## WORLD METEOROLOGICAL ORGANIZATION

**Guide to the**

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

**(2016 edition)**

**(Version 0.2.2)**

**DRAFT**

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Note:

The used colour code is as follows:

x.y.z: the provision for which guidance material has to be developed

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**INTRODUCTION (or PREFACE)**

**General**

This is first edition of the Guide on the WMO Integrated Global Observing System. It was developed in a conjunction with the WMO Technical Regulations (WMO-No. 49), Volume I, PART I – WIGOS and its Annex IX, Manual on the WIGOS (WMO-No. XXXX).

**Purpose and Scope of the Guide**

In essence, the WMO Technical Regulations (WMO-No. 49), Volume I, Part I – WIGOS and Manual on WIGOS specify where, when, what and how is to be observed in order to meet the relevant observational requirements of Members.

The Guide to WIGOS provides detailed guidance on how to establish, operate and manage WMO observing system to make the observations in a way as regulated by the WMO Technical Regulations (WMO-No. 49), Volume I, Part I – WIGOS and Manual on WIGOS.

The Guide explains and describes WIGOS practices, procedures and specifications and is aimed at assisting the technical and administrative staff of National Meteorological and Hydrological Services responsible for the networks of observing stations in preparing national instructions for observers. The Guide should be used in conjunction with many other WMO guides, technical documents and other related publications as they complement each other.

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

The subsequent step of how observations are to be reported and encoded is specified in the Manual on Codes (WMO-No. 306).

The Guide to the Global Observing System (WMO-No. 488) is the authoritative reference for all matters related to the GOS.

… ICAO Annex 3, Doc.9837 provides … related to the

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Here is the list of the publications relevant and related to the *Guide to WIGOS*. The most relevant are indicated by an asterisk following the publication name. Publications that are more specific / relevant to the individual sections are listed inside each section.

***[Technical Regulations, Volumes I - IV](http://www.wmo.int/pages/governance/policy/tech_regu_en.html)* [(WMO-No. 49)](http://www.wmo.int/pages/governance/policy/tech_regu_en.html) \***

1. ***Manuals:***
2. *[Manual on Codes – International Codes, Volume I.1: Part A – Alphanumeric Codes (WMO-No. 306)](http://library.wmo.int/opac/index.php?lvl=notice_display&id=13617)* (2011 edition updated in 2012)
3. *[Manual on Codes - International Codes, Volume I.2: Part B and Part C](http://library.wmo.int/opac/index.php?lvl=notice_display&id=10684)* [(WMO-No. 306)](http://library.wmo.int/opac/index.php?lvl=notice_display&id=10684) (2011 edition updated in 2012)
4. *[Manual on the Global Telecommunication System, Volume I](http://library.wmo.int/opac/index.php?lvl=notice_display&id=10728)* [(WMO-No. 386)](http://library.wmo.int/opac/index.php?lvl=notice_display&id=10728) (2011 edition updated in 2013)
5. *[International Cloud Atlas, Volume I](http://library.wmo.int/opac/index.php?lvl=notice_display&id=5357)* [(WMO-No. 407)](http://library.wmo.int/opac/index.php?lvl=notice_display&id=5357) (1975 edition) \*
6. *[International Cloud Atlas, Volume II](http://library.wmo.int/opac/index.php?lvl=notice_display&id=5358)* [(WMO-No. 407)](http://library.wmo.int/opac/index.php?lvl=notice_display&id=5358) (1987 edition) \*
7. *[Manual on the Global Data-Processing and Forecasting System](http://library.wmo.int/opac/index.php?lvl=notice_display&id=12793)* [(WMO-No. 485)](http://library.wmo.int/opac/index.php?lvl=notice_display&id=12793) (2010 edition updated in 2013)
8. *[Manual on the Global Observing System](http://library.wmo.int/opac/index.php?lvl=notice_display&id=3856), Volume I*[(WMO-No. 544)](http://library.wmo.int/opac/index.php?lvl=notice_display&id=3856" \l ".U4SxkBbpvIY) (2010 edition updated in 2013) \*
9. *[Manual on Marine Meteorological Services](http://library.wmo.int/opac/index.php?lvl=notice_display&id=9784)* [(WMO-No. 558)](http://library.wmo.int/opac/index.php?lvl=notice_display&id=9784) (2012 edition)
10. *[Manual on the Implementation of Education and Training Standards in Meteorology and Hydrology: Volume I – Meteorology](http://library.wmo.int/pmb_ged/wmo_1083_en.pdf)* [(WMO-No. 1083)](http://library.wmo.int/pmb_ged/wmo_1083_en.pdf) (2012 edition)
11. *[Manual on the WMO Information System](http://library.wmo.int/opac/index.php?lvl=notice_display&id=9254)* [(WMO-No. 1060)](http://library.wmo.int/opac/index.php?lvl=notice_display&id=9254) (2012 edition updated in 2013)
12. *Manual on the WIGOS* (WMO-No. XXXX) \*
13. ***Guides:***
14. *[Guide to Meteorological Instruments and Methods of Observation](http://library.wmo.int/opac/index.php?lvl=notice_display&id=13617" \l ".U4SuGRbpvIY)* [(WMO-No. 8)](http://library.wmo.int/opac/index.php?lvl=notice_display&id=13617" \l ".U4SuGRbpvIY) (2008 edition updated in 2012) \*
15. *[Guide to Climatological Practices](http://library.wmo.int/opac/index.php?lvl=notice_display&id=5668" \l ".U4SylxbpvIY)* [(WMO-No. 100)](http://library.wmo.int/opac/index.php?lvl=notice_display&id=5668" \l ".U4SylxbpvIY) (2011 edition) \*
16. *[Guide to Agricultural Meteorological Practices](http://library.wmo.int/opac/index.php?lvl=notice_display&id=12113" \l ".U4SyyxbpvIY)* [(WMO-No. 134)](http://library.wmo.int/opac/index.php?lvl=notice_display&id=12113" \l ".U4SyyxbpvIY) (2010 edition updated in 2012)
17. *[Guide to Hydrological Practices, Vol. I](http://library.wmo.int/opac/index.php?lvl=notice_display&id=542" \l ".U4S05xbpvIY)* [(WMO-No. 168)](http://library.wmo.int/opac/index.php?lvl=notice_display&id=542" \l ".U4S05xbpvIY) (2008 edition) \*
18. *[Guidelines for the Education and Training of Personnel in Meteorology and Operational Hydrology, Volume I: Meteorology](http://library.wmo.int/opac/index.php?lvl=notice_display&id=176)* [(WMO-No. 258)](http://library.wmo.int/opac/index.php?lvl=notice_display&id=176) (2002 Edition)
19. *[Guidelines for the Education and Training of Personnel in Meteorology and Operational Hydrology, Volume II: Hydrology](http://library.wmo.int/opac/index.php?lvl=notice_display&id=6760)* [(WMO-No. 258)](http://library.wmo.int/opac/index.php?lvl=notice_display&id=6760) (2003 Edition)
20. *[Guide on the Global Data-Processing System](http://library.wmo.int/opac/index.php?lvl=notice_display&id=6832)* [(WMO-No. 305)](http://library.wmo.int/opac/index.php?lvl=notice_display&id=6832) (1993 edition)
21. *[Guide to Marine Meteorological Services](http://library.wmo.int/opac/index.php?lvl=notice_display&id=7469" \l ".U4S1cBbpvIY)* [(WMO-No. 471)](http://library.wmo.int/opac/index.php?lvl=notice_display&id=7469" \l ".U4S1cBbpvIY)  (2001 edition)
22. *[Guide to the Global Observing System](http://library.wmo.int/opac/index.php?lvl=notice_display&id=12516" \l ".U4S1oBbpvIY)* [(WMO-No. 488)](http://library.wmo.int/opac/index.php?lvl=notice_display&id=12516" \l ".U4S1oBbpvIY) (2010 edition updated in 2013) \*
23. *[Guide to the Quality Management System for the Provision of Meteorological Service for International Air Navigation](http://library.wmo.int/opac/index.php?lvl=notice_display&id=7938)* [(WMO-No. 1001)](http://library.wmo.int/opac/index.php?lvl=notice_display&id=7938) (2011 edition)
24. *[Guide to the Implementation of a Quality Management System for National Meteorological and Hydrological Services](http://library.wmo.int/opac/index.php?lvl=notice_display&id=15574" \l ".U4S4ExbpvIY)* [(WMO-No. 1100)](http://library.wmo.int/opac/index.php?lvl=notice_display&id=15574" \l ".U4S4ExbpvIY) (2013 edition)
25. *[Guide to the WMO Information System](http://library.wmo.int/opac/index.php?lvl=notice_display&id=6856)* [(WMO-No. 1061)](http://library.wmo.int/opac/index.php?lvl=notice_display&id=6856) (2013)
26. ***Technical documents/technical notes:***
27. *[Baseline Surface Radiation Network (BSRN), Operations Manual](http://www.wmo.int/pages/prog/gcos/documents/gruanmanuals/WCRP/WCRP21_TD1274_BSRN.pdf)* [(WCRP-121, WMO/TD-No. 1274)](http://www.wmo.int/pages/prog/gcos/documents/gruanmanuals/WCRP/WCRP21_TD1274_BSRN.pdf) (2005)
28. *[Global Atmosphere Watch Measurements Guide](http://library.wmo.int/opac/index.php?lvl=notice_display&id=11075)* [(WMO/TD-No. 1073)](http://library.wmo.int/opac/index.php?lvl=notice_display&id=11075) (2001)
29. *[Guide to the GCOS Surface Network (GSN) and GCOS Upper-Air Network (GUAN)](http://www.wmo.int/pages/prog/gcos/Publications/GCOS-144_en.pdf)* [(WMO/TD-No. 1558) (GCOS-144)](http://www.wmo.int/pages/prog/gcos/Publications/GCOS-144_en.pdf) (2010 Update of GCOS-73)
30. *[International Meteorological Tables](http://library.wmo.int/opac/index.php?lvl=notice_display&id=5552)* [(WMO-No. 188, TP 94)](http://library.wmo.int/opac/index.php?lvl=notice_display&id=5552) (1966) \*
31. *[Manual on sea level measurement and interpretation, Volume IV](http://unesdoc.unesco.org/images/0014/001477/147773e.pdf)* [(WMO/TD, 1339)](http://unesdoc.unesco.org/images/0014/001477/147773e.pdf) (Update to 2006)
32. *[Note on the standardization of pressure reduction in the International Network of Synoptic stations](http://library.wmo.int/opac/index.php?lvl=notice_display&id=5477)* [(WMO-No. 154, TP 74)](http://library.wmo.int/opac/index.php?lvl=notice_display&id=5477) (1964)
33. *[WMO Global Atmosphere Watch (GAW) Strategic Plan: 2008-2015 - A contribution to the Implementation of the WMO Strategic Plan: 2008-2011](http://library.wmo.int/pmb_ged/wmo-td_1384.pdf)* [(WMO/TD-No. 1384)](http://library.wmo.int/pmb_ged/wmo-td_1384.pdf) (revised in 2007) \*
34. ***Guidelines and other related publications:***
35. *[Aircraft Meteorological Data Relay (AMDAR) Reference Manual](http://library.wmo.int/opac/index.php?lvl=notice_display&id=7920)* [(WMO, 958) (2003)](http://library.wmo.int/opac/index.php?lvl=notice_display&id=7920)
36. *[GAW Reports](http://www.wmo.int/pages/prog/arep/gaw/gaw-reports.html)*
37. *[GCOS Upper-Air reference Network (GRUAN) – Manual (WIGOS Technical Report No. 2013-02, GCOS-170)](http://library.wmo.int/pmb_ged/gcos_170.pdf)* (2013)
38. *[GCOS Upper-Air reference Network (GRUAN) – Guide](http://library.wmo.int/pmb_ged/gcos_171.pdf)* [(WIGOS Technical Report No. 2013-03, GCOS-171)](http://library.wmo.int/pmb_ged/gcos_171.pdf)  (2013)
39. *[Hydrology and Water Resources Programme (HWRP) Manuals](http://www.wmo.int/pages/prog/hwrp/manuals.php)*
40. *[JCOMM Catalogue of Practices and Standards](http://www.jcomm.info/index.php?option=com_content&view=article&id=159&Itemid=23) (Manuals and Guides, Observation Standards, such as IOC Manuals and Guides)*
41. *[Marine Meteorology and Oceanography Programme Publications and Documents](http://www.wmo.int/pages/prog/amp/mmop/publications.html)*
42. *[Sixth WMO Long-term Plan (2004–2011)](http://library.wmo.int/opac/index.php?lvl=notice_display&id=6455" \l ".U4S3uBbpvIY)* [(WMO-No. 962)](http://library.wmo.int/opac/index.php?lvl=notice_display&id=6455" \l ".U4S3uBbpvIY) (Updated in 2004)
43. [Guidelines for the education and training of personnel in meteorology and operational hydrology – Volume I. Meteorology (WMO-No. 258)](http://library.wmo.int/opac/index.php?lvl=notice_display&id=176) (2002)
44. [Guidelines for the education and training of personnel in meteorology and operational hydrology – Volume II. Hydrology (WMO-No. 258)](http://library.wmo.int/opac/index.php?lvl=notice_display&id=6760) (2003)

**Organization of the *Guide***

The Guide follows a structure similar to that used in Volume I Part I – WIGOS of the WMO Technical Regulations (WMO-No. 49) and the Manual on the WIGOS (WMO-No. XXXX).

