish.

Note: in addition to these WIGOS specific provisions, there are many other general requirements for the content of a QMS which are not specific to WIGOS observations and observational metadata, hence are not repeated here.

**2.6.4.2 Requirements related to management and planning**

2.6.4.2.1 Members should clearly demonstrate and document their management commitment to the integration of WIGOS quality management practices within their QMS.

2.6.4.2.2 Members should carefully identify and routinely review user requirements for observations and observational metadata prior to attempting to meet user needs.

2.6.4.2.3 Members should ensure that their published quality policy is consistent with the WIGOS quality policy (refer to section 2.6.2.1).

2.6.4.2.4 Members should establish and make known objectives for their future provision of observations and observational metadata so as to provide guidance to stakeholders, users and clients on the expected evolution of and changes to the observing systems that they operate as a contribution to WIGOS.

Note: The objectives referred to in this provision constitute the WIGOS quality objectives.

2.6.4.2.5 Members should appoint a quality manager to ensure that the QMS is maintained, promoted and incorporates the quality management requirements for WIGOS.

**2.6.4.3 Requirements related to resource management**

2.6.4.3.1 Members should determine and provide the resources needed to maintain and continually improve the effectiveness and efficiency of the processes and procedures of WIGOS quality management as a component of their QMS.

2.6.4.3.2 Members should define the competencies required of staff involved in the provision of observations and observational metadata.

2.6.4.3.3 Members should take steps to rectify any competency shortcomings identified for new or existing employees.

2.6.4.3.4 Members should implement policies and procedures to maintain the infrastructure and work environment required for the provision of observations and observational metadata.

**2.6.4.4 Requirements related to the provision of observations and observational metadata**

2.6.4.4.1 Members should undertake sound planning for the provision of observations and observational metadata, which should incorporate the following activities and processes:

1. Determination and continuous review of user/client requirements;
2. The translation of user/client requirements into objectives and targets for observations and observing system design;
3. Initial and ongoing allocation of adequate resources for all aspects of the design, implementation and maintenance processes of observing systems;
4. Implementation of design processes and activities, including communication strategies and risk management, that will ensure and confirm the development and implementation of observing systems that meet objectives and user/client requirements; and,
5. Appropriate and ongoing documentation of planning processes and their results.

2.6.4.4.2 Members should identify their users and establish and document their users' requirements for observations and observational metadata.

Note 1: The means for doing this include:

i. The WMO Rolling Review of Requirements (RRR) process, described in section 2.2

ii. Other processes to establish user requirements within WMO programmes through the activities of WMO Technical Commissions;

iii. Regional processes through the activities of WMO Regional Associations and other multi-lateral groupings of Members: and,

iv. National processes.

Note 2: It is important to note the difference between aspirational requirements and agreed requirements. Once requirements are established, this will provide essential information for the monitoring and measurement of conformance.

2.6.4.4.3 Members should have a clear description of the requirements that are agreed upon and have or endeavour to develop the capability to deliver these requirements.

2.6.4.4.4 Members should identify and adhere to any statutory or regulatory requirements in relation to the provision of observations and observational metadata.

2.6.4.4.5 Members should design and develop, or otherwise implement, observing systems to satisfy the agreed user requirements.

Note: The means to do this include:

i. participation in and application of the RRR process and implementation of the resulting plans;

ii. the application of and integration into national processes of relevant WMO guidance and best practice for observing system planning and design; and,

iii. the application and implementation of the outcomes of national and regional design and planning activities.

2.6.4.4.6 Members should use a formal change management process, including the maintenance of records and observational metadata, to keep track of all changes made to observing systems, aiming to ensure that all changes are assessed, approved, implemented and reviewed in a controlled manner. Details about the change management process are provided in section 2.4.

2.6.4.4.7 Members should conduct purchasing in a controlled manner.

Note: observing systems often require large expenditure and are highly specialized, and that clear and concise specifications are needed. Staff responsible for purchasing orders or for providing information to suppliers must ensure that the information and specifications provided are clear, unambiguous and based on meeting the design objectives and system requirements to enable the supply of the appropriate and correct products and services. The undertaking of purchasing in a controlled manner entails application of the following activities and processes:

i. Undertaking written specification of all performance requirements for equipment and/or services;

ii. Ensuring that purchasing is subject to a competitive process of more than one candidate for supply of equipment or services;

iii. Assessment of candidates for supply of equipment or services based on merit and suitability for purpose, which can be discerned from:

a. Written tendering or quotation of candidates;

b. Experience or reliable anecdotal evidence of past performance: and,

c. Recommendation of Member or recognized organizations and agencies; and,

iv. Documentation of the purchasing process and outcomes.

2.6.4.4.8 Members should include in their QMS the provisions of sections 2.3, 2.4 and 2.5 relating to the detailed requirements for WIGOS observations and observational metadata, covering all associated activities and processes including methods of observation, calibration and traceability, operational practices, maintenance.

Note: Observations and observational metadata need to be checked as they are produced to ensure they meet the agreed requirements. The means to do this include automated algorithms and manual inspection and oversight.

2.6.4.4.9 Members should ensure that practices and procedures that have been put in place to ensure that observations and observational metadata remain accurate and continue to meet the requirements of users, are applied consistently. The means to do this include the application of those provisions made in the following section.

Note: the means to do this include the application of those provisions made in the following section.

**2.6.4.5 Requirements for monitoring, performance measurement, analysis and improvement**

2.6.4.5.1 Members should use the agreed user requirements for observations and observational metadata (see 2.6.4.3) as a basis to define and implement appropriate measures of performance and success.

Note: It is important to gain a clear understanding of how satisfied users are with observations and observational metadata. It requires the monitoring of information relating to users’ perception and whether their expectations have been met. Surveys are commonly used for this purpose.

2.6.4.5.2 Members should implement activities to gain information on the satisfaction of users of observations and observational metadata.

2.6.4.5.3 Members should ensure that staff are made aware of the methods that have been employed for determining user perceptions and expectations and that they are applied consistently.

2.6.4.5.4 Members should regularly conduct and analyse the result of internal audits of WIGOS processes and procedures as part of the management processes of the observing system.

Note: A detailed explanation on the requirements of the internal audit process can be found on page 24 in the Guide to the Implementation of a Quality Management System for National Meteorological and Hydrological Services.

2.6.4.5.5 Members should monitor the degree of adherence to the defined processes and requirements for producing observations and observational metadata.

Note: Ideally performance monitoring will be conducted against specific Key Performance Indicators and target levels of performance.

2.6.4.5.6 Members should monitor and measure the fitness for purpose and the quality of their observations and observational metadata as they are produced in order to compare their characteristics with the agreed requirements.

Note: The means to do this include:

i. the devising, implementation and routine analysis of manually or automatically generated Key Performance Indicators and their associated targets; and,

ii. manual inspection and oversight of observational data produced.

2.6.4.5.7 Members should record instances of non-conformity with requirements, and endeavour to rectify problems in a timely manner and given priority in accordance with requirements for the affected observational data.

2.6.4.5.8 Members should maintain a documented corrective action procedure relevant to observations and observational metadata.

2.6.4.5.9 Members should have a procedure that describes how non-conforming observations or observational metadata are identified, how they are dealt with, who is responsible for deciding what to do, what action should be taken and what records are to be kept.

Note: A detailed explanation on the requirements of the corrective action process can be found on page 25 in the Guide to the Implementation of a Quality Management System for National Meteorological and Hydrological Services.

2.6.4.5.10 Members should analyse monitoring results to detect any performance related changes, trends and deficiencies and use the results and analyses as input to activities aimed at continual improvement.

Note: Analysing trends and taking action prior to the occurrence of a case on non-conformity helps to prevent problems.

2.6.4.5.11 Members should maintain documented preventive action procedures relevant to observing systems and ensure that staff are aware of and, if necessary, trained in their routine application.

Note: Due consideration might be given to combining the preventive and the corrective action procedures for efficiency and to simplify the process.

**2.6.5 Compliance, Certification and Accreditation**

2.6.5.1 Compliance by Members in the implementation and maintenance of recommended practices for WIGOS quality management should be consistent and in accordance with the requirements for compliance by Members as described within the General Provisions of the Technical Regulations [ref. Vol. I, General Provisions, Sections 6 and 7] and with the WMO Quality Management Frame [ref. Vol. III, E.1.1, Section 7].

2.6.5.2 For each of the Component Systems and subsystems of WIGOS specific quality management practices are recommended within this manual and these should be adhered to by Members.

2.6.5.3 In line with the WMO QMF, it is strongly recommended that the QMS that are established by Members are compliant with the ISO 9000 family of standards or other internationally recognized standards and that regulations for WIGOS are appropriately integrated into these QMS.

Note 1: While WMO encourages the certification of Member quality management systems by recognized accreditation agencies, unless otherwise specified as a requirement of a particular WIGOS Component System or subsystem, there is no general regulated requirement for certification of QMS for WIGOS observing systems.

Note 2: The following regulatory standards have requirements for certified compliance by Members which may have an impact on the quality management practices of WIGOS observing systems:

i) The implementation of the World Area Forecast System (WAFS) jointly with ICAO (see WMO 1001: Guide to the Quality Management System for the Provision of Meteorological Service for International Air Navigation; also ICAO 9873), and Amendment 75 to ICAO Annex 3 which introduced, as a Standard, the requirement of each ICAO Contracting State/WMO Member to establish and implement a quality management system, which became applicable on 15 November 2012;

The ICAO clause 2.2.4 recommendation states that a quality management system ‘should be in conformity with the International Organization for Standardization (ISO) 9000 series of quality assurance standards’. As a point of clarification, this means that there is currently no ICAO requirement to be certified compliant with ISO 9001 by a third party certification body. It is of note that ICAO has both articulated how it expects providers of aviation weather services to demonstrate being “in conformity with”. However achieving certification of compliance through a third party certification body is the most effective way to demonstrate conformity.

ii) According to the Single European Sky (SES) regulations, the providers of the meteorological services to air navigation in the European Union are required to be SES certified by an accredited national Supervisory Authority; and,

iii) The reference testing and calibration laboratories (see The Guide to Meteorological Instruments and Methods of Observation (WMO-No. 8), 1.4 Accreditation of laboratories, pp II.1.8- III.1.9; and ISO/IeC 17025, provides general requirements for the competence of testing and calibration laboratories, including designated Regional Instrument Centers [Reference to relevant section above].

**2.6.6 Documentation**

**2.6.6.1 Member Documentation**

2.6.6.1.1 Members should include the WIGOS quality policy (2.6.2.1) and objectives (2.6.4.2) in their QMS Quality Manual.

2.6.6.2 Members should incorporate the relevant provisions of the Manual on WIGOS in their QMS Quality Manual.

2.6.6.3 Members should include in their QMS documentation, those documents that describe the procedures related to WIGOS, including in particular those relating to control of non-conforming observations and observational metadata, corrective actions and preventive actions.

2.6.6.4 Members should include in their QMS documentation those documents that describe the procedures required to ensure the effective planning, operation and control of its WIGOS processes.

2.6.6.5 Members should include in their QMS documentation those records required by the ISO 9001 standard.

Note: More detailed information on Documentation requirements can be found on page 12 of the Guide to the implementation of a Quality Management System for National Meteorological and Hydrological Services.

**2.7 Capacity Development**

**2.7.1** **General**

2.7.1.1 Members should identify their needs for capacity development in all activity areas of WIGOS.

2.7.1.2 Members should develop plans to meet their capacity development needs.

Note: in addition to national resources allocated to National Meteorological and Hydrological Services, other support may be available to Members such as: other domestic agencies, their WMO Regional Association, other Members through bilateral or multilateral arrangements, and WMO programmes (including appropriate Technical Commissions).

2.7.1.3 Members should establish bilateral and multi-lateral collaborations (within and beyond their Region) where necessary to address significant capacity development needs.

**2.7.2 Training**

2.7.2.1 Members shall provide adequate training for their staff, or take other appropriate actions to ensure that all staff are suitably qualified and competent for the work assigned to them.

Note: This requirement is applied both to initial recruitment / introductory training and to continuing professional development.

2.7.2.2 Each Member should ensure that the qualifications, competencies, skills (and thus training) and numbers of their personnel or other contractors are well matched to the range of tasks to be performed.

2.7.2.3 Each Member should communicate to the staff their role and how they contribute to the achievement of the quality objectives.

**2.7.3 Infrastructural Capacity Development**

Members should regularly review their infrastructure for collecting and making available observations and observational metadata and, as necessary, develop prioritized plans and priorities for capacity development.

**3.** **COMMON ATTRIBUTES SPECIFIC TO THE SURFACE-BASED SUB-SYSTEM OF WIGOS**

3.1. **Requirements**

Note: the observational user requirements of WMO Application Areas are expressed in a technology free manner. Hence they apply to all of WIGOS in common, not to any specific sub-system. The provisions of section 2.1 apply across all WIGOS sub-systems.

3.2. **Design, planning and evolution**

3.2.1 **Composition of the surface-based sub-system of WIGOS**

Note: The detailed composition of the surface-based sub-system of WIGOS is to be listed in the WIGOS Guide which is in development (e.g. surface synoptic stations (land and sea stations); upper-air synoptic stations; aircraft meteorological stations; climatological stations; etc. ).

Members shall implement elements of the WIGOS surface-based sub-system under the coordination of Regional Associations.

3.3. **Instrumentation and Methods of Observation**

3.3.1 **General Requirements**

3.3.1.1 Members shall classify their surface meteorological observing stations on land according to [The Guide to Meteorological Instruments and Methods of Observation (WMO-No. 8), I.1, Annex 1.B].

Note: This will be moved into a future appendix; the classification is applicable only for meteorological and climatological stations.

3.3.1.2 Members should locate each observing station at a site that permits correct exposure of the instruments and enables satisfactory non-instrumental observations.

Note: Requirements for GAW stations are formulated in section 5.

3.3.1.3 Members should compare observations from new instruments over an extended interval before the old measurement system is taken out of service. The same applies when there has been a change of site. Where this procedure is impractical at all sites, members should carry out comparisons at selected representative sites.

Note 1: This does not apply to all types of station, among the exceptions are water level / stage stations, radiosonde stations etc.

Note 2: Further details can be found in the Guide to Climatological Practices, WMO no. 100, 2011, including the required minimum intervals for comparison.

3.3.1.1 Members shall accurately know and refer the position of a station to the World Geodetic System 1984 (WGS-84) Earth Geodetic Model 1996 (EGM96) according to the Guide to Meteorological Instruments and Methods of Observation (WMO-No. 8).

Note 1: This geodetic system is currently not in general use in hydrology.

Note 2: This material will be in an appendix in a future edition.

3.3.1.2 Members shall define the elevation of the station according to the Guide to Meteorological Instruments and Methods of Observation (WMO-No. 8), Part I, Chapter 1, Section 1.3.3.2 (c). If a station is located at an aerodrome, members shall specify the official elevation of the aerodrome (Technical Regulation [C.3.3.], Appendix 3, 4.7.2).

Note: This material will be in an appendix in a future edition.

3.3.1.3 Members operating Regional Centres should follow the guidelines laid out in [The Guide to Meteorological Instruments and Methods of Observation (WMO-No. 8), Part I, Chapter 1, Annex 1.A] concerning capabilities and corresponding functions.

Note: This material will be in an appendix in a future edition.

3.3.1.4 Members operating Regional Marine Instrument Centres should follow the guidelines laid out in [The Guide to Meteorological Instruments and Methods of Observation (WMO-No. 8), Part II, Chapter 4, Annex 4.A] concerning capabilities and corresponding functions.

Note: This material will be in an appendix in a future edition.

3.3.2 **Requirements on Sensors**

3.3.2.1 Members shall avoid the use of mercury. Where mercury is still in use, members shall obey to the safety precautions laid out in the Guide to Meteorological Instruments and Methods of Observation (WMO-No. 8).

Note: This material will be in an appendix in a future edition.

3.3.2.2 For meteorological balloons, members should prefer helium over hydrogen. If hydrogen is used, however, members shall obey to the safety precautions laid out in the Guide to Meteorological Instruments and Methods of Observation (WMO-No. 8), Part II,Chapter 6, 10.6.1.

Note: This material will be in an appendix in a future edition.

3.3.2.3 Members shall calibrate all pyrheliometers, other than absolute pyrheliometers, by comparison using the sun as the source with a pyrheliometer that has traceability to the WSG and a likely uncertainty of calibration equal to or better than the pyrheliometer being calibrated.