Sections 1 and 2 apply to the all of WIGOS component observing systems. Section 3 provides further information applicable to the surface based sub-system of WIGOS while Section 4 provides further information applicable to the space based sub-system of WIGOS. Sections 5 - 8 (system specific sections) provide further information relevant to the Global Atmosphere Watch, the Global Cryosphere Watch, the Global Observing System of the World Weather Watch and the WMO Hydrological Observing System, respectively.

When using this Guide, readers are strongly encouraged to consult all of the relevant Sections recognizing the way in which the Sections build upon each other.

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**DEFINITIONS**

**Note 1:** Other definitions related to observing systems may be found in the Volume I of the WMO Technical Regulations and the *Manual on the GOS* (WMO-No. 544). Definitions are not duplicated between Manuals hence it is important to consult all documents.

**Note 2:** Further definitions may be found in the *Manual on Codes* (WMO-No. 306), *Manual on the Global Data Processing and Forecasting System* (WMO-No. 485), Volume I, *Manual on the Global Telecommunication System* (WMO-No. 386); Volume I, and other WMO publications.

**Note 3:** 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.

The following terms, when used in the *Manual on WIGOS* (WMO-No. XXXX), have the meanings given below.

***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.

***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.

***Adaptive maintenance.*** Modification of an instrument, software etc. performed after installation to keep the product usable in a changed or changing environment.

***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.

***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.

***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.

***Catchment Area***. Area having a common outlet for its surface runoff.

***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.

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

***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.

***Current meter***. Instrument for measuring water velocity.

***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.

***Data compatibility.*** The capacity for two systems to exchange data without having to be altered to do so including making any changes in data formats.

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

***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.

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

***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.

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

***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.

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

***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.

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

***GAW Station Information System (GAWSIS).*** The official catalogue for monitoring sites/platforms/stations operating within Global Atmosphere Watch (GAW) as well as related programmes providing station metadata and serving as the clearing house for unique station identifiers. GAWSIS represents the metadata source for OSCAR for GAW observations.

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

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

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

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

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

***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.*** A formalized process to assess the relative performance of two or more systems (observing, forecasting, etc.)

***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

***Quality***. The degree to which a set of inherent characteristics fulfils requirements.

***Quality Assurance***. That part of quality management focused on providing confidence that quality requirements will be fulfilled.

***Quality Control.*** That part of quality management focused on fulfilling quality requirements.

***Quality Management***. The coordinated activities to direct and control an organization with respect to quality.

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

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

***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.

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

***Stage***. See water level.

***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.

***Streamflow***. General term for water flowing in a watercourse.

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

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

***Verification.*** The process of establishing the truth, accuracy, or validity of something.

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

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

**1.1 Purpose and Scope 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 in support of all WMO Programmes and activities.

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

1.1.2 The WIGOS **shall** facilitate the use by WMO Members of observations from systems that are owned, managed and operated by a diverse array of organizations and programmes.

1.1.3 The principal purpose of WIGOS **shall** be to meet the evolving requirements of Members for observations.

1.1.4 The interoperability (including data compatibility) of WIGOS component observing systems **shall** be achieved through their common utilization and application of internationally accepted standards and recommended practices and procedures. Data compatibility **shall** also be supported through the use of data representation standards.

WIGOS provides a framework for enabling the integration and optimized evolution of WMO observing systems, and of WMO’s contribution to co-sponsored systems[[1]](#footnote-1) to meet evolving observing requirements of WMO Members in delivering their weather, climate, water and related environmental services. Such a framework significantly improves the availability, usefulness, quality and utilization of observational data and products through a single focus for the operational and management functions of all WMO observing systems as well as a mechanism for interactions with WMO co-sponsored observing systems. This framework also facilitates standardization and interoperability and helps to improve availability and utilization of, and access to, good-quality data and products, and associated metadata.

WIGOS builds upon and adds value to the WMO existing observing systems by coordinating their efforts, addressing shortcomings, and supporting their interoperability. While WIGOS provides an overall framework for integration and optimization of WMO observing systems, these systems continue to be owned, managed and operated by a diverse array of organizations and programmes.

In the context of WIGOS, integration is defined as joint efforts by data users and data producers at the national and international levels to establish a comprehensive, coordinated and sustainable system of observing systems, ensuring interoperability between its component systems.

Interoperability (including data compatibility) is achieved through the common utilization and application of international standards and recommendations. Interoperability within, among and between WIGOS component observing systems is best achieved through the careful utilization and implementation of the standards and recommendations provided in Volume I Part I - WIGOS of the WMO Technical Regulations (WMO-No. 49) as well as the Manual on WIGOS (WMO-No. XXXX).

The WIGOS framework focuses on the integration of governance and management functions, mechanisms and activities to be accomplished by contributing observing systems on a global, regional and national level.

WIGOS allows WMO Members’ NMHSs and other relevant national and international institutions to better fulfil their mandates, including response to natural hazards, hydrological and environmental monitoring, climate observation, and adaptation to climate change and human induced environmental impacts.

WIGOS enhances the coordination of WMO observing systems with those of partner organizations for the benefit of society. Benefits will emerge as the WIGOS is fully adopted by Members, the organizations they represent and all partner organizations.

Further information is available at the WIGOS website: [www.wmo.int/wigos](http://www.wmo.int/wigos).

**1.2 WIGOS component observing systems**

1.2.1 The component observing systems of WIGOS **shall** comprise the Global Observing System (GOS) of the World Weather Watch (WWW) Programme, the observing component of the Global Atmosphere Watch (GAW) Programme, the WMO Hydrological Observing System (WHOS) of the Hydrology and Water Resources Programme (HWRP) and the observing component of the Global Cryosphere Watch (GCW), including their surface-based and space-based components.

Note: The above component systems include all WMO contributions to the co-sponsored systems, as well as the WMO contributions to the Global Framework for Climate Services (GFCS) and Global Earth Observation System of Systems (GEOSS).

The component observing systems of WIGOS consist of the observing component of the Global Atmosphere Watch (GAW) Programme, the observing component of the Global Cryosphere Watch (GCW), the Global Observing System (GOS) of the World Weather Watch (WWW) Programme, and the WMO Hydrological Observing System (WHOS) of the Hydrology and Water Resources Programme (HWRP), including their surface-based and space-based components.

These components systems are inclusive of all WMO contributions to co-sponsored observing systems as well as the WMO contributions to GFCS and GEOSS. 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).

While the WIGOS component observing systems each have individual identities and stakeholder communities, they also support a single collective identity of all WMO observing systems (including co-sponsored systems) called the WIGOS.

**1.2.1 Global Observing System of the World Weather Watch**

1.2.1.1 The Global Observing System (GOS) **shall** be constituted as a coordinated system of observing networks, 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.

1.2.1.2 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.

1.2.1.3 The Global Observing System **shall** consist of: (i) a surface-based sub-system composed of regional basic networks of stations and platforms, and other networks of stations and platforms; and (ii) a space-based sub-system composed of: (a) an Earth observation space segment; (b) an associated ground system for data reception, dissemination and stewardship; and

(c) a user segment.

1.2.1.4 The Global Observing System **shall** comply with the provisions specified in the sections 1, 2, 3, 4 and 5.

The Global Observing System (GOS) is constituted as a coordinated system of observing networks, 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.

The purpose of the Global Observing System is 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.

The Global Observing System consists of: (i) a surface-based sub-system composed of regional basic networks of stations and platforms, and other networks of stations and platforms; and (ii) a space-based sub-system composed of: (a) an Earth observation space segment; (b) an associated ground system for data reception, dissemination and stewardship; and (c) a user segment.

OR

*The GOS is a coordinated system of different observing subsystems, the main purpose of which is to provide in a cost-effective way high-quality standardized meteorological and related environmental and geophysical observations from all parts of the globe and outer space, as they are required for the real-time preparation of weather analyses and forecasts, including warnings. The Global Observing System also provides observational data for research purposes in support of other WMO Programmes or relevant programmes of other international organizations, as agreed by the Organization.*

*The Global Observing System (GOS) provides (from the Earth and outer space) observations of the state of the atmosphere and ocean surface for the preparation of weather analyses, forecasts and warnings for all WMO Programmes and relevant environmental programmes of other inter- national organizations. It is operated by National Meteorological Services, national or international satellite agencies, and involves several consortia dealing with specific observing systems or geographic regions.*

*The GOS consists of (i) a surface-based sub-system composed of regional basic networks of stations/platforms, and other networks of stations/platforms, and (ii) a space-based sub-system composed of (a) an Earth observation space segment, (b) an associated ground system for data reception, dissemination and stewardship, and (c) a user segment.*

**1.2.2 Global Atmosphere Watch (observing component)**

1.2.2.1 The Global Atmosphere Watch (GAW) **shall** be a coordinated system of observing networks, methods, techniques, facilities and arrangements encompassing the many monitoring and related scientific assessment activities devoted to the investigation of the chemical composition and related physical characteristics of the atmosphere.

Note: The GAW Programme has six focal areas: ozone, greenhouse gases, reactive gases, aerosols, UV radiation and total atmospheric deposition. GAW stations in addition to measuring one or more of the parameters related to these areas may also measure ancillary variables, like radiation, radio nuclides, and persistent organic pollutants.

1.2.2.2 The purpose of the Global Atmosphere Watch **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 6, 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.

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

1.2.3.4 The observing component of the Global Atmosphere Watch Programme **shall** be operated in accordance with the provisions specified in the sections 1, 2, 3, 4 and 6.

The observing component of the Global Atmosphere Watch (GAW) is a coordinated system of observing networks, methods, techniques, facilities and arrangements encompassing the many monitoring and related scientific assessment activities devoted to the investigation of the chemical composition and related physical characteristics of the atmosphere.

The purpose of the Global Atmosphere Watch is 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 of this Manual, 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.

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

OR

*The Global Atmosphere Watch Programme provides reliable scientific data and information on the chemical composition of the atmosphere, its natural and anthropogenic change, and helps to improve the understanding of interactions between the atmosphere, the oceans and the biosphere.*

*The purpose and long-term goal of the Global Atmosphere Watch (GAW) Programme is to provide data and other information on the atmospheric chemical composition and related physical characteristics of the background, unpolluted atmosphere, 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.*

*The observing component of the Global Atmosphere Watch Programme is 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 WMO Hydrological Observing System**

1.2.3.1 The WMO Hydrological Observing System (WHOS) **shall** comprise hydrological observations, initially focusing on water level and discharge.

Note: The composition of the WMO hydrological observing systems is provided in the Volume III – Hydrology, Chapter D.1.2 of the *WMO Technical Regulations* (WMO-No. 49).

1.2.3.2 The WMO hydrological observing systems **shall** expand to include other elements identified through the application of the Rolling Review of Requirements (RRR) process (specified in section 2.2.4 and Appendix 2.3) at the national, regional and global levels.

1.2.3.3 The purpose of the WHOS **shall** be to provide real time stream data (both water level and discharge) from participating Members.

1.2.3.4 Members making their hydrological observations available through the WMO Hydrological Observing System (WHOS) **shall** comply with the provisions specified in the sections 1, 2, 3, 4 and 7.

Note: Volume III – Hydrology, the *Guide to Hydrological Practices* (WMO-No. 168), and the *Manual on Stream Gauging* (WMO-No. 1044) and the *Manual on Flood Forecasting and Warning* (WMO-No. 1072) provide the necessary information to operate hydrological stations to prescribed standards.

The WMO Hydrological Observing System (WHOS) comprises hydrological observations, initially focusing on water level and discharge, and it also includes the World Hydrological Cycle Observing System programme (WHYCOS) intended to improve basic observation activities, strengthen international cooperation and promote the free exchange of data in the field of hydrology.

The composition of the WHOS is provided in the Technical Regulations, Volume III – Hydrology, Chapter D.1.2 of the WMO Technical Regulations (WMO-No. 49).

The WHOS will expand to include other elements identified through the application of the Rolling Review of Requirements (RRR) process (specified in section 2.2.4 and Appendix 2.3 of this Manual) at the national, regional and global levels.

The purpose of the WHOS is to provide real time stream data (both water level and discharge) from participating Members.

Volume III – Hydrology, the Guide to Hydrological Practices (WMO-No. 168), and the Manual on Stream Gauging (WMO-No. 1044) and the Manual on Flood Forecasting and Warning (WMO-No. 1072) provide the necessary information to operate hydrological stations to prescribed standards.

OR

*The WMO Hydrological Observing System (WHOS) provides hydrological observations, initially focusing on water level and discharge, and includes the World Hydrological Cycle Observing System programme (WHYCOS) intended to improve basic observation activities, strengthen international cooperation and promote the free exchange of data in the field of hydrology. The composition of hydrological observations is provided in Volume III – Hydrology, Chapter D.1.2.*

*The purpose of the WHOS is to provide near real-time streamflow data (both water level and discharge) from as many National Hydrological Services as possible. WHOS draws from the water information systems of countries around the world that make their data freely and openly available, including HYCOS projects.*

**1.2.4 Global Cryosphere Watch (observing component)**

1.2.4.1 The Global Cryosphere Watch (GCW) **shall** be a coordinated system of observing networks, methods, techniques, facilities and arrangements encompassing monitoring and related scientific assessment activities devoted to the investigation of the Cryosphere.

1.2.4.2 The purpose of the Global Cryosphere Watch **shall** be to provide data and other information on the cryosphere, from a local to the global scale, to improve understanding of its behaviour, interactions with other components of the climate system, and impacts on society.

1.2.4.3 The GCW observing network and its standardized core network (CryoNet) **shall** build on existing observing programmes and promote the addition of standardized cryospheric observations to existing facilities.

1.2.4.4 The observing component of the Global Cryosphere Watch **shall** comply with the provisions specified in the sections 1, 2, 3, 4 and 8.

The Global Cryosphere Watch (GCW) is a coordinated system of observing networks, methods, techniques, facilities and arrangements encompassing monitoring and related scientific assessment activities devoted to the investigation of the Cryosphere.

The purpose of the Global Cryosphere Watch is to provide data and other information on the cryosphere, from a local to the global scale, to improve understanding of its behaviour, interactions with other components of the climate system, and impacts on society.

The GCW observing network and its standardized core network (CryoNet) SHALL build on existing observing programmes and promote the addition of standardized cryospheric observations to existing facilities.

The GCW Implementation Plan available at:  <http://globalcryospherewatch.org/reference/documents/> provides more information.

Existing Cryosphere observing programmes include cryospheric observational programs within WMO programmes (including the Joint WMO/IOC Technical Commission on Oceanography and Marine Meteorology (JCOMM)), the co-sponsored Programmes (GCOS, GTOS, GOOS) and including, but are not limited to, observational programmes of the International Permafrost Association (IPA), the World Glacier Monitoring Service (WGMS), a service of the International Association of Cryospheric Sciences (IACS), the Scientific Committee for Antarctic Research (SCAR), and the Global Precipitation Climatology Centre (GPCC), and the US National Snow and Ice Data Center (NSIDC).

OR

*The Global Cryosphere Watch provides authoritative, clear, and useable data, information, and analyses on the past, current and future state of the cryosphere.*

*The Global Cryosphere Watch (GCW) is 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) is built on existing Cryosphere observing programmes and promotes the addition of standardized Cryospheric observations to existing facilities.*

*The purpose and long-term goal of the Global Cryosphere Watch is 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.*

**1.3 Governance and Management**

**1.3.1 Implementation and Operation of WIGOS**

1.3.1.1 Members **shall** be responsible for all activities connected with the implementation and operation of WIGOS on the territories of their individual countries.

1.3.1.2 Members should, as far as possible, use national resources for the implementation and operation of WIGOS, 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.

1.3.1.3 Members should participate voluntarily in the implementation and operation of WIGOS in regions outside the territories of individual countries (e.g. outer space, oceans, the Antarctic), if they desire and are able to contribute by providing facilities and services, either individually or jointly.

In implementing and operating the WIGOS, the guiding principle is that all activities and facilities connected with the establishment and operation of the System in the territories of individual countries are the responsibility of the countries themselves and should be met to the extent possible with national resources. Where this is not possible, assistance may be provided by the United Nations Development Programme, through other multilateral or bilateral assistance programmes or by the WMO Voluntary Cooperation Programme.

Implementation of WIGOS outside the territories of individual countries, such as outer space, the oceans and the Antarctic, is based on the principle of voluntary participation of countries that are willing and able to contribute by providing facilities and services individually or jointly from their national resources or through collective financing.

***Agents for Implementation***

For the surface-based observing systems, the implementation of WIGOS actions rely mainly on national agencies such as NMSs and NMHSs, although in several cases, in-situ observing networks are implemented by non-meteorological institutes or agencies in the context of an international programme or within a strong international cooperation. In some cases the networks are funded for research purposes and their sustainability is therefore a concern.

For the space-based observing systems, the agents are sometimes satellite operators and national agencies operating satellites for research and/or operational purposes, and sometimes multi-national agencies specialized in space observations.

For both surface and space-based systems, the level of international cooperation needed is high and requires several programmes sponsored or co-sponsored by WMO in partnership with other international organizations. For observing systems evolving from research to operational status, three WMO Technical Commissions have a leading role: the Commission for Basic Systems (CBS), the Commission for Atmospheric Sciences (CAS) and the Commission for Instruments and Methods of Observation (CIMO).

For land-based in-situ observing networks, the design and development is often carried out through RAs, which have a key coordination role in their respective regions, using the guidelines of TCs, primarily (but not only) CBS. A number of requirements are met through co-sponsored observing systems (GCOS, GOOS, GTOS). Concerning ocean in-situ observing networks, the Joint WMO-IOC Technical Commission for Oceanography and Marine Meteorology (JCOMM) is involved for all the observing systems making marine meteorological measurements at the surface, as well as oceanographic measurements at the ocean surface or at depth. Atmospheric chemistry observations are implemented through the Global Atmospheric Watch (GAW) Programme and its strategic plan and addendum (see web references given in section 5.3.1.4). For space-based observing systems, there is a general tendency for the observations to be global and less regional than in-situ observing networks. But the role of WMO is equally important, and WMO works in close cooperation with the Coordinating Group for Meteorological Satellites (CGMS), and with national and international agencies.

**1.3.2 WIGOS Quality Management**

Note 1: Provisions relating to the WMO Quality Management Framework, WMO QMF, are provided in the *Technical Regulations* (WMO-No. 49), Volume IV – Quality Management, 2011 edition).

Note 2: 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 their quality management system for the provision of meteorological, hydrological, climatological and other related environmental observations.

Note 3: Section 2.6 provides detailed provisions on WIGOS Quality Management.

The World Meteorological Organization (WMO) has established, documented, implemented and maintains a Quality Management Framework (QMF) whose purpose is to provide a comprehensive system of recommended procedures and practices, with regard to quality of data, products and services that should be used by Members in establishing quality management systems for the provision of meteorological and hydrological services. The establishment, operation and maintenance of the WIGOS observing system by Members will benefit substantially through their utilization of a quality management system.

The following documents will provide Members with valuable information and guidance pertaining to the implementation of a quality management system:

* *[Guide to the Quality Management System for the Provision of Meteorological Service for International Air Navigation](http://library.wmo.int/opac/index.php?lvl=notice_display&id=7938)* [(WMO-No. 1001)](http://library.wmo.int/opac/index.php?lvl=notice_display&id=7938) (2011 edition)
* *[Guide to the Implementation of a Quality Management System for National Meteorological and Hydrological Services](http://library.wmo.int/opac/index.php?lvl=notice_display&id=15574" \l ".U4S4ExbpvIY)* [(WMO-No. 1100)](http://library.wmo.int/opac/index.php?lvl=notice_display&id=15574" \l ".U4S4ExbpvIY) (2013 edition)
* *[Guidelines for Implementing a Quality Management System in Hydrology](http://www.wmo.int/pages/prog/hwrp/qmf-h/index.php)*
* *[ISO 9000:2005, Quality management systems – Fundamentals and vocabulary](http://www.iso.org/iso/catalogue_detail?csnumber=42180)*
* *[ISO 9001:2008, Quality management systems – Requirements](http://www.iso.org/iso/catalogue_detail?csnumber=46486)*

Members should also avail themselves of the additional and valuable reference material on quality management available on the WMO Quality Management website and the ISO website.

Further specific guidance regarding the application of quality management to WIGOS is provided in Sec. 2.6 of this Guide.

**1.3.3 WIGOS High Level Processes**

1.3.3.1 Members should adopt a process-based approach to the management of WIGOS observing systems as described in Attachment 1.

Further guidance:

* WMO-No. 8, Part III, Chapter 1
* WMO-No. 488; Part III, 3.1.3, 3.1.4, 3.3.3

**1.4 Collaboration with partners responsible for co-sponsored and non-WMO observing systems**

In contrast to the primarily NMHS owned observing systems upon which the WWW was built, the WIGOS component observing systems are owned and operated by a diverse array of organizations, both research and operational.

The interaction between these various communities is important for the implementation and ongoing operation of WIGOS. In particular, strengthening the interaction between research and operational observing communities is important for sustaining and evolving observing systems and practices, in line with new science and technology outcomes.

Improved coordination and cooperation is supported by the high-level reconciliation mechanisms/arrangements defined between WMO-UNESCO/IOC-UNEP-FAO-ICSU. Such mechanisms resolve possible problems in data policy, product delivery and other governance issues. Members should implement similar arrangements among meteorological, hydrological, marine/oceanographic and other related academic/research institutions/services where they are separated at the national level for the implementation and operation of WIGOS, GFCS, GCOS, GOOS, GTOS, and GEOSS.

**References and Further Reading**

World Meteorological Organization: *WIGOS Operational Information Resource (WIR)* – Online resource available at: <http://www.wmo.int/pages/prog/www/wigos/wir/index_en.html>

World Meteorological Organization: *Observing Systems Capability Analysis and Review Tool (OSCAR)* – Online resource available at: <http://www.wmo-sat.info/oscar/>

World Meteorological Organization: *Rolling Review of Requirements and Statements of Guidance* – Online resource available at: <http://www.wmo.int/pages/prog/www/OSY/GOS-RRR.html>

World Meteorological Organization, 2009: *Vision for the GOS in 2025*. An online resource available at: <http://www.wmo.int/pages/prog/www/OSY/WorkingStructure/documents/CBS-2009_Vision-GOS-2025.pdf>

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**ATTACHMENT 1**

**WIGOS High Level Processes**

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

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.