3.3.2.4 Members shall compare, calibrate and maintain barometers according to the guidelines in the Guide to Meteorological Instruments and Methods of Observation (WMO-No. 8), Part I, Chapter 3, 3.10].

Note: This material will be in an appendix in a future edition.

3.4. **Operations**

3.4.1 **General Requirements**

3.4.1.1 An observing station shall be uniquely identified by the identifier assigned by the Member (or group of Members) concerned within the allocations made to that Member (or group) in compliance, as far as possible, with the corresponding identifier system, coordinated by WMO, IOC, IMO, ITU, and the other relevant international organizations.

3.4.1.2 Each time a new site/platform is established or replaced with a different identifier, the concerned Member (or group) shall send the metadata related to this site/platform to the organizations or centres officially in charge of their collection. The Member (or group) shall do this as early as practical and before the platform becomes operational.

3.4.1.3 Each Member should publish the handbook for national safety practices and procedures for operation of the observing systems that stresses precautions and practices specific to the conditions in the country concerned.

3.4.1.4 The handbook shall satisfy all of the requirements of the country including legal, health and safety.

3.4.2 **Observing Practices**

3.4.2.1 The exposure, when applicable, of instruments for the same type of observation at different stations shall be similar in order that observations may be compatible.

3.4.2.2 A reference height shall be determined at each surface observing station/system.

3.4.2.3 Metadata records should provide details and history of local conditions of the observing system, instruments, operating procedures as well as information describing data sets and data processing algorithms and other factors pertinent to using and interpreting the data as specified in more details in the Part 3.5 and the other relevant Parts of this Manual.

Note: Detailed guidance regarding the establishment, maintenance and update of metadata records is given in the Guide to Meteorological Instruments and Methods of Observation (WMO-No. 8), Part I, Chapter 1, 1.3.4 and Part III, Chapter 1, 1.9; Guide to Climatological Practices (WMO-No. 100), Chapter 3, 3.3.4; Guide to the Global Observing System (WMO-No. 488), Appendix III.3, and the Guide to Hydrological Practices (WMO-No. 168, 2008, Volume I, Chapter 10.

3.4.3 Quality Control

Note: Provisions of 2.4.3 apply

3.4.4 Data and Metadata Reporting

Note: Provisions of 3.4.3 apply

3.4.5 Incident Management

Note: Provisions of 3.4.5 apply

3.4.6 Change Management

Note: Provisions of 3.4.6 apply

3.4.7 **Maintenance**

3.4.7.1 Members should ensure that each observing system is rigorously maintained.

3.4.7.2 Observing sites and instruments should be maintained regularly so that the quality of observations does not deteriorate significantly between station inspections.

3.4.7.3 Members should perform regular preventive maintenance.

Note: Well‑organized preventive maintenance of all system components is recommended to minimize corrective maintenance and to increase the performance of an observing system.

3.4.7.4 The frequency and timing (schedule) of the preventive maintenance should be determined taking into account the type of the observing system, environmental and climate conditions of the observing site, and the instrumentation installed.

3.4.7.5 Members should perform corrective maintenance in case of observing system component fault as soon as possible after detection of the problem.

3.4.7.6 Adaptive maintenance should consider the requirements for stability, continuity and consistency of observations through time.

Note: Detailed guidance on maintenance of observing sites, observing systems and instruments is given in the Guide to Meteorological Instruments and Methods of Observation (WMO-No. 8), the Guide to Hydrological Practices (WMO-No. 168, 2008) and the Manual on Stream Gauging (WMO-No. 1044, 2010).

3.4.8 **Inspection and Supervision**

3.4.8.1 Each Member [shall/shall for hydrological observations] arrange for its surface observing site/station/system to be inspected at sufficiently frequent intervals to ensure that a high standard of observations is maintained; instruments and all their indicators are functioning correctly; and the exposure, when applicable, of the instruments has not changed significantly.

Note 1: Reference is made to the Parts 5-8 of this Manual for the frequency intervals specified for the several types of WIGOS surface observing stations.

Note 2: Detailed guidance on the inspection including the frequency is given in the Guide on WIGOS (WMO-No. YYYY), Guide to Meteorological Instruments and Methods of Observation (WMO-No. 8).

Note 3: Reference is made to the Technical Regulations (WMO-No. 49), Volume II for guidance on the inspection of aeronautical meteorological stations including the frequency of inspections.

3.4.8.2 Members [shall/should for hydrological observations] ensure that inspection is performed by qualified and adequately trained staff. Members should ensure that:

(a) The siting, selection and installation, as well as exposure when applicable, 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.

Note: Detailed guidance on inspection and supervision of observing systems and sites is given in the Guide to Meteorological Instruments and Methods of Observation (WMO-No. 8) including all of the GAW measurement guides as referenced in Chapter 16, the Guide to Hydrological Practices (WMO-No. 168) and the Manual on Stream Gauging (WMO-No. 1044).

3.4.9 **Calibration Procedures**

3.4.9.1 Members shall ensure that measurement systems and instruments are calibrated regularly in accordance with procedures described in the relevant parts of this Manual.

Note: Where international or national standards are not available, the basis for calibration must be recorded. It may be defined or supplied by the manufacturer.

3.4.9.2 Each Member shall ensure that the measuring devices are:

(a) Calibrated or verified at specified intervals, or prior to use, against measurement standards traceable to international or national measurement standards; where no such standards exist, the basis used for calibration or verification must be recorded;

(b) Adjusted or readjusted as necessary, but at the same time safeguarded from adjustments that would invalidate the measurements;

(c) Identified, enabling the calibration status to be determined; and

(d) Protected from damage and deterioration during handling, maintenance and storage.

Note: Detailed guidance is given in the Guide to Meteorological Instruments and Methods of Observation (WMO-No. 8), the Guide to Hydrological Practices (WMO-No. 168, 2008) and the Manual on Stream Gauging (WMO-No. 1044, 2010).

3.4.9.3 When the equipment is found not to conform to requirements, the Member should assess and record the validity of previous measuring results, and take appropriate action on the equipment and the products affected.

3.4.9.4 Each Member should record and maintain the results of calibration and verification.

* 1. **Observational Metadata**

Note: The provisions of section 2.5 are common to all WIGOS sub-systems and component observing systems. No additional provisions for observational metadata specific to the WIGOS surface-based sub-system appear here. Further provisions for observational metadata specific to a WIGOS component observing system appear in sections 5, 6, 7 and 8.

3.6. **Quality Management**

Note: The provisions of section 2.6 are common to all WIGOS sub-systems and component observing systems. No provisions for quality management specific to the WIGOS surface-based sub-system appear here. Further provisions for quality management specific to a WIGOS sub-system or a WIGOS component observing system appear in sections 4, 5, 6, 7 and 8.

3.7. **Capacity Development**

Note: The provisions of section 3.7 are common to all WIGOS sub-systems and component observing systems. No additional provisions for capacity development specific to the WIGOS surface-based sub-system appear here. Further provisions for capacity development specific to a WIGOS sub-system or a WIGOS component observing system appear in sections 4, 5, 6, 7 and 8.

**Section 4: WORK IN PROGRESS – SUBJECT TO CHANGE**

**4.** **COMMON ATTRIBUTES SPECIFIC TO THE SPACE-BASED SUB-SYSTEM OF WIGOS**

4.1. **Requirements**

4.1.1 **General**

Members shall strive to develop, implement and operate a space based environmental observing system in support of WMO programmes.

Note 1: The space-based sub-system of WIGOS shall be established from dedicated satellites, remotely observing the characteristics of the atmosphere, the earth and the oceans. The transmitted and acquired information is processed into quantitative data.

Note 2: These environmental satellite systems shall provide quantitative data and qualitative information enabling, independently, as a constellation, or in conjunction with surface-based observations, the determination of variables as stated in this Manual.

4.1.2 **Observed Variables**

Members operating environmental observing satellites shall implement these systems capable to provide quantitative data and qualitative information enabling, independently, as a constellation, or in conjunction with surface-based observations, the determination of the following variables:

(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 gas concentration;

(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 field, particle flows, electron content)

4.1.3 **Overarching requirements**

4.1.3.1 **General**

Members operating environmental satellites shall strive to meet, to the extent possible, the uncertainty, timeliness, temporal resolution, spatial resolution, and coverage requirements of the WIGOS as defined in the WIGOS Operational Information Resource (WIR), based on the Rolling Requirements Review (RRR) process described in Chapter 2 of this Manual.