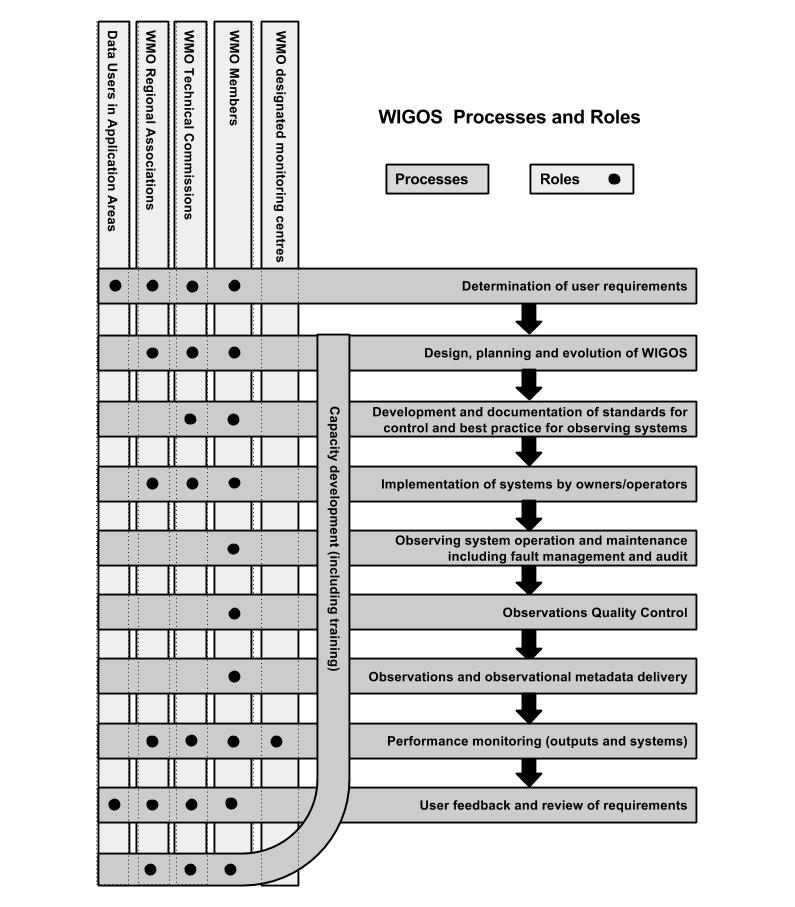


FIGURE 1: Schematic diagram of WIGOS high-level processes (horizontal bars), the collaborating entities (vertical columns) and those having primary involvement in each process (marked by solid circles).

These processes are carried out by Members 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).

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 operation of the WMO.

The following example illustrates the relation between the WIGOS high-level processes and the structure of the regulatory material. In section 2 the standard and recommended practices and procedures 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 standard and recommended practices and procedures for observing systems: 2.3
* Implementation of observing system by owners and operators: 2.3, 2.4
* Observing system operation and maintenance including fault management and audit: 2.4
* Observation quality control: 2.4, 2.6
* Observations and observational metadata delivery: 2.4, 2.5
* Performance monitoring: 2.4, 2.6
* User feedback and review of requirements: 2.2, 2.6
* Capacity development (including training): 2.7

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

**2.1 Requirements**

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

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 specified under 2.2.4 and Appendix 2.3.

Through the implementation and operation of WIGOS, the WMO intends to enable Members to manage their observing systems more effectively and efficiently.

By considering the WIGOS component networks as a whole, Members should seek opportunities to integrate and coordinate the establishment, operation and maintenance of their observing systems. Members may, for example, identify opportunities to use common hardware or software systems to achieve greater reliability of the networks at a lower cost. Members may also find opportunities to train staff to maintain equipment etc. for multiple component networks thereby enabling them to better utilize their staff.

Members should consider the sustainability of their networks throughout their decision making process. When establishing new stations or networks, Members should ensure they obtain the resources or the commitment to the resources necessary to operate and maintain the stations for a minimum of ten years. When preparing a proposal or request for funding for new or replacement stations, Members should estimate the ongoing operation and maintenance costs (including spare parts, staff time etc.) as well as the initial installation and establishment costs and seek commitments to the complete resource envelope.

A view on sustainability should also be kept during the operation and maintenance phase of a network. Members should develop a strategy for preventative maintenance of the WIGOS network to ensure continued, reliable and sustainable operation. Working with staff of the organization as well as manufacturers of the equipment, Members may be able to develop a strategy for preventative maintenance that mitigates the risk of unexpected failures leading to interruption in the delivery of observations. When unexpected failures occur, it is important for Members to address the issue quickly (particularly for critical networks) to minimize the loss of observations.

The *Guide to the Global Observing System* (WMO-No. 48), Part II, Chapter 1, (2.1) provides further guidance regarding general requirements; it is written with the GOS component in mind but the guidance is applicable more broadly.

Members should actively consider users requirements for observations in the establishment and operation of their WIGOS observational networks. This will require Members to establish processes to actively engage users. Members may use a variety of approaches in such processes – ranging from regular meetings through to the utilization of surveys, website feedback forms etc. – to develop and maintain a continuing understanding of users requirements. In some cases, Members may work with other countries or with the WMO Region in the determination of such requirements.

Members should collect, review, update and make available these observational user requirements for the Application Areas as defined for the WMO Rolling Review of Requirements (RRR).

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

The RRR, under the leadership and guidance of the Commission for Basic Systems, and with assistance from the WMO Secretariat, is a key process/system enabling members to effectively participate in the global assessment of user requirements. It is important for Members to effectively contribute their users requirements to the RRR process so the full development and design of WIGOS observing systems can effectively respond to these requirements.

Further details on the RRR process including the WMO application areas follows later in this Guide. The *Guide to the Global Observing System (WMO-No. 488)* (Part II, Appendix II.2) provides an example of the outcomes of the RRR process.

The *Guide to the Global Observing System (WMO-No. 488),* (Part II, Chapters 2 and 3) provide further guidance regarding observational data requirements including an extended description of the RRR process.

**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 capable of 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   Members **shall** plan and operate their networks in a sustainable and reliable manner utilizing WIGOS standard and recommended practices and procedures, and tools.

Note: Sustainability over at least a ten year period is recommended; however, this depends on paying sufficient attention to maintenance and operations following the original establishment.

As discussed above, it is critical that Members, organizationally and through the participation of their experts in the activities of Regional Associations and Technical Commissions, contribute to the Rolling Review of Requirements (RRR) process. The RRR process is fundamental to the work of the WMO and all Members in the design and planning of WIOGS including the component observing systems. It is planned that WIGOS will be a flexible and evolving system capable of continuous improvement. Understanding users changing requirements is critically important to identifying the improvements necessary in observational systems.

In addition to the specific user requirements identified through the RRR process, other 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.

Considering the user requirements identified within the RRR process as well as these factors, WIGOS plans, standards, recommended practices and procedures and tools (such as WIS) are continually revised and updated to inform the continued evolution of the observing systems.

The WMO periodically publishes plans for the evolution of WIGOS observing systems which are intended to be used by Members when planning and managing their observing systems. While Members are implementing these plans, they should also consider any specific plans developed by their Regional Association as well as specific national user requirements. Members can most effectively design and plan the evolution of their networks by considering carefully the global, regional and national plans and needs. The *Guide to the Global Observing System (WMO-No. 488), Part II, Chapters 4* provides further guidance regarding the requirements to meet national requirements with observing networks.

As they are developing, revising and/or updating their WIGOS observing networks, Members need also to identify the impact on all users prior to implementing any changes. In some situations, Members will need to work closely with users to enable them to understand and adapt to necessary changes while, in other cases, Members will modify their proposed plans to effectively mitigate the impact of change on the users.

In considering the evolution of their networks, Members need to consider all regional and national factors that may affect them. For example, Members need to maintain close coordination with their national telecommunication authorities to register their frequencies for adequate protection, and to defend the availability of frequencies for all WIGOS component observing systems. Members need to stay well informed regarding such national laws, regulations and requirements that could impact the WIGOS observing system now and in the future.

Through careful design and planning and utilization of all WIGOS materials, Members can most effectively achieve sustainability of their networks thereby achieving observational records that meet long-term requirements of users. Observational records equal to or exceeding ten years become significant to some users in the assessment of changes in the environment etc.

The evaluation reports of WIGOS Pilot Project II (Integrated SADC-HYCOS and SARFFGS: <http://www.wmo.int/pages/prog/www/wigos/documents/Evaluation/PP-CHy-Evaluation_2011-01.doc> ) and WIGOS Pilot Project III (Integration of AMDAR into WIGOS: <http://www.wmo.int/pages/prog/www/wigos/documents/Evaluation/PP-AMDAR_Evaluation_2011-01.doc> ) both identify the need to have appropriate resources (including sufficient and appropriately trained staff) to effectively implement WIGOS initiatives.

Further guidance:

* “Observing System Strategy” ([www.wmo.int/wigos](http://www.wmo.int/wigos))
* Requirements for the Implementation and Operation of an AMDAR Programme (WIGOS TR 2014-02)

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

**2.2.2.1** **Observing Network Design Principles**

2.2.2.1.1 Members should follow the principles specified in Appendix 2.1 when designing and evolving their observing system networks.

2.2.2.1.2 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.

The Principles have been specifically developed to guide the design, planning and evolution of WIGOS and it’s component observing systems. Members should consider carefully how to integrate these principles into their activities at the national level to assure their effective utilization and implementation

Note: Here will come the “Guidance on OND Principles” by J. Eyre et al;

Further guidance:

* WMO-No. 100, Chapter 2, 2.5
* WMO-No. 134, Chapter 2, 2.2.4, 2.4.1.11.3;
* WMO-No. 488, Part III, 3.1

**2.2.2.2 GCOS Climate Monitoring Principles**

2.2.2.2.1 Members designing and operating observing systems for monitoring climate should adhere to the principles specified in Appendix 2.2.

Note: Fifty Essential Climate Variables (ECVs) have been identified for GCOS, which are required to support the work of the United Nations Framework Convention on Climate Change (UNFCCC) and the Inter-governmental Panel on Climate Change (IPCC). The ECVs cover the atmospheric, oceanic and terrestrial domains, and all are technically and economically feasible for systematic observation. Further information about the ECVs is in the "Implementation Plan for the Global Observing System for Climate in support of the UNFCCC (2010 Update)" (GCOS-138, also identified as WMO-TD/No.1523).

The GCOS Climate Monitoring Principles (GCMPs) provide basic guidance regarding the planning, operation, and management of observing networks and systems, including satellites, to ensure that high-quality climate data are available and contribute to effective climate information. The GCMPs address issues such as the effective incorporation of new systems and networks; the importance of calibration, validation, and data homogeneity; the uninterrupted operation of individual stations and systems; the importance of additional observations in data-poor regions and regions sensitive to change; and the crucial importance of data management systems that facilitate access, use, and interpretation of the data. These principles have been adopted or agreed by the UNFCCC, WMO, the Committee on Earth Observation Satellites (CEOS), and other bodies. The implementation Actions now call on all data providers to adhere to the GCMPs and to initiate effective programmes of data quality control. When calibrating observing systems, traceability to SI standards should be ensured where possible.

These principles should be considered and utilized when operating observing systems for monitoring the climate.

**2.2.3 Vision for WIGOS Observing Systems**

2.2.3.1 Members **shall** take into account the “*Vision for the global observing system in 2025”*when planning the evolution of their observing networks.

Note 1: The “*Vision for the global observing system in 2025*” provides high-level goals to guide the evolution of the WMO integrated global observing systems in the coming decades. The Vision is updated on a multi-year time scale (typically decadal).

Note 2: The “*Vision for the global observing system in 2025*” is available at: http://www.wmo.int/pages/prog/www/OSY/gos-vision.html

The “*Vision for the global observing system in 2025*” (<http://www.wmo.int/pages/prog/www/OSY/gos-vision.html>) was adopted by CBS in 2009 and provides guidance that should be considered when planning the evolution of WIGOS observing networks.

This Vision provides valuable guidance to use in planning the future evolution of observing networks. While it was developed specifically for the GOS component, it is valuable to consider it for the evolution of the full WIGOS observing system given the expectation of an integrated and coordinated observing system.

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

2.2.4.1 Members, both directly and 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.

Note: Appendix 2.3 provides further details on the RRR process.

The RRR is a key process of the WMO to guide the development of WIGOS. Appendix 2.2 of the Manual on WIGOS provides some details and further information may be found on the WMO web site at: <http://www.wmo.int/pages/prog/www/OSY/GOS-RRR.html>

The RRR process compiles:

(a) information on Members evolving requirements for observations in the application areas that directly use observations;

(b) the extent to which current and planned WMO observing systems satisfy those requirements;

(c) guidance from experts in each application area on priorities for addressing the deficiencies and opportunities in WMO observing systems;

and hence plan for the future evolution of WMO observing systems (that is, WIGOS).

The *Guide to the Global Observing System* (WMO-No. 448), Part II (Observational Data Requirements, 2.3.1) provides a detailed description of the RRR process with an emphasis on the GOS component network but with sufficient generality to be a valuable guide to the process for the full WIGOS network.

**2.2.5 Observation Impact Studies**

2.2.5.1 Members, or groups of Members within regions, should conduct and/or participate in observation impact studies and related scientific evaluations to address WIGOS network design questions.

2.2.5.2 Members should provide expertise 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.

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 these Application Areas.

To maximize the efficiency and effectiveness of the full WIGOS, it is important to systematically investigate the impact of different observing sub-systems on the WMO application areas. These investigations are used to assist in the planning and design of the WIGOS to ensure it provides the greatest value to the application areas at the minimum cost to operators. Observation impact studies are designed to undertake such investigations and provide the necessary information to support decisions by network operators.

Such impact studies are most advanced in Numerical Weather Prediction where Observing System Experiments (OSEs) are carried out to quantify the relative contribution made by ground-based and satellite-based operational systems to forecast performance. The impact of a specified observing sub-system is assessed by comparing extended data assimilation and regular forecasts based on the total operational system (“control experiments”) with those generated excluding the particular observing system under investigation (“data denial”). The value of new or experimental observing systems can be assessed in a similar manner. Observing System Simulation Experiments (OSSEs) are used to assess the prospective impact of proposed additions or enhancements to the current global observing system; OSSEs serve as a design and decision-support tool for the WIGOS of tomorrow.

OSE’s or OSSE’s may be designed and conducted at a national, regional or potentially global level depending on the networks being evaluated and the changes being considered. Such studies may be designed and lead under the auspices of a Technical Commission, at a regional level, at a multi-national level or at a national level. Such studies require the expertise of individuals from Members and all operators of WIGOS networks to design, conduct and analyse the results of the study. The studies should provide recommendations regarding the best mix of observing systems and observing strategies to address gaps identified through the RRR process.

Guide: WMO-No. 488, Part II, 2.2, 2.3

**2.2.6 Evolution of WIGOS Observing Systems**

2.2.6.1 Members should follow the plans published by WMO for evolution of WIGOS component observing systems when planning and managing their WIGOS observing systems.

Note1: The planning and coordination of the evolution of WIGOS observing systems 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.

Note 2: The current WMO plan for the evolution of WIGOS observing systems was published as the "*Implementation Plan for the Evolution of Global Observing Systems (EGOS-IP)*" (WIGOS Technical Report No. 2013-4). It contains guidelines and recommended actions to be undertaken by Members, technical commissions, regional associations, and satellite operators and other relevant parties in order to stimulate cost-effective evolution of the WMO observing systems to address in an integrated way the requirements of WMO Programmes and co-sponsored programmes.

Note 3: The WMO plan for the evolution of WIGOS observing systems is regularly updated and new versions are published on a multi-year time scale (typically decadal), taking into account the Vision for the WIGOS observing systems, and the advice of technical commissions and regional associations, concerned and relevant WMO co-sponsored observing systems, and international experts in all application areas.

2.2.3.6.2 Members **shall** coordinate the activities by agencies within their country including the National Meteorological and Hydrological Services (NMHSs) and other relevant agencies, in addressing relevant actions of the WMO plans for evolution of WIGOS observing systems.

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

2.2.3.6.4 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.

The WIGOS gradually evolves to address the changing global, regional and national requirements for observational data using new and existing observational methods and instruments. The WMO plan for the evolution of WIGOS contain guidelines and recommended actions to be undertaken by Members, Technical Commissions, Regional Associations, and satellite operators and other relevant parties in order to stimulate cost-effective evolution of the WMO observing systems to address in an integrated way the requirements of WMO programmes and co-sponsored programmes. The WMO plan for the evolution of WIGOS is 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 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 Commission on Basic System, 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.

The continuous evolution of the WIGOS component observing systems is guided by the *Implementation Plan for the Evolution of WIGOS (WIGOS-IP)*. The WIGOS-IP contains 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. Considering the *Vision for the GOS*, the CBS, in consultation with other Technical Commissions and Regional Associations, concerned and relevant WMO co-sponsored observing systems, and international experts in all application areas will elaborate on a decadal basis, and regularly update the WIGOS-IP. The Rolling Review of Requirements process, including the result of impact studies, critical reviews, and the gaps identified in the Statements of Guidance shall contribute to this exercise.

Regional Associations, through their respective WIGOS regional working bodies, follow the technical guidance as represented in the WIGOS-IP and other observation system implementation plans in order to evolve and implement observing systems in the various Regions. Regional Associations coordinate and identify issues regarding the data and product utilization needs of Members within the Region. They consider the actions and guidance from the WIGOS-IP and this WIGOS Manual to inform and influence observing system development and implementation.

Members take the WIGOS-IP into account, as well as the global requirements, regional requirements and plans, and national requirements and priorities when planning the evolution of their observing networks contributing to WMO application areas. In particular, Members coordinate with NMHSs and relevant national agencies, and investigate the possible national responses to be given to each of the actions of the WIGOS-IP assigned to Members and/or NMHSs.

Further guidance: WMO-No. 488, Part II, 2.5

**2.2.6.1 Monitoring the Evolution of WIGOS Observing Systems**

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

Note: The Commission for Basic Systems, 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.

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**APPENDIX 2.1**

**Observing Network Design (OND) Principles**

1. SERVING MANY APPLICATION AREAS

Observing networks should be designed to meet the requirements of multiple application areas within WMO and WMO co-sponsored programmes.

2. RESPONDING TO USER REQUIREMENTS

Observing networks should be designed to address stated user requirements, in terms of the geophysical variables to be observed and the space-time resolution, uncertainty, timeliness and stability needed.

3. MEETING NATIONAL, REGIONAL AND GLOBAL REQUIREMENTS

Observing networks designed to meet national needs should also take into account the needs of the WMO at the regional and global levels.

4. DESIGNING APPROPRIATELY SPACED NETWORKS

Where high-level user requirements imply a need for spatial and temporal uniformity of observations, network design should also take account of other user requirements, such as the representativeness and usefulness of the observations.

5. DESIGNING COST-EFFECTIVE NETWORKS

Observing networks should be designed to make the most cost-effective use of available resources. This will include the use of composite observing networks.

6. ACHIEVING HOMOGENEITY IN OBSERVATIONAL DATA

Observing networks should be designed so that the level of homogeneity of the delivered observational data meets the needs of the intended applications.

7. DESIGNING THROUGH A TIERED APPROACH

Observing network design should use a tiered structure, through which information from reference observations of high quality can be transferred to and used to improve the quality and utility of other observations.

8. DESIGNING RELIABLE AND STABLE NETWORKS

Observing networks should be designed to be reliable and stable.

9. MAKING OBSERVATIONAL DATA AVAILABLE

Observing networks should be designed and should evolve in such a way as to ensure that the observations are made available to other WMO Members, at space-time resolutions and with a timeliness to meet the needs of regional and global applications.

10. PROVIDING INFORMATION SO THAT THE OBSERVATIONS CAN BE INTERPRETED

Observing networks should be designed and operated in such a way that the details and history of instruments, their environments and operating conditions, their data processing procedures and other factors pertinent to the understanding and interpretation of the observational data (i.e. metadata) are documented and treated with the same care as the data themselves.

11. ACHIEVING SUSTAINABLE NETWORKS

Improvements in sustained availability of observations should be promoted through the design and funding of networks that are sustainable in the long-term including, where appropriate, through the transition of research systems to operational status.

12. MANAGING CHANGE

The design of new observing networks and changes to existing networks should ensure adequate consistency, quality and continuity of observations across the transition from the old system to the new.

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**APPENDIX 2.2**

**GCOS Climate Monitoring Principles**

***Effective monitoring systems for 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[[2]](#footnote-2) 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;

Furthermore, 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 interannual) changes can be resolved.

***Thus 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;

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Regarding DM ((j) above): Guide WMO-No. 100, 3.3.9**APPENDIX 2.3**

**The RRR Process**

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 WIGOS observing systems satisfy those requirements; guidance from experts in each application area on the gaps and the priorities for addressing the deficiencies and opportunities in WMO observing systems; and hence plans for the future evolution of WIGOS observing systems.

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.

Note 1: A detailed and up-to-date description of the RRR process is available on the WMO website at <http://www.wmo.int/pages/prog/www/OSY/GOS-RRR.html>.

In addition, observational requirements for WMO polar activities and the Global Framework for Climate Services (GFCS) are also being 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 for each Application Area to be the Point of Contact (PoCs). 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.

The nominated Point of Contact should 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 <http://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 Statement of Guidance for the Application Area.

Note 2: The observational user requirements compiled through the RRR process are stored and made available by the WIGOS Operational Information Resource (WIR) (OSCAR/Requirements database) as described in detail in Attachment 2.2.

The RRR process consists of four stages:

(1) 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);

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

(3) A Critical Review, a comparison of requirements with the observing system capabilities; and

(4) A Statement of Guidance providing a gap analysis with recommendations on addressing the gaps for each Application Area.

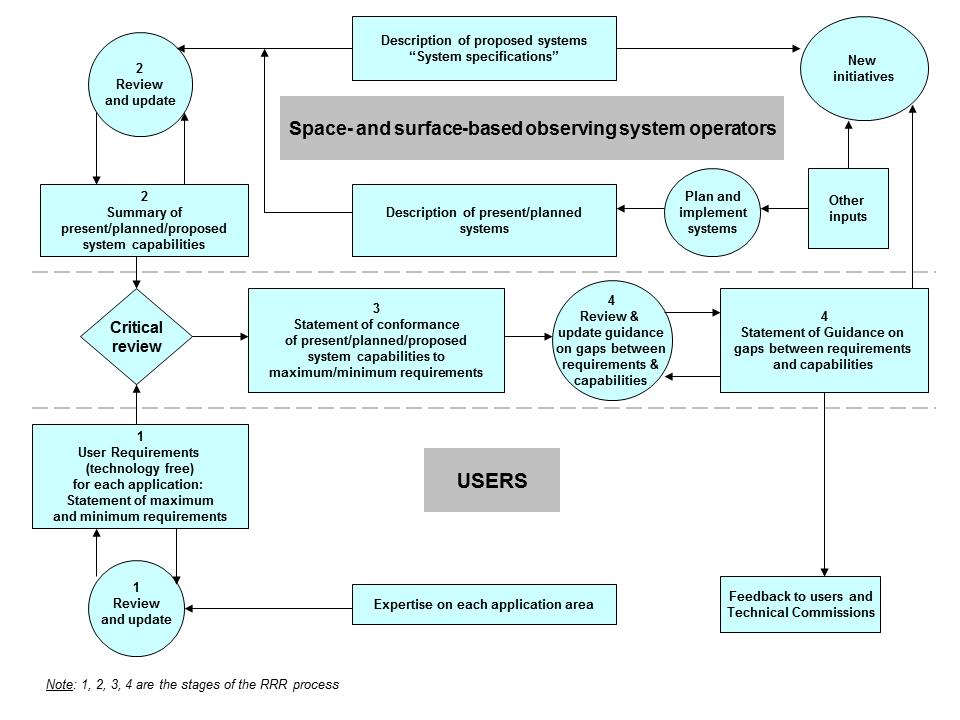


Figure 2: Schematic representation of the steps included in the Rolling Review of Requirements process.