Note: these requirements are recorded and maintained in the requirements database: http://www.wmo.int/oscar

4.1.3.2 **Collaboration**

Members shall ensure that a constellation of satellite systems will exist to guarantee the continuation of space-based observations in support of WMO Programmes.

Note: practices are based on recommendations from the Coordination Group for Meteorological Satellites (CGMS) which includes all Members operating space-based observation systems in support of WMO Programmes

4.1.3.3 **Essential constraints**

Members or coordinated groups of Members operating environmental satellites providing data to the WIGOS shall meet the following three constraints:

1. Technical coordination: Members operating satellites shall ensure the greatest possible compatibility between their different systems, through following WMO recommended practices, and publish details of the technical characteristics of their instrumentation, data processing and transmissions, as well as the dissemination schedules.
2. Continuity: A period of overlap of new and old satellite systems shall be ensured by the Members to determine inter-satellite instrumental biases and maintain the homogeneity and consistency of time series observations, unless reliable transfer standards are available.
3. Contingency arrangements: Members shall ensure that 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 sub-system.

Note 1: The WMO recommended practices are based on recommendations from the Coordination Group for Meteorological Satellites (CGMS).

Note 2: A coordinated group of Members operating environmental satellites are a group of Members acting jointly to establish a space-based system through an international space agency such as ESA or EUMETSAT.

4.2. **Design, planning and evolution**

4.2.1 **Composition of the space-based sub-system**

The main elements of the space-based sub-system shall be:

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. Associated ground segment for data reception, dissemination, and stewardship.

c. A user segment.

4.3. **Instruments and Methods of Observation**

4.3.1 **General features of space-based sensors**

Space-based observations shall be performed by instruments using either active or passive remote sensing technologies and operating in various spectral ranges.

Note 1: these spectral ranges are from X-Ray to Extreme Ultraviolet (EUV), Ultraviolet (UV), Visible, Infrared, microwave and radio wavelengths domains.

Note 2: Earth observation sensors include imagers, which provide a continuous spatial coverage of the observed scene, or cross-nadir sounders, which can sample the scene and focus on spectral variations of the signal in order to retrieve a 3D information, or limb sounders which scan the atmosphere tangentially. The coverage depends on the spacecraft orbit and on the instrument field of regard and scanning mode.

4.3.2 **Calibration and Traceability**

4.3.2.1 Members or coordinated groups of Members operating environmental satellites shall demonstrate before launch the instrument functionality.

4.3.2.2 After launch, Members or coordinated groups of Members operating environmental satellites shall calibrate all instruments on a routine basis against reference instruments or calibration targets, using established and documented methodologies thereby with a view to establish the traceability to SI.

Note 1: To assist with space-based instrument calibration Members operating environmental satellites are recommended to maintain a spacecraft with at least one calibrated high-quality Hyperspectral Infrared instrument in a LEO orbit to act as a reference to provide reference measurements for calibration of operational Infrared instruments respectively in geostationary or LEO orbit.

Note 2: Advantage should be taken of satellite collocation to perform instrument [inter]comparison and calibration.

4.3.2.3 To ensure traceability to SI, Members or coordinated groups of Members operating environmental satellites shall define a range of ground-based reference targets for calibration purposes.

4.4. **Space Segment Implementation**

4.4.1 **Operational satellites on Geostationary Earth Orbit**

4.4.1.1 **Functional requirements**

The following capability shall be provided by Members,:

1. Multispectral visible and infrared imagery;
2. Infrared sounding;
3. Lightning mapping;
4. Data collection from in-situ observing systems;
5. Space environment monitoring;
6. Other capabilities as appropriate, e.g. broadband and spectral visible and infrared (for Earth radiation budget estimates), high spectral resolution UV sounding (for atmospheric composition), high-spectral resolution visible and infrared imaging (for ocean color), solar activity monitoring.

4.4.1.2 **Operational requirements**

4.4.1.2.1 Members operating environmental satellites shall ensure the constellation of satellites in geostationary orbit provides full disc imagery at least every 15 minutes, throughout a field of view between 600 S and 600 N.

Note: This implies the availability of at least six operational geostationary satellites if located at evenly distributed longitudes, with in-orbit redundancy.

4.4.1.2.2 Members operating environmental satellites should implement rapid-scan capabilities where feasible.

4.4.1.2.3 Members operating environmental satellites, shall follow observing cycles, required coverages and performance characteristics through following WMO recommended practices,

Note 1: The operational requirements are based on recommendations from the Coordination Group for Meteorological Satellites (CGMS).

Note 2: This required observing cycles, coverages and performance characteristics of operational satellites are documented in the Guide to Meteorological Instruments and Methods of Observations (WMO-No. 8), Part IV

4.4.2 **Operational satellites on Geostationary Earth Orbit**

4.4.2.1 For the imagery mission, Members operating environmental satellites, shall ensure the availability rate of rectified and calibrated data is at least 99 percent as a target.

4.4.2.2 To fulfil the essential constraints Members operating environmental satellites, shall strive to contingency plans, involving the use of in-orbit stand-by flight models and rapid call up of replacement systems and launches in order to achieve continuity.

4.4.2 **Operational spacecraft on distributed sun-synchronous Low Earth Orbits**

4.4.2.1 **Missions**

The following capability shall be provided by Members operating environmental satellites, on several, distributed orbital planes:

1. Multispectral visible and infrared imagery;
2. Infrared sounding;
3. Microwave imagery;
4. Microwave sounding;
5. Scatterometry (for ocean surface winds);
6. Radar altimetry (for ocean surface topography);
7. Radio-occultation sounding;
8. Broadband visible and infrared radiometry for Earth radiation budget measurements;
9. Passive UV sounding (for atmospheric composition monitoring);
10. Space environment monitoring including particle detection and magnetic field measurement;
11. Solar activity monitoring;
12. Data collection from in-situ observing systems;
13. Direct broadcast;
14. Other capabilities as appropriate.

4.4.2.2 **Core meteorological constellation on three orbital planes**

4.4.2.2.1 Members operating environmental satellites, shall maintain an orbital configuration of satellites in sun-synchronous orbits to provide global coverage for imagery in the Visible, Infrared and microwave spectral range, and sounding in the Infrared and microwave range, at least six times per day with a regular temporal sampling, which represents the core meteorological constellation.

Note: 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.

4.4.2.2.2 Members operating environmental satellites, shall maintain at least one operational satellite on each of these planes, with redundancy on the a.m. and p.m. orbits.

4.4.2.2.3 Members operating environmental satellites, shall ensure that at least two of these satellites, one in a.m. and one in p.m., performs Infrared sounding with a hyperspectral sensor.

Note: This required core constellation of operational satellites is further documented in the Guide to Meteorological Instruments and Methods of Observations (WMO-No. 8), Part IV

4.4.2.3 **Other sun-synchronous missions**

Members shall strive to ensure that:

1. At least two satellites, one in a.m. and one in p.m., are equipped with radio-occultation receivers;
2. At least two satellites, on well separated orbits, are equipped with wind scatterometers;
3. At least two satellites, one in a.m. and one in p.m., perform broadband Visible/Infrared Earth radiation monitoring;
4. At least two sun-synchronous satellites, on well-separated orbits, are equipped with altimeter packages for global ocean surface topography monitoring.

4.4.2.4 **Coverage and continuity**

Members shall strive to ensure that:

1. Data from polar-orbiting satellites are acquired on a global basis, without temporal gaps for blind orbits, and delivered to users to meet timeliness requirements.
2. The constellation is 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 percent 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.

4.4.3 **Other operational/sustained spacecraft on appropriate Low Earth Orbits**

4.4.3.1 **Missions**

Members shall provide the following missions :

1. High-precision radar altimetry (for ocean surface topography);
2. Radio-occultation sounding from non sun-synchronous orbits;
3. Total solar irradiance;
4. Dual-angle view infrared imagery (for high-accuracy sea surface temperature measurement);
5. Narrow-band Visible and Near Infrared imagers for ocean color, vegetation and aerosol monitoring;
6. High-spatial resolution multispectral Visible and Infrared imagery.