**1) Review of observational user requirements**

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

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

**2) 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: Information on 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.

**3) 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.

**4) Statements of Guidance**

Note 1: The Statement of Guidance interprets the output of the critical review as a gap analysis and 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.

See:

1) WMO-No. 544, Part II, 2

2) WMO-No. 488, Part II, 2.3

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**2.3 Instrumentation and Methods of Observation**

**2.3.1 General Requirements**

Note: Details are provided in the *Technical Regulations* (WMO-No. 49), Volume III: Hydrology, the *Guide to Meteorological Instruments and Methods of Observation* (WMO-No. 8), *Weather Reporting* (WMO-No. 9), Volume D – Information for Shipping, and the *Guide to Hydrological Practices* (WMO-No. 168), Volume I: Hydrology – From Measurement to Hydrological Information.

2.3.1.1 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.

2.3.1.2 Members should employ properly calibrated instruments and sensors that provide observations satisfying at least measurement uncertainties that meet the specified requirements.

Note 1: Achievable measurement uncertainty is specified in the *Guide to Meteorological Instruments and Methods of Observation* (WMO-No. 8), Part I, Chapter 1 (1.6), Annex 1.D.

Note 2: A number of operational, financial, environmental and instrumental issues may cause the system to not always satisfy the specified requirements, e. g. Annex 1.D (the column „achievable“) provides a list of the achievable and affordable measurement uncertainties which in some cases might not satisfy specified requirements.

2.3.1.3 Members should describe uncertainty of observations and observational metadata as specified in the *Guide to Meteorological Instruments and Methods of Observation* (WMO-No. 8), Part I, Chapter 1 (1.6).

Note 1: The corresponding text from the *Guide to Meteorological Instruments and Methods of Observation* (WMO-No. 8), Part I, Chapter 1 (1.6) will be included as an Appendix in a future edition.

Note 2: The definition of uncertainty in the *Guide to Meteorological Instruments and Methods of Observation* (WMO-No. 8), Part I, Chapter1 (1.6) is consistent with international standards approved by the International Committee for Weights and Measures (CIPM).

2.3.1.4 Members should follow the definitions and specifications for the calculation of derived observations specified in the WMO Technical Regulations.

Note 1: Further methods provided or referenced by the *Guide to Meteorological Instruments and Methods of Observation* (WMO-No. 8) and the *Guide to Hydrological Practices* (WMO-No. 168), Volume I: Hydrology – From Measurement to Hydrological Information could be also considered.

Note 2: Such derivations can take many forms, such a statistical processing of average or smooth values, or multivariate algorithm to determine streamflow discharge.

Note 3: The corresponding text from the *Guide to Meteorological Instruments and Methods of Observation* (WMO-No. 8) will be included as an Appendix in a future edition.

It is intended that the observations and observational metadata of WIGOS be traceable to International Standards where they exist. *The Guide for the Use of the International System of Units (SI)*[[3]](#footnote-3) provides information that can assist in applying such standards. The *Guide to Meteorological Instruments and Methods of Observation* (WMO-No. 8) (Part I, Chapter 1, (1.6.5.2), Annex 1.D) specifies both the required (i.e. as required by users) and achievable measurement uncertainties for some of the WIGOS network. Observing systems (equipment, installation, operations) should provide observations that meet requirements; ultimately, the intent is to meet the required measurement uncertainties. Employing properly calibrated instruments and sensors enables meeting requirements.

There are a number of operational, financial, environmental and instrumental issues that may cause the system to not always satisfy the required measurement uncertainties. Annex 1.D (the column “achievable“) provides a list of the achievable and affordable measurement uncertainties which in some cases might not satisfy specified requirements. For some of the quantities, even these uncertainties are achievable only with the highest quality equipment and procedures.

The *Guide to Meteorological Instruments and Methods of Observation* (WMO-No. 8) (Part I, Chapter 1, (1.6)) provides definitions and guidance on how to describe uncertainty of observations and observational metadata. In order to describe the uncertainty of observations, one must consider the many possible sources of error that can arise:

1. Errors in the international, national and working standards and in the comparisons made between them. These may typically be assumed to be negligible unless specifically identified issues are known.
2. Errors in the comparisons made between the working, travelling and/or check standards and the field instruments in the laboratory or in whatever process is used to establish traceability. These are typically small if good processes are established and utilized but may quite easily be larger, depending on the skill of the operator and the quality of the equipment;
3. Non-linearity, drift, repeatability and reproducibility in the field instrument and associated hardware systems (e.g. recorder etc.)
4. The effectiveness of the instrument in properly recording the intended environmental value. These should typically be identified by the manufacturer for various operating conditions;
5. The effectiveness of the exposure shelter in assuring the instrument is well exposed to measure the intended environmental value while being sheltered from non-desirable influences (e.g. the effectiveness of a shelter in exposing a thermometer to the ambient air temperature while appropriately shading it from direct insolation etc.) Large errors may be introduced depending on the design and deployment of the shelter.
6. The exposure, which should ensure that the instrument shelter is representative of the region to be monitored. The nearby environment including the built environment (e.g. buildings, dams, roads, wires etc.) and topography (hills, land-water boundaries) may introduce large errors.

The station metadata should contain a good and regularly updated description of the relevant factors to inform data users about possible errors in station observations.

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 *Guide to Meteorological Instruments and Methods of Observation* (WMO-No. 8) and the *Guide to Hydrological Practices* (WMO-No. 168), Volume I: Hydrology – From Measurement to Hydrological Information.

Further guidance:

* WMO-No. 100, Chapter 2, 2.3.5;
* WMO-No. 188;
* WMO-No. 154;
* WMO-No. 731; Chapter 2

**2.4 Operations**

**2.4.1 General Requirements**

Note: Provision 2.4.1.1, Volume I, Part I of the *Technical Regulations* (WMO-No. 49) applies.

2.4.1.1 WMO observing stations and platforms **shall** be uniquely identified by a WIGOS station identifier.

Note: The structure of WIGOS station identifiers is specified in Attachment 2.1

2.4.1.2 Members **shall** issue WIGOS station identifiers for observing stations and platforms within their geographic area of responsibility that contribute to a WMO or co-sponsored programme and **shall** ensure that no WIGOS station identifier is issued to more than one station.

Note: Members may issue WIGOS station identifiers for observing stations and platforms within their geographic area of responsibility that do not contribute to a WMO or co-sponsored programme, provided that the operator has committed to providing and maintaining WIGOS metadata.

2.4.1.3 Before issuing a station identifier, Members should ensure that the operator of a station or platform has committed to providing and maintaining WIGOS metadata for that station or platform.

Note 1: In circumstances when a WIGOS identifier is required for a station or platform to support a WMO or co-sponsored programme and no Member is in a position to issue one (e.g. Antarctica), the Secretary-General may issue a WIGOS station identifier for that station or platform provided that its operator has committed to:

(a) Providing WIGOS metadata; and

(b) Conforming to relevant Technical Regulations.

Note 2: In circumstances where a WIGOS identifier is required for a station or platform to support a WMO or co-sponsored programme and a Member is not able to issue a WIGOS identifier, the Secretary-General will work with the Member concerned to issue a WIGOS station identifier for that station or platform provided that its operator has committed to:

(a) Providing WIGOS metadata; and

(b) Conforming to relevant Technical Regulations.

2.4.1.4 Members **shall** make available to WMO the updated metadata each time a new station identifier is issued.

2.4.1.5 Members **shall** operate 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).

2.4.1.6 Members should address the requirements for uncertainty, timeliness, temporal resolution, spatial resolution, and coverage which result from the RRR process specified in section 2.2.4 and in accordance with the details provided by other sections as appropriate.

2.4.1.7 Members **shall** ensure that proper safety procedures are specified, documented and utilized in all its operations.

Note: Safety practices and procedures are those that are concerned with assuring the welfare of staff while promoting overall efficiency and effectiveness of the NMHS and responding to national laws, regulations and requirements for occupational health and safety.

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

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).

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).

A deliberate and systematic approach is recommended for the operation of WIGOS observation networks. Such an approach begins with the selection, installation and continued maintenance of properly calibrated instruments. As discussed in 2.3, it is necessary to appropriately assess the potential sources of error and, as possible, mitigate those causes during the operation of the observing system. Documented processes should be established regarding the approved methods and procedures for the regular calibration of instruments – noting that such procedures will need to reflect a variety of influences including manufacturer recommendations, user requirements, operational environment etc. Original equipment manufacturers usually prescribe procedures and techniques to be followed in determining and correcting equipment malfunctioning. These techniques and procedures are based on laboratory testing and experience gained from field operations and must be followed first in attempting to correct equipment failures and maintain the quality standards of the operation.

It is also necessary to clearly specify and document observing and measuring techniques that are to be used across the operations of the network. These specifications provide requirements for staff and operating partners to use to ensure the observations meet requirements including the standards and recommendations of Vol. 1 Part 1 and the Manual on WIGOS.

The proper development and implementation of a systematic approach to the observation networks will enable the continuity of operation and availability of observations generated by the observing systems. A systematic approach to operations should be inclusive of the day to day operations as well as the conduct of routine maintenance.

The RRR process identifies the agreed requirements for uncertainty, timeliness, temporal resolution, spatial resolution, and coverage for observational networks. Observing practices and procedures are developed, implemented and maintained to enable the networks to meet particularly the requirements for uncertainty and timeliness on a continuing basis.

Proper safety procedures for the operation of observing systems must also be specified, documented and utilized. This can be best accomplished by publishing a handbook of national safety practices and procedures for operation of the observing systems. The handbook should stress precautions and practices specific to the conditions in the country concerned and satisfy country specific requirements regarding legal, health and safety codes. To prepare the handbook, a risk assessment of the work of all in the observing system should be conducted. From these risks, policies, procedures and directions can be prepared for the handbook in order to minimize the identified risks. As part of these procedures, a system should be established for staff to easily report safety issues and incidents. These reports need to be routinely analysed to identify causative factors and to thereby improve the documented safety procedures.

Further guidance:

* WMO-No. 100, Chapter 2, 2.6;

**2.4.2 Observing Practices**

2.4.2.1 Members should ensure that their observing practices are adequate to comply with the observational user requirements.

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

Technical specifications and details are given primarily provided in the *Guide to Meteorological Instruments and Methods of Observation* (WMO-No. 8), *Guide to Climatological Practices* (WMO-No. 100), *Guide to Hydrological Practices* (WMO-No. 168), Volume I: Hydrology – From Measurement to Hydrological Information, *Guide on the Global Data-Processing System* (WMO-305), and *Guide to the Global Observing System* (WMO-No. 488).

Observing practices (inclusive of station operation, data processing practices and procedures, applied calculation rules, documentation on calibration practices and associated metadata) should be developed and utilized to ensure that observations are adequate to meet with the observational user requirements determined through the RRR process.

Appendix 2.1 of the Manual on WIGOS identifies the 12 WMO Application Areas. In developing observing practices, one should consider the requirements of these Application areas and ensure the overall availability of observations to meet these requirements. Some of these application areas (like numerical weather prediction) require special attention, as other application areas are dependent on their results. Other application areas (like climate applications) require special attention to meet the priorities of the Members of the WMO (e.g the Global Framework for the Climate Services.) And, some application areas may require special attention as they constitute a priority regional or national initiative.

Through our standardized observing practices, we want to ensure timely, quality-assured, quality-controlled, and well-documented compatible long-term observations are available to users in all application areas in accordance with the practices and procedures specified in these Technical Regulations, the Manual on WIGOS and the other relevant Manuals.

**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 exchange of observations via the WMO Information System.

Note 1: Quality control of observations consists of examination of observations at stations and at data centres to detect errors so that observations may be either corrected or flagged. A quality control system should include procedures for returning to the source of observations to verify them and to prevent recurrence of errors. Quality control is applied in real time, but it also operates in non-real-time, as delayed quality control. Observations quality depends on the quality control procedures applied during observations acquisition and processing and during preparation of messages, in order to eliminate the main sources of errors and ensure the highest possible standard of accuracy for the optimum use of these observations by all possible users.

Notes 2: 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 observations in data processing (i.e. objective analysis and forecasting).

Note 3: Recommended minimum standards of quality control of the meteorological and climatological observations 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. The *Guide on the Global Data-processing System* (WMO-No. 305) should be consulted for more detailed guidance.

Note 4: 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 5: Recommended practices and procedures regarding the quality of observations for GAW requirements are formulated in Measurement Guidelines through Data Quality Objectives.

Recommended minimum standards of quality control of the meteorological and climatological observations 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. The *Guide on the Global Data-processing System* (WMO-No. 305) should be consulted for more detailed guidance (all ref. should be in more detailed way, not just the guide itself). Further guidance is available in the *Guide to Meteorological Instruments and Methods of Observation* (WMO-No. 8), the *Guide to Climatological Practices* (WMO-No. 100), and the *Guide to the Global Observing System* (WMO-No. 488), Part VI.

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). Further guidance is available in Volume I: Hydrology – From Measurement to Hydrological Information.

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

The need for quality control of observational data is linked with the fundamental importance of obtaining consistent and accurate data for their optimum use by all possible users. Users need to be confident that the observations they receive from other countries are made according to agreed standards set by WMO.

Standardized practices and procedures for the quality control of observations should be developed and documented. These should then be conducted in both real-time and non-real-time. Real-time quality control of observations should be conducted prior to the exchange of observations via the WMO Information system. Non-real-time quality control of observations should be conducted prior to the forwarding of observations for archiving. Where difficulty is encountered in routinely applying quality control procedures, it is suggested that agreements be made (e.g. with an appropriate Regional or World meteorological centre) to have the necessary quality control performed.

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

WIGOS observations should be subject to quality control that is focused on fulfilling quality requirements prior to the dissemination of observational data. Data quality control (DQC) is a special and fundamental aspect of WIGOS quality management for which rigorous standards should be defined and applied at each step in the measurement process and for all observational data processing components of all WIGOS Component Systems and subsystems.

Typically, data quality control processes are applied whenever a data value is acquired, measured, derived, decoded or encoded within a message or product for transfer or transmission of WIGOS observations. Observational data must be quality controlled at different levels of data pre-processing and processing and transfer in real time and non-real time, using various procedures.

The levels of quality control procedures are as follows:

1. The observing site, starting with data acquisition by manual or automatic stations;
2. Data collection centres, prior to the transmission of observational data over the Global Telecommunication System;
3. GTS centres (standard telecommunication procedures, for example, control of timeliness and data format);
4. GDPFS centres and other available facilities.

The use of these levels of quality control varies by sub-component network.

WIGOS DQC processes should be developed and implemented in order to meet data quality standards or as specified within the Manual on WIGOS and should 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
7. The removal of invalid data from data products or messages.

Further guidance:

* WMO‑No. 485, Part II, 2.1.3 – Minimum standards;
* WMO‑No. 305, Chapter 6;
* WMO-No. 100, 2.6.3, 2.6.8, 3.4;
* WMO-No. 305, Chapter 6;
* WMO-No. 488 Chapter VI and VII;
* WMO-No. 958, Chapter 6;
* Marine observations: WMO‑No. 781, 3.1.4, Appendix I; WMO‑No. 471, 3.2.9, Annex 3E; WMO‑No. 558, Volume I, 5.6.3; Data, Manuals and Guides, No. 26, UNESCO.

2.4.3.3 Members not capable of implementing these standards should establish agreements with an appropriate Regional Meteorological Centre or World Meteorological Centre to perform the necessary quality control.

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

2.4.3.5 Members should develop and implement adequate quality control processes.

Note 1: Quality control processes include (but are not necessarily limited to): (a) validation; (b) cleaning; (c) monitoring.

Note 2: Further guidance is available in the *Guide to Meteorological Instruments and Methods of Observation* (WMO-No. 8), Part II, Chapter 1, 1.3.2.8, 1.5.2; Chapter 12, 12.9; Part III, Chapter 1, 1.1, 1.6, 1.7; *Guide to Climatological Practices* (WMO-No. 100), *Guide to Hydrological Practices* (WMO‑No. 168), Volume I: Hydrology – From Measurement to Hydrological Information, and *Guide to the Global Observing System* (WMO-No. 488).

Recommended standard formats for the reporting and sharing observations are specified Annex II to the Technical Regulations (*Manual on Codes* (WMO-No. 306)).

For GAW observations, recommended stated formats are provided by GAW data centres.

See No.49, Vol. II., 2.2.5 & Note

**2.4.4 Data and Metadata Reporting**

2.4.4.1 Members **shall** report and make available observations in standard formats specified by the *Manual on Codes* (WMO-No. 306).

2.4.4.2 In the case of GAW observations, Members **shall** report and make available observations in standard formats as advised by GAW data centres, in accordance with the provisions in section 6.

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

Further guidance:

* Requirements for the international exchange of observational data and product are specified in the *WMO Technical Regulations* (WMO-No. 49), Vol. I.
* No.49, Vol. II., 2.2.5 & Note; WMO-No. 837
* WMO-No. 544, Part III

**2.4.5 Incident Management**

2.4.5.1 Members should implement incident management to detect, identify, record, analyse 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, analyse and respond to system faults and human errors at the earliest stage possible.

2.4.5.3 Members should record and analyse incidents as appropriate.

With large, distributed networks of observing stations, preparations must be made for unexpected incidents produced by any number of causes (e.g. vandalism, storms, floods, power outages, communications interruptions etc.) The goal is to minimize negative impacts on the quality or availability of observations from the WIGOS observing system.

As part of network operating procedures and systems, a system should be developed and continuously operated for incident management to detect, identify, record, analyze and respond to any incident affecting observations. This incident management system should define procedures for restoring a normal observing system operation as quickly as possible thereby minimizing any negative impact. The system should also enable a post-incident review to assess the underlying causes and identify revised observing system procedures to prevent or reduce the likelihood of a future re-occurrence.

**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 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.

With on-going program, user requirements, technological etc. changes, it is recognized that WIGOS observing systems will regularly undergo changes. It is critical to carefully plan and control such changes to ensure continuity and consistency of observations while also clearly recording such changes in the metadata for the observing system. This requirement applies to any change in the observing system, including an observing station, observing programme, instruments, methods of observation, etc.

Particularly for system-wide changes to one or more component networks, it is preferable to follow project management approach utilizing industry standard project management methods (e.g Prince II.) Such an approach enables one to more effectively plan and control the changes (including the associated costs) and to schedule the implementation to minimize disruption to the observing system.

In the case of significant changes in instruments or methods of observation used or the location in which observations are made, it is important ensure 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 inhomogeneity’s. Such a dual operation will provide a dataset that enables users (current and future) to properly assess the new data and adjust their use of the data as required to their application. Appropriate metadata needs to be recorded to ensure users of the observations can appropriately apply the parallel series of observations. Frequently, reports etc. are prepared describing the new and old systems, providing an analysis of the observations and providing recommendations and advice to users on their application.

**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: Carefully 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 platform, 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 Chapters 16 and 17 of the Guide, the *Guide to Hydrological Practices* (WMO‑No. 168) and the *Manual on Stream Gauging* (WMO-No. 1044).

Detailed guidance on maintenance of observing systems and instruments is given in the *Guide to Meteorological Instruments and Methods of Observation,* Chapter 12 (sec. 12.9) (WMO-No. 8) and including 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).

Regular and routine maintenance of all elements of an observing system is critical to assuring the reliability and quality of the observational program. The maintenance programme should include preventive maintenance, equipment calibration, periodic cleaning and lubrication, performance testing, corrective and adaptive maintenance and equipment modification, as necessary. Preventative maintenance is conducted regularly to prevent the occurrence of failures in the observing system that either impact the availability or the quality of the observations. The frequency and timing (schedule) of preventive maintenance is determined considering the type of the observing system, environmental and climate conditions of the observing site/platform, and the characteristics of the installed instrumentation. Manufacturers of instruments may provide recommended maintenance schedules that should be considered in developing specific plans.

To increase user confidence in the reliability of information derived from a network, it is necessary to institute a continuously operational real-time and near-real-time monitoring programme and thereby validate the quality of the data generated by the network. Notwithstanding a program of preventative maintenance, observing component faults will occur that do affect either or both of the availability and quality of the observations. In these cases, corrective maintenance should be undertaken as soon as practicable. Such a program of corrective maintenance is critically dependent on regular performance management (Sec. 2.4.3) and real-time quality control programs (Sec. 2.4.4) providing information about suspected faults.

It is also appropriate to develop and operate a program of adaptive maintenance. This maintenance ensures the continued upgrade of hardware, software and other systems to ensure the observing system satisfies the requirements for stability, continuity and consistency of observations through time. A program of adaptive maintenance requires the continued monitoring of observational developments and user requirements to identify needs and opportunities for adaptive upgrades and system changes.

Further guidance:

* WMO-No. 8, Part II, Chapter 1;
* WMO-No. 731, Chapter 2, 2.4.6, 2.5.4, 2.7.6, 2.8.6, 2.9.6, 2.10.6,
* WMO-No. 488; Part III, 3.1.3.11, 3.3.3.3

**2.4.8 Inspection**

2.4.8.1 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.

Technical specifications and details are given in the *Guide to Meteorological Instruments and Methods of Observation* (WMO-No. 8), *Guide to Climatological Practices* (WMO-No. 100), *Guide to Hydrological Practices* (WMO-No. 168), Volume I: Hydrology – From Measurement to Hydrological Information, and *Guide to the Global Observing System* (WMO-No. 488) and the *Manual on Stream Gauging* (WMO-No. 1044).

(See also the ICAO Manual on Automatic Meteorological Observing Systems at Aerodromes (Doc 9837) for guidance on the inspection of aeronautical meteorological stations including the frequency of inspections.)

Regular inspections, including routine maintenance activities, help to ensure the smooth functioning of an observing station. The inspection should follow a standardized checklist whereby information accumulated from the previous inspection, relevant station files, notification by other users and, if necessary, from special inquiries made before departure, will provide additional guidance to the inspector. Field tests of instruments at the station may be included among the items requiring the inspector’s attention.

The findings of regular inspections should be documented in an inspection report which should be circulated to the users of the observational data within the organization, the administration and others involved in the station’s activities. Such reports become part of the detailed metadata for the station.

Guide: See the ICAO Manual on Automatic Meteorological Observing Systems at Aerodromes (Doc 9837) for guidance on the inspection of aeronautical meteorological stations including the frequency of inspections.

Further guidance:

* WMO-No. 8, Part II, Chapter 1;
* WMO-No. 100, Chapter 2, 2.6.6
* WMO-No. 134, Chapter 2, 2.2.6
* WMO-No. 488, Part III, 3.1.3.8, 3.1.4;
* WMO-No. 168, 9.8.4
* WMO-No. 544, 3.1.6

**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 for each type of system and instrument, as described in the relevant sections.

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).

Further guidance:

* WMO-No. 8, Part III, Chapter 4, 4.3
* WMO-No. 100, 2.3.5;
* WMO-No. 134, Chapter 2, 2.4.1.11;
* WMO-No. 731, Chapter 2, 2.4.6, 2.5.4, 2.7.6, 2.8.6, 2.9.6, 2.10.6,
* IOM-119;
* JCGM 100:2008, GUM 1995 (Evaluation of measurement data — Guide to the expression of uncertainty in measurement); JCGM 101:2008; JCGM 102:2011; JCGM 104:2009;
* WMO-No. 958, Chapter 2

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

2.4.9.2 Members **shall** ensure that the measuring devices they use 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** 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: Details regarding the hydrological observations are given in the WMO *Technical Regulations* (WMO WMO‑No. 49), Volume III – Hydrology; guidance is available 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).

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 Members **shall** record and maintain the results of calibration and verification.