4.4.3.2 **Capabilities**

For this purpose, Members shall strive to ensure that:

1. An altimetry mission on high-precision, inclined orbit complements the two altimetry missions in sun-synchronous orbits to build a robust ocean surface topography constellation;
2. A constellation of dedicated spacecraft with radio-occultation sensors on appropriate orbits complements the radio-occultation missions on sun-synchronous orbits;
3. At least one satellite performs downward solar irradiance monitoring, with provisions for overlap between consecutive missions in order to maintain measurement continuity;
4. A sun-synchronous spacecraft is maintained on an a.m. orbit with high-accuracy Infrared imagery to provide reference measurements of sea surface temperature;
5. Continuity is provided for at least one narrow-band Visible and Near Infrared imager on a sun-synchronous a.m. orbit to monitor ocean color, vegetation and aerosols;
6. Several sun-synchronous satellites in a.m. orbit are equipped with high-resolution (10-m class) multispectral Visible / Infrared imagers to build a constellation providing sufficient coverage of the land surface.

4.4.4 **Space programme life cycles**

Members operating operational environmental satellites shall consider a trade-off between the need for a long series to pay-off the development cost and the user learning curve, on one hand, and the need to develop a new generation in order to benefit from state-of-the-art technology, on the other hand.

Note 1: The development of an operational satellite programme is conducted in several phases including: user requirements definition, feasibility assessment at system level, preliminary design, detailed design, development and testing of the subsystems, integration of all subsystems, system testing, launch campaign, and on-orbit commissioning. The overall duration of these development phases is typically of the order of 10 to 15 years.

Note 2: The exploitation phase for an operational programme including a series of recurring satellites is typically of the order of 15 years.

4.4.5 **Research and Development satellites**

4.4.5.1 **Purposes**

The main purposes of research and development satellites shall be:

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

4.4.5.2 **Missions**

4.4.5.2.1 Members operating Research and Development satellites shall consider providing the following observing capabilities:

1. 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;
2. 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.

4.4.5.2.2 Members shall strive to optimize the usefulness of observations from these systems to support the operational applications. Members operating Research and Development satellites shall make provisions when relevant to enable near-real time data availability to promote the early use of new types of observations in an operational environment.

Note 1: Although neither long term continuity of service nor a reliable replacement policy are assured, research and development satellites provide, in many cases, observations of great value for operational use.

Note 2: Because they are not operational systems, Research and Development satellites have proven to support operational meteorology, oceanography, hydrology and climatology substantially.

4.5 **Ground Segment Implementation**

4.5.1 **General**

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

4.5.1.2 Members operating environmental observation satellites shall implement facilities for the reception of remote-sensing data (and Data Collection System data when relevant) from operational satellites, and for the processing of quality-controlled environmental observation information, with a view of further near-real time distribution.

4.5.2 **Data dissemination**

4.5.2.1 Members operating operational environmental observation satellite systems shall ensure near-real-time data dissemination of the appropriate data sets, per the requirement of Members, either by direct broadcast or re-broadcast via telecommunication satellites.

4.5.2.2 In particular, Members operating operational sun-synchronous satellites providing the core meteorological imagery and sounding mission shall ensure they include Direct Broadcast capability as follows:

1. 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.
2. Direct broadcast shall be provided through a high data rate stream, such as the High Resolution Picture Transmission (HRPT) or its evolution, to provide meteorological centers with all the data required for numerical weather prediction (NWP), Nowcasting, and other real-time applications;
3. If possible, a low data rate stream should also be provided, such as the Low Rate Picture Transmission (LRPT), to convey an essential volume of data to users with lower connectivity or low-cost receiving stations.

4.5.2.3 Members operating satellites shall consider implementing re-broadcast via telecommunication satellites to complement and supplement direct broadcast services, to facilitate access to integrated data streams including data from different satellites, non-satellite data and geophysical products.

4.5.3 **Data Stewardship**

4.5.3.1 Members operating environmental satellites shall 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. Members operating environmental satellites shall 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.

4.5.3.2 Members operating environmental satellites shall operate satellite data archives that shall include Level 1B, together with all relevant metadata pertaining to the location, orbit and calibration procedures used. Members archiving system shall be capable of providing on-line access to the archive catalogue with a browse facility, and description of data formats, and allowing users to download data.

4.5.4 **Data collection systems**

4.5.4.1 Members operating satellites with a capability to receive data from Data Collection Platforms (DCP) shall maintain technical and operational co-ordination under the auspices of CGMS in order to ensure compatibility. Members operating satellites shall maintain a number of “international” DCP channels identically on all geostationary satellites to allow movement of mobile platforms across their individual footprints.

4.5.4.2 Members operating satellites shall publish details of the technical characteristics and operational procedures of their data-collection missions, including the admission and certification procedures.

4.5.5 **User Segment**

4.5.5.1 Members shall 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.

4.5.5.2 Members operating research and development satellites shall implement capabilities enabling Members to download the data from the appropriate servers, or install a relevant re-broadcast service providing the required information, or install an appropriate on-board direct broadcast capability.

4.5.5.3 Where appropriate, Members shall strive to utilize fixed or moving DCP systems (for example to cover data sparse areas) to take advantage of the data-collection and relay capability of the environmental observation satellites.

4.6. **Observational Metadata**

For each space-based system they operate, Members shall record, retain and make available observational metadata in accordance with the provisions of section 2.5

4.7. **Quality Management**

4.7.1 **Quality Indicators**

Members operating environmental satellite systems shall include appropriate quality indicators in the metadata for each datasets, in accordance with the provisions of section 2.5 of this Manual

4.8. **Capacity Development**

4.8.1 **Centres of Excellence**

Members operating environmental satellites, and other Members having the capability to do so, shall provide support to education and training of instructors in the use of satellite data and capabilities e.g. at specialized Regional Meteorological Training Centres (RMTCs) or other training institutes designated as Centres of Excellence (CoE) in satellite meteorology, in order to build up expertise and facilities at a number of regional growth points.

4.8.2 **Training strategy**

Members operating environmental satellites should focus their assistance, to the extent possible, on one or more of these CoEs within their service areas and contribute to the Virtual Laboratory (VLab) for Training and Education in Satellite Meteorology.

Note: The aim of the Education and 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.

4.8.3 **User preparation to new systems**

4.8.3.1 For smooth transition to new satellite capabilities, Members operating satellites should make provisions 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.

4.8.3.2 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.

4.8.4 **Engagement between Users and Providers**

To achieve the most effective utilization of satellite data, Members should pursue the close engagement between users and providers at a regional level. Working with their regional association, Members should follow systematic steps to document the regional requirements for satellite data access and exchange.

Note 1: Information on the principles of Earth Observation from space, the different types of space-based instruments, and the derivation of geophysical variables from space-based measurements can be found in the Guide on Instruments and Methods of Observations, Part IV.

Note 2: The Observing System Capabilities 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.

Note 3: Information on the detailed characteristics and capabilities of current and planned systems of environmental satellites of the GOS is contained in the Observing System Capabilities Analysis and Review tool (OSCAR), which is available on line: http://www.wmo.int/oscar/space.

**5.** **OBSERVING COMPONENT OF THE GLOBAL ATMOSPHERIC WATCH (GAW)**

**General**

The observing component of the GAW Programme shall be a co-ordinated system of networks of observing stations, facilities, expert teams and related procedures devoted to the observation of the changing chemical composition and related physical characteristics of the global atmosphere. The GAW Programme has six focal areas (ozone, greenhouse gases, reactive gases, aerosols, UV radiation and precipitation chemistry).

5.1. **Requirements**

5.1.1 Members should perform the observations of atmospheric composition and related physical parameters using a combination of surface-based platforms (fixed stations, mobile platforms and remote sensing) and from satellites.

5.1.2 Members should use the requirements from the RRR process in the atmospheric chemistry application area in developing their GAW stations.

Note: The user requirements are reviewed on a regular basis through the RRR process by the Scientific Advisory Groups for each variable, in consultation with the user community and input from Members.

5.1.3 Members should follow the Data Quality Objectives (DQOs) specified by the SAGs for the individual variables observed at their stations.

Note: Scientific Advisory Groups (SAGs) exist for the six focal areas of GAW and their terms of reference are defined by the Commission for Atmospheric Sciences

5.1.4 Members should establish and operate a GAW station such that it satisfies the station requirements in Appendix 5.1

5.1.5 Members operating a GAW station shall guarantee long-term, uninterrupted operation of GAW stations.

5.1.6 Members should guarantee prolonged stability and continuity of data collection that is adequate for purpose within GAW.

5.2. **Design, planning and evolution**

5.2.1 Members should design, plan and further evolve their national GAW observing network / stations to meet the user requirements that address key environmental issues in the following areas:

• Stratospheric ozone depletion and the increase of ultraviolet (UV) radiation.

• Changes in the weather and climate related to human influence on atmospheric composition, particularly, related to the changes in greenhouse gases, ozone and aerosols.

• Risk assessment of air pollution on human health and agriculture and issues involving long-range transport of air pollution and its deposition.

5.2.2 Members should contribute to the global observations through operating or supporting Global or Regional stations, or through contributing networks.

5.2.3 When doing so, Members shall register their contribution in the GAW station information system (GAWSIS), and submit their observations to the relevant GAW Data Centre.

5.2.4 Members operating a contributing network shall provide a description of the network and a list of stations to GAWSIS.

5.2.5 Members should ensure that the frequency and spacing of the various observations is suited to the temporal and spatial requirements of the specific issues addressed.

5.3. **Instrumentation and Methods of Observation**

5.3.1 **General requirements of Instruments**

Members should use one of the recommended types of instrument or method for variables observed at their stations, and follow the most recent Standard Operating Procedures (SOP) or Measurement Guidelines (MG) available.

Note 1: Instruments suitable for use at GAW sites are defined by the SAGs for each parameter, in terms of stability, precision and accuracy.

Note 2: Standard Operating Procedures (SOP) describe the standard approach to operate this kind of instrument

Note 3: Measurement Guidelines (MG) describe the standard approach for this kind of measurement regardless of the instrument

5.3.2 **Calibration and Traceability**

5.3.2.1 Members shall perform calibrations as specified by the Standard Operating Procedures and Measurement Guidelines, maintain traceability to the single network standard, and participate in intercomparisons.

5.3.2.2 Members should utilise GAW central facilities to underpin the global compatibility of observations.

Note: GAW central facilities include: Central Calibration Laboratories, World Calibration Centres, Regional Calibration Centres, Quality Assurance/Scientific Activities Centres

5.3.2.3 Members should ensure that they maintain the traceability of observations to GAW primary standards, where available.

Note: A list of Standard Operating Procedures and Measurement Guidelines for the GAW variables can be found in The Guide to Meteorological Instruments and Methods of Observation (WMO-No. 8), Chapter 16 and Chapter 7 (UV Radiation).

5.4. **Operations**

5.4.1 **Observing system implementation monitoring**

5.4.1.1 Members shall monitor the operation of the GAW stations for which they are responsible and ensure that they follow the relevant procedures for Quality assurance and data submission, and seek assistance from Central Facilities, Scientific Advisory Groups and Expert Teams if operational problems cannot be solved locally.

Note: The procedures to be used in monitoring the operation of the GAW are determined by the Commission for Atmospheric Sciences (CAS) in consultation with the participating Members.

5.4.1.2 Monitoring of compliance with GAW regulations should be systematically performed by the Members, in collaboration with relevant constituent bodies and the Secretariat, in order to identify critical cases of non-compliance (deficiencies) and undertake measures for their timely resolution.

5.4.2 **Quality Assurance**

5.4.2.1 Members should follow quality assurance practices and procedures specified in the GAW Standard Operational Procedures and Measurement Guidelines, and further documents provided by the Scientific Advisory Groups and Central Facilities.

5.4.2.2 Members shall maintain detailed metadata records in accordance with procedures and practices specified in this manual.

5.4.2.3 Members should participate in independent evaluation of quality of observations, including intercomparisons and system audit, as appropriate to the observed variables.

5.4.2.4 Members shall permit World Data Centres to perform independent evaluation of observational data quality

5.4.3 **Data and Metadata representation and format**

5.4.3.1 Members shall submit their observational data and associated metadata to the relevant GAW World Data Centres for the variables observed at the station.

5.4.3.2 Members shall use the formats specified by the relevant World Data Centre when submitting their observational data and metadata.

5.5. **Observational Metadata**

Note: the general provisions on observation metadata are specified in 2.5.

5.5.1.1 Members shall provide metadata associated with instrumentation, site or platform, calibration history as requested by the World Data Centre for each parameter, and by GAWSIS.

5.5.1.2 Members shall provide such additional metadata as required by GAWSIS and any World Data Centre to which they contribute that are necessary to understand their observations (as listed in individual Measurement Guidelines).

5.6. **Quality Management**

Note: the general regulations on Quality management are specified in chapter 2.6

5.7. **Capacity Development**

Note: General provisions for capacity development are provided in section 2.7, 3.7 and 4.7

5.7.1 Members not capable of implementing required standards should establish agreements with appropriate Central Facilities or establish partnership with more experienced stations in the form of stations twinning.

Note: In some regions of the world, and for some GAW variables, where there is a clear lack of capacity, members may be requested to help support a station, or existing stations may be approached to become a part of GAW. Such requests and invitations come after approval by the appropriate SAGs.

5.7.2 Members should use the GAWTEC programme for capacity building and staff training in measurement of the specific GAW variables.

**APPENDIX 5.1**

**General requirements for GAW stations**

Stations fall into 3 categories: Global, Regional and Contributing.

Essential Characteristics of GAW Regional Stations are as follows:

1. The station location is chosen such that, for the variables measured, it is regionally representative and is normally free of the influence of significant local pollution sources.

2. There are adequate power, air conditioning, communication and building facilities to sustain long term observations with greater than 90% data capture (i.e. <10% missing data).

3. The technical support provided is trained in the operation of the equipment.

4. There is a commitment by the responsible agency to long term observations of at least one of the GAW variables in the GAW focal areas (ozone, aerosols, greenhouse gases, reactive gases, UV radiation, precipitation chemistry).

5. The GAW observations made are of known quality and linked to the GAW Primary Standard.

6. The data and associated metadata are submitted to one of the GAW World Data Centres no later than one year after the observations are made. Changes of metadata including instrumentation, traceability, observation procedures, are reported to the responsible WDC in a timely manner.

7. If required, observations are submitted to a designated data distribution system in near-real-time.

8. Standard meteorological in situ observations, necessary for the accurate determination and interpretation of the GAW variables, are made with known accuracy and precision.

9. The station characteristics and observational programme are updated in the GAW Station Information System (GAWSIS) on a regular basis.

10. A station logbook (i.e. record of observations made and activities that may affect observations) is maintained and is used in the data validation process.

***Additional Essential Characteristics Needed for a GAW Global Station:***

In addition to the characteristics of Regional or Contributing stations, a GAW Global station should fulfil the following additional requirements, namely

11. Measure variables in at least three of the six GAW focal areas.

12. Have a strong scientific supporting programme with appropriate data analysis and interpretation within the country and, if possible, the support of more than one agency.

13. Make measurements of other atmospheric variables important to weather and climate including upper air radio sondes at the site or in the region.

14. Provide a facility at which intensive campaign research can augment the long term routine GAW observations and where testing and development of new GAW methods can be undertaken.

GAW Contributing Stations

The contributing stations should satisfy the criteria of either regional or global stations adjusted by the contributing network regulations (e.g. within the contributing network data submission requirements or standard used can differ from those required for regional and global stations). In the case of the different from WMO standards use, the network standards must have a confirmed traceability to the WMO standards in the cases where such standards exist. Data submission regulations for the contributing networks must be not worse than the ones required within GAW. To be used in global assessments data from the contributing stations must be submitted to the GAW World Data Centers.

**6.** **OBSERVING COMPONENT OF THE GLOBAL CRYOSPHERIC WATCH (GCW)**

Note: the provisions of sections 1., 2., 3. and 4. of this Manual are common to all component observing systems of WIGOS including the GCW. The further provisions of section 6. are specific to the GCW.

6.1 Members should collaborate actively in, and give all possible support to, the development and implementation of the observing component of Global Cryosphere Watch.

Note: GCW implementation encompasses the use of surface- and space-based observations, observing standards and best practices for the measurement of essential cryospheric variables, and full assessment of error characteristics of in situ and satellite products. The initial focus of CryoNet, the surface-based observational network, is to promote the addition of cryospheric observations taken according to GCW standards, guidelines and best practices, at existing sites rather than creating new sites. The development of GCW includes the development of a CryoNet Guide.

6.2 Members should encourage partnerships between organizations to coordinate observing, capacity building and training activities relevant to cryospheric observations and to assist with the compilation and development of manuals on best practices for cryospheric observation.

**7.** **GLOBAL OBSERVING SYSTEM (GOS)**

Note 1: the provisions of sections 1., 2., 3. and 4. of this Manual are common to all component observing systems of WIGOS including the GOS. The further provisions of section 7. are specific to the GOS.

Note 2: provisions specific to the GOS are currently set out in Annex V (Manual on the Global Observing System (WMO-No.544), Volume I).

**8.** **WHO HYDROLOGICAL OBSERVING SYSTEM (WHOS)**

**8.1 Requirements**

8.1.1 Members should establish and operate a hydrological observing system according to its national requirements.

8.1.2 Members should also operate their hydrological observing systems to meet the requirements of the RRR process for the hydrology application area.

Note 1: A hydrological observing system includes networks of hydrological observing stations as defined in Technical Regulations Volume III – Hydrology, Chapter D.1.1 which should make observations of elements as described in Chapter D.1.2 Hydrological Observations.

Note 2: Chapter D.1.4 Hydrological Data Transmission states “Transmission facilities should be organized for the international exchange of hydrological data, forecast and warnings on the basis of bilateral or multilateral agreement.” Further provisions for data transmission and international exchange through the WMO Information System (WIS) are given in Technical Regulations Volume I Part 2 and the Manuals on WIS and the Global Telecommunication System.

8.1.3 Members shall provide on a free and unrestricted basis those hydrological data and products which are necessary for the provision of services in support of the protection of life and property and for the well-being of all peoples.

8.1.4 Members should also provide additional hydrological data and products where available, which are required by WMO programmes and its Members.

8.1.5 At a global level, the WMO Hydrological Observing System (WHOS) shall allow access to sources of hydrological observations in near real-time from Members around the world.

Note: Currently, many Members are publically making such observations available on the internet.

8.1.6 Members should provide these sources of observations to the WHOS.

Note: Hydrological observations available through WHOS will initially comprise stage (water level) and discharge. This will likely expand over time to include other elements as identified in the Rolling Review of Requirements process at the national, regional and global levels.

**8.2 Design, planning and evolution**

Note: Design, planning and evolution is common to all WIGOS component observing systems.

Members should design and plan their observing network considering the review of the current and planned WMO Hydrological Observing System capabilities undertaken as outlined in the Rolling Review of Requirements (RRR) as described in Section 2.2.

**8.3 Instrumentation and Methods of Observation**

**8.3.1 General Requirements of Instruments**

8.3.1.1 Members should equip its stations with properly calibrated instruments and should arrange for these stations to follow adequate observational and measuring techniques to ensure that the measurements and observations of the various hydrological elements are accurate enough to meet the needs of hydrology.

Note: Technical Regulations Volume III provides that Members should use instruments for measurement of stage (water level) in conformance with the specifications of its annex II — Water level measuring devices.

8.3.1.2 Members should ensure that the uncertainty in the observation of the stage (water level) of rivers, estuaries, lakes, and reservoirs not exceed:

(a) In general, 10 mm at the 95 per cent confidence level;

(b) Under difficult conditions, 20 mm at the 95 per cent confidence level.

Note: Stage (Water level) observations are used primarily as an index for computing streamflow discharge when a unique relation exists between stage (water level) and discharge.

**8.3.2 Stage and discharge observations from hydrometric stations**

Note 1: Technical Regulations, Volume III provides that Members should establish and operate hydrometric stations for measuring stage (water level), velocity and discharge in conformance with the specifications of its annex VI — Establishment and operation of a hydrometric station.

Note 2: Technical Regulations, Volume III provides that Members should, when undertaking moving-boat discharge measurements, ensure that equipment and operational procedures are as specified in its annex XII — Discharge measurements by the moving-boat method.

8.3.2.1 Members should ensure that the number of discharge measurements at a stream gauging station are adequate to define the rating curve for the station at all times.

Note: Technical Regulations, Volume III provides that Members should use the methods for determining the stage-discharge relation (rating curve) of a station as specified in its annex VII — Determination of the stage-discharge relation.

8.3.2.2 Members should measure river discharges to an accuracy commensurate with flow and local conditions. Percentage uncertainty of the discharge measurement should not exceed:

(a) In general, 5 per cent at the 95 per cent confidence level;

(b) Under difficult conditions, 10 per cent at the 95 per cent confidence level.

Note 1: Technical Regulations, Volume III provides that Members should evaluate the uncertainty in discharge measurements in conformance with the specifications in its annex VIII — Estimation of uncertainty of discharge measurements.

Note 2: Discharge measurements are taken to establish and verify the stability of a rating curve. Stage (water level) observations are converted to estimates of discharge using the rating curve on an on-going basis.

**8.3.3 Calibration Procedures**

Note 1: Technical Regulations, Volume III provides that Members should adhere to the specifications of facilities, equipment and procedure for the calibration of current meters as specified in its annex I — Calibration of current meters in straight open tanks.

Note 2: Technical Regulations, Volume III provides that Members should ensure that operational requirements, construction, calibration and maintenance of rotating element current meters are as specified in its annex IV — Rotating element type current meters.

8.3.3.1 Members should recalibrate acoustic velocity meters on a routine basis to ensure stability of the calibration, using measurement standards traceable to international or national standards. Where no such standards exist, Members should record the basis used for calibration or verification.

Note: Additional information pertaining to the calibration of instruments can be found in the Guide to Hydrological Practices, Volume I (WMO-No. 168) and the Manual on Stream Gauging (WMO-No. 1044).

**8.4 Operations**

**8.4.1 Observing Practices**

8.4.1.1 Members should collect and preserve their hydrological records.

8.4.1.2 Members should make the necessary arrangements to facilitate the retrieval and analysis of their hydrological observations by automatic data-processing equipment.

8.4.1.3 Where automatic registration is not available, Members should ensure the observations of elements for hydrological purposes are made at regular intervals appropriate for the elements and their intended purposes.

8.4.1.4 Members should maintain in their archives an up-to-date inventory of their hydrological observations.

8.4.1.5 Members should generally ensure uniformity in time of observations within a catchment area.

8.4.1.6 Members should select the time units used in processing hydrological data for international exchange from the following:

(a) The Gregorian calendar year;

(b) The months of this calendar;

(c) The mean solar day, from midnight to midnight, according to the zonal time, when the data permit;

(d) Other periods by mutual agreement in the case of international drainage basins or in the case of drainage basins in the same type of region.

8.4.1.7 For hydrometric stations where data are internationally exchanged, Members should process the following characteristics for each year:

(a) Maximum instantaneous and minimum daily mean values of stages (water levels) and discharge;

(b) mean daily stages (water levels) and/or mean daily discharges.

8.4.1.8 For rivers under flood conditions or where there are variable controls, Members should make special measurements at intervals frequent enough to define the hydrograph.

8.4.1.9 When sudden and dangerous increases in river levels occur, Members should make and report observations as soon as possible without regard to the usual time of observation, to meet the intended operational use.

8.4.1.10 Members should measure and store stage (water level) observations as instantaneous values rather than averaged values.

**8.4.2 Quality Control**

8.4.2.1 Members should maintain detailed records for each station and for each parameter, containing metadata related to the measurements, maintenance and calibration of equipment.

8.4.2.2 Members should perform periodic audits of their stations and collected data.

8.4.2.3 Members should ensure that recorded hydrological observations are converted to a form suitable for archiving and retrieval.

Note: Observations may be initially recorded using various media from paper to electronic digital form. As computer archiving has become a standard practice by most Members, it is advantageous to convert data to the required format early in the process.

8.4.2.4 Members should ensure their data undergo, at various stages, a range of checks to determine their accuracy and correctness.

8.4.2.5 With accelerating developments in technology, Members should ensure data-processing and quality control systems are well-organized and understood by the people involved in collecting and using them.

Note 1: Data are collected and recorded in many ways, ranging from manual reading of simple gauges to a variety of automated data-collection, transmission and filing systems.

Note 2: Quality assurance encourages the adoption of recognized best practices and advances in data validation.

8.4.2.6 Members should consider the adoption of a quality management system, as described in section 2.6.

Note: Organizations usually employ an accredited certification agency to provide independent verification and advice on developing such a system.

8.4.2.7 Members should undertake data processing and quality control as described in relevant publications.

Note: Such publications include the Guide to Hydrological Practices Volume 1 Chapter 9 (WMO-No. 168), the Manual on Flood Forecasting and Warning Chapter 6 (WMO-No. 1072) and the Manual on Stream Gauging Volume II Chapter 6 (WMO-No. 1044).

**8.4.3 Observations and Observational Metadata Reporting**

8.4.3.1 Members should ensure when making available hydrological information for international purposes the use of open text or appropriate code forms as specified on the basis of bilateral or multilateral agreements.

8.4.3.2 Members should ensure that transmission facilities are organized for the international exchange of hydrological observations on the basis of bilateral or multilateral agreement.

8.4.3.3 In order to make data globally available for real-time exchange and for discovery, access and retrieval, Members should report stage and discharge observations and observational metadata in compliance with WMO Information System (WIS) standards.

Note 1: WIS may also be used for access to hydrological observations not required in real time.

Note 2: The regulation governing exchanges in international code (Technical Regulations, Volume I (2011 edition), Part I 2.3.1) states that coded information exchanged for international purposes shall be in the appropriate international code forms, specified in Annex II (Manual on Codes (Publication No. 306), Volume I).

Note 3: Coded information exclusively for bilateral or multilateral exchange amongst Members may be in other forms by mutual agreement.

**8.4.4 Incident Management**

Note: General provisions for Incident Management are provided in section 2.4.5.

**8.4.5 Change Management**

Note: General provisions for Change Management are provided in section 2.4.6.

**8.4.6 Maintenance**

8.4.6.1 Members should determine the frequency and timing of visits to recording stations by the length of time that the station can be expected to function without maintenance and the accuracy requirements of the data.

Note 1: There is a relation between the frequency of the visits and the resultant quality of the data collected. Too long a time between visits may result in frequent recorder malfunction and, thus, in loss of data, while frequent visits are both time consuming and costly.

Note 2: Some data collection devices may suffer a drift in the relationship between the variable that is recorded and that which the recorded value represents. An example of this is a non-stable stage-discharge relationship.

Note 3: Two visits per year are considered an absolute minimum, and preferably more often to avoid the dangers of losing data and/or having data severely affected by problems such as silting, vandalism or seasonal vegetative growth.

8.4.6.2 In such cases, Members should schedule periodical visits to the station to recalibrate the equipment or the measurement equations.

8.4.6.3 Members should periodically inspect stations using trained personnel to ensure the correct functioning of instruments.

8.4.6.4 In addition, Members should ensure a formal written inspection is done routinely, preferably each year, to check overall performance of instruments (and local observer, if applicable).

8.4.6.5 Members, when routinely inspecting sites, should:

(a) measure gauge datum to check for and record any changes in levels:

(b) check the stability of the rating curve, review the relationships between the gauges and permanent level reference points to verify that no movement of the gauges has taken place;

(c) review the gauging frequency achieved and the rating changes identified; and

(d) undertake a number of maintenance activities as described in section 8.4.6.8 and 8.4.6.9.

Note: It is vital, for the quality of data, that resources for gaugings be allocated and prioritized using rigorous and timely analysis of the probability and frequency of rating changes.

8.4.6.6 Members should ensure maintenance activities are conducted at data-collection sites at intervals sufficient to ensure that the quality of the data being recorded is adequate.

8.4.6.7 Members should ensure such activities are conducted by the observer responsible for the sites, if there is one. Members should ensure such activities are also occasionally performed by an inspector.

8.4.6.8 Members should undertake the following maintenance activities at all collection sites:

1. Service the instruments;
2. Replace or upgrade instruments, as required;
3. Retrieve or record observations;
4. Perform the recommended checks on retrieved records;
5. Carry out general checks of all equipment, for example, transmission lines;
6. Check and maintain the site to the recommended specifications;
7. Check and maintain access to the station;
8. Record, in note form, all of the above activities;
9. Comment on changes in land use or vegetation;
10. Clear debris and overgrowth from all parts of the installation.

8.4.6.9 Members should undertake the following maintenance activities at discharge collection sites:

1. Check the bank stability, as necessary;
2. Check the level and condition of gauge boards, as necessary;
3. Check and service the flow-measuring devices (cableways, etc.), as necessary;
4. Check and repair control structures, as necessary;
5. Regularly survey cross-sections and take photographs of major station changes after events or with vegetation or land-use changes;
6. Record, in note form, all of the above activities and their results; and
7. Inspect the area around or upstream of the site, and record any significant land-use or other changes in related hydrological characteristics, such as ice.

Note: Further details are found in the Manual on Stream Gauging (WMO-No. 1044).

8.4.6.10 Members should have a well-trained technician or inspector visit stations immediately after every severe flood in order to check the stability of the river section and the gauges. If there is a local observer, this person should be trained to check for these problems and communicate them to the regional or local office.

8.4.6.11 Members should not programme flood gaugings as part of a routine inspection trip because of the unpredictable nature of floods.

8.4.6.12 Members should establish a flood action plan prior to the beginning of the storm or flood season and should specify priority sites and types of data required.

Note: If flood gaugings are required at a site, the preparations ideally would be made during the preceding dry or non-flood season so that all is ready during the annual flood season.

8.4.6.13 Members should consider undertaking the following additional measures if severe flooding is likely:

8.4.6.14 Following the recession of flood waters, Members should pay particular attention to ensuring the safety and security of the data-collection site and to restoring normal operation of on-site instrumentation.

Note: In some cases, redesign and reconstruction of the site may be required. Such work would ideally take into account information obtained as a result of the flood.

**8.4.7 Calibration procedures**

Note: Determination of a rating curve is described in Part 8.3.2. Calibration procedures for current meters, is described in Part 8.3.3.

**8.5 Observational Metadata**

Note 1: Provisions for describing observational metadata, for recording and retaining observational metadata, and for exchanging and archiving observational metadata are provided in section 2.5. These apply to all WIGOS component observing systems including the WHOS. Further provisions specific to WHOS are stated here.

Note 2: The contents of observational metadata are detailed in Annex 2.1 of this Manual, including core metadata and other metadata of specific relevance for WHOS.

Note 3: Within an organization or country, a hydrological information system or a station registration file and a historical operations file (as indicated in the Guide to Hydrological Practices, WMO–No.168) or similar repositories may be used as a convenient means to compile a set of metadata about a hydrological station and its observations.

8.5.1 In addition to the provisions in section 2.5,Members should record, retain and make available the core observational metadata and also the additional observational metadata specified for WHOS in the Annex 2.1.

8.5.2 Members who use their own station identifiers for hydrological stations should maintain the means to match these with the WMO station identifiers, as specified in Annex 2.1.

8.5.3 Members should collect and record additional detailed observational metadata identifying the purpose of the station.

Note: Further details are found in the Guide to Hydrological Practices Volume I Chapter 10, page 8 (WMO-No. 168)

**8.6 Quality Management**

Note 1: Provisions for the implementation of quality management in WIGOS are provided in section 2.6. These apply to all WIGOS component observing systems including the WHOS.

Note 2: the WMO Hydrology and Water Resources Programme has developed material on the implementation of the WMO Quality Management Framework in Hydrology and for adopting this in national operations. Some Members have achieved compliance with the ISO 9001:2008 standard and examples have been documented to assist other Members.

**8.7 Capacity Development**

Note 1: Provisions for the implementation of capacity development in WIGOS are provided in section 2.7.

Note 2: Whatever the level of technical sophistication of a data-collection authority, the quality of its staff remains its most valuable resource.

8.7.1 Members should undertake careful recruitment, training and management to attain and maintain the appropriate personnel with the most appropriate skill sets.

8.7.2 Members should pursue a carefully structured training programme for all personnel engaged in field and office practices pertaining to data collection because they are in a strong position to influence the quality of the final data.

Note: Formal training ideally will aim at providing both a general course in first principles, plus training modules to teach in-house field and office procedures. All material is to be relevant and current.

8.7.3 Members should provide training classes, follow-up exercises, and on-the-job training to field personnel before they make streamflow and survey measurements using various technologies such as ADCP and mechanical current meters.

8.7.4 Members should provide training classes, follow-up exercises, and on-the-job training on data collection practices and processing of data to increase employee productivity and programme effectiveness.

8.7.5 Members should have appropriate technologies in place, such as hydrological information systems, to allow for streamflow data processing and to allow the effective and efficient delivery of metadata, data and data products to users.

8.7.6 Members should have adequate number of stations to meet priority needs and ensure sufficient resources to maintain and operate sites to attain required accuracies and reliability of data for their intended use.

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