**ATTACHMENT 2.1**

**Structure of WIGOS Station Identifiers**

The structure of the WIGOS Identifier is shown in Figure 1. The meaning of the components of the WIGOS identifier is given in Table 1.

|  |  |  |  |
| --- | --- | --- | --- |
| WIGOS Identifier series | Issuer of Identifier | Issue Number | Local Identifier |

**Figure 1**. Structure of WIGOS identifier

**Table 1**. Allocating the component parts of a WIGOS station identifier

|  |  |  |
| --- | --- | --- |
| **Component** | **Description** | **Initial Range – series 0 (Stations)** |
| WIGOS Identifier Series | This is used to distinguish between different systems for allocating identifiers. It allows future expansion of the system so that entities do not have to be issued with new identifiers if the structure of the WIGOS identifiers proves unable to meet future requirements. Different values of the WIGOS Identifier Series may correspond to different structures of the WIGOS identifier. Initial permitted range: 0-14 | 0 |
| Issuer of Identifier | A number that is used to distinguish between identifiers issued by different organizations. It is allocated by WMO to ensure that only one organization can create a given WIGOS station identifier. | 0-65534 |
| Issue Number | An identifier that an organization responsible for issuing an identifier may use to ensure global uniqueness of its identifiers. For example, allocating one issue number for hydrological stations and another for voluntary climate observing stations would enable the managers of the two networks to issue Local Identifiers independently without needing to check with each other that they were not duplicating identifiers. | 0-65534 |
| Local Identifier | This is the individual identifier issued for each entity. An organization issuing identifiers must ensure that the combination of Issue Number and Local Identifier is unique; in that way global uniqueness is guaranteed. | 16 characters |

Notes:

(1) The structure of WIGOS station identifiers has been designed to be general enough to identify other entities, such as individual instruments; however, this has not yet been implemented.

(2) Although the table proposes initial ranges of permitted values of the components that make up a WIGOS identifier, future changes in requirements may result in these ranges being increased. IT systems must, therefore, be designed to process identifiers whose components are of arbitrary length. BUFR encodings will need to be prepared for WIGOS identifiers to allow efficient representation and these may use code lists to represent components of the WIGOS identifier that are shared by many entities. Currently, station identifier = 0.

**Notation for the WIGOS identifier**

The convention for writing the WIGOS identifier (in the context of WIGOS) is:

<WIGOS Identifier series>-<Issuer of Identifier>-<Issue Number>-<Local Identifier>

*Note:* as an example the WIGOS Identifier

|  |  |  |  |
| --- | --- | --- | --- |
| **WIGOS Identifier series** | **Issuer of Identifier** | **Issue Number** | **Local Identifier** |
| 0 | 513 | 215 | 5678 |

would be written as 0-513-215-5678.

**Representing the WIGOS identifier in contexts outside WIGOS**

The following conventions should be used to represent the WIGOS identifier in contexts outside WIGOS or to show the relationship between the WIGOS identifier and an identifier that has been defined in a different context.

|  |  |  |
| --- | --- | --- |
| int.wmo.wigos | WIGOS identifier | WIGOS supplementary identifier |

**Figure 2**. Structure of an extended WIGOS identifier. Both the int.wmo.wigos and the WIGOS supplementary identifier elements are optional.

*int.wmo.wigos*

The first component of the extended WIGOS identifier (int.wmo.wigos) allows the identifier to be recognized as a WIGOS identifier when used in contexts where it may be ambiguous as to what type of identifier is being used. This is optional and need not be represented in BUFR, because the entries for the WIGOS identifier provide this information.

*WIGOS identifier*

The second component (WIGOS identifier) is defined above. Within a WIGOS context it is the only component of the WIGOS identifier that is always required.

*WIGOS supplementary identifier*

The final component of the extended WIGOS identifier (WIGOS supplementary identifier) is optional and is used to associate identifiers issued using other systems to be associated with the WIGOS unique identifier. A single WIGOS identifier may be associated with many WIGOS supplementary identifiers (such as an observing site that is used for both synoptic and aviation reporting), and a WIGOS supplementary identifier may be associated with many WIGOS unique identifiers (such as a World Weather Watch drifting buoy identifier that has been issued to many drifting buoys). In BUFR, this would be specified through a specific table entry (such as IIiii for World Weather Watch station identifier).

*Note*: if above example of a WIGOS identifier (0-513-215-5678) was also associated with an identifier (MYLOCATION) issued by another authority, a valid extended WIGOS identifier would be int.wmo.wigos-0-513-215-5678-MYLOCATION.

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**2.5. Observational Metadata**

**2.5.1 Purpose and scope**

Note 1: Observational metadata are essential as they enable users of observations to assess their suitability for the intended application and managers of observing systems to monitor and control their systems and networks. WMO Members benefit from sharing observational metadata which describe quality of observations and provide information about stations and networks used to collect those observations.

Note 2: Discovery metadata, defined in the *Manual on the WMO Information System* (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 the WMO Information System* (WMO-No. 1060) and are not considered further here.

2.5.1.1 For all WIGOS observations they make available internationally, Members **shall** record and retain the observational metadata specified as mandatory in the WIGOS Metadata Standard defined in Appendix 2.4.

Note 1: The WIGOS Metadata Standard defines a common set of requirements for elements to be provided in observational metadata. It includes a detailed list of mandatory, conditional and optional metadata.

Note 2: A record of “not available”, "unknown" or "not applicable" are valid values for many elements of the WIGOS Metadata Standard. This assists Members to achieve compliance with the standard, particularly in a transitional step towards capability to report actual values.

2.5.1.2 For all WIGOS observations they make available internationally, Members **shall** record and retain the observational metadata specified as conditional in the WIGOS Metadata Standard in Appendix 2.4 whenever the related condition is met.

2.5.1.3 For all WIGOS observations they make available internationally, Members should record and retain the observational metadata specified as optional in the WIGOS Metadata Standard in Appendix 2.4.

Note 1: Further requirements for observational metadata beyond the WIGOS Metadata Standard are stated in the following sections. In the case of the Global Observing System, as noted in section 5, the *Manual on the GOS* (WMO-No. 544) provides further provisions for GOS metadata.

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.

Observational metadata are essential as they enable users of observations to assess their suitability for the intended application and managers of observing systems to monitor and control their systems and networks. WMO Members benefit from sharing observational metadata which describe quality of observations and provide information about stations and networks used to collect those observations. When WIGOS observations are shared internationally, the associated metadata needs to be readily available to users of those observations.

Discovery metadata, defined in the *Manual on WMO Information System* (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 WMO Information System* (WMO-No. 1060) and are not considered further in the WIGOS Guide.

The WIGOS Core Metadata Standard defines a common set of requirements for elements to be provided in observational metadata. It includes a detailed list of mandatory, conditional and optional metadata. A record of “not available” is a valid value for many elements of the WIGOS Core Metadata Standard. This assists Members to achieve compliance with the standard.

Further requirements for observational metadata beyond the WIGOS Core Metadata Standard are stated in the following sections of the Manual on WIGOS. In a case of the Global Observing System, as noted in Section 7, the *Manual on the Global Observing System* (WMO-No. 544) provides further provisions for GOS metadata. Some application areas will need the observational metadata to be provided at the same time as the observation, whereas other applications may only need a small portion of the observational metadata to be provided at the same time as the observations particularly if a large proportion of the observational metadata changes infrequently.

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

Further guidance:

* WMO-No. 134, Chapter 2, 2.1.6, 2.2.5

**2.5.2 Exchanging and archiving observational metadata**

2.5.2.1 Members **shall** make available internationally and without restriction, those mandatory and conditional (whenever the condition is met) 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 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.

As observational metadata are critical to the application of observations by users, the metadata associated with observations needs to be readily available to users as long as those observations are available. Observations that are shared in real-time need to have their observational metadata also available in rea-time. Observations that are archived for long-term availability also need to have their metadata stored for long-term availability. In short, the availability of the metadata should always match the availability of the observation.

Further guidance:

* WMO-No. 731, Chapter 5

**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 metadata that are specified as mandatory or conditional (whenever the condition is met).

Note: global compilations of WIGOS 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. Other global compilations of specific components of WIGOS metadata include elements of the GAWSIS, the JCOMMOPS database and others. Purposes and management of WIGOS Operational Information Resource (WIR) and OSCAR are described in Attachment 2.2.

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.

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

2.5.3.4 Members **shall** designate their 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.

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. Other global compilations of specific components of WIGOS metadata include elements of the GAWSIS, the JCOMM Ops database and others. Appendix 2.3 of the Manual specifies which components of the WIGOS Core Metadata Standard are to be made available in OSCAR. The purpose and management of WIGOS Operational Information Resource (WIR) and OSCAR are described in Attachment 2.2 of the Manual.

These databases of metadata benefit when they are reviewed and feedback is provided regarding discrepancies, possible errors, and changes that may be required. Feedback is provided to the appropriate part of the WMO Secretariat so that corrective action may be taken.

The mechanisms for making metadata available for global compilation are managed by the WMO Secretariat.

Further guidance:

* WMO-No. 100, Chapter 2, 2.6.9

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**APPENDIX 2.4**

**The WIGOS Metadata Standard**

***General***

This Appendix refers to the “*WIGOS Metadata Standard*”, which consists of the set of observational metadata elements to be made available internationally. They are required for the effective interpretation of observations from all WIGOS component observing systems by all observational data users, allowing them to access important information about why, where, and how an observation was made, along with how the raw data has been processed and the quality of the data. Note that WIGOS metadata which is required from specific components or sub-systems is detailed in the sections 3-8.

The table below presents 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).

The definition of each metadata element, together with notes and examples, as well as the explanation of the condition to apply to the conditional elements are specified in the WIGOS Metadata Standard , Attachment to this Appendix.

***Members’ obligations***

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

Conditional metadata elements **shall** be made available 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 made available.

Optional metadata elements should be made available, as they provide useful information that can help to better understand an observation. These elements are likely to be important for a particular community, but less so for others.

***Adoption through a Phased Approach***

Making available WIGOS metadata will generate substantial benefits for Members, but developing the capacity to make available these metadata also requires a substantial effort on the part of (meta)data providers. To help Members comply with reporting obligations, guidance material will be developed and provided.

Moreover, reporting obligations will be enforced in phases, in order to allow Members sufficient time to develop the capacity to comply. Balancing the effort required to generate and make available individual elements, and the need to have this information to make adequate use of observations, implementation will proceed through three phases as shown in the table below. Importantly, elements required by the end of **Phase I** are either the mandatory elements in WMO Publication No. 9, Vol. A or are of critical importance for the Observing Systems Capability Analysis and Review (OSCAR) tool of the WIR, and are considered of benefit for all WMO Application Areas. **Phase II** adds elements recognized to be more challenging for Members, but the knowledge of which is still of rather immediate need for the adequate use of observations, in particular for assessing quality of observations. **Phase III** adds the remaining elements specified in this version of the standard.

Elements emerging as being important for specific application areas or observing programmes will be added to the standard as it evolves.

**List of elements specified in the WIGOS metadata standard and the phases for Members implementation**

|  |  |  |  |
| --- | --- | --- | --- |
| **Category** | **Phase I** | **Phase II** | **Phase III** |
|  | **2016** | **2017-2018** | **2019-2020** |
| 1. Observed variable | **1-01 Observed variable – measurand (M)** | 1-05 Representativeness (O) |  |
|  | **1-02 Measurement unit (C)** |  |  |
|  | **1-03 Temporal extent (M)** |  |  |
|  | **1-04 Spatial extent (M)** |  |  |
| 2. Purpose of observation | **2-01 Application area(s) (M)** |  |  |
| **2-02 Programmes/Network affiliation (M)** |  |  |
| 3. Station/Platform | *3-01 Region of origin of data (C)* | **3-04 Station/platform type (M)** | **3-05 Station/platform model (M)** |
|  | *3-02 Territory of origin of data (C)* | 3-08 Data communication method (O) |  |
|  | **3-03 Station/platform name (M)** |  |  |
|  | **3-06 Station/platform unique identifier (M)** |  |  |
|  | **3-07 Geospatial location (M)** |  |  |
|  | **3-09 Station status (M)** |  |  |
| 4. Environment |  | 4-04 Events at Station/platform (O) | *4-01 Surface cover (C)* |
|  |  | 4-05 Site information (O) | *4-02 Surface Cover classification scheme (C)* |
|  |  |  | *4-03 Topography or Bathymetry (C)* |
| 5. Instruments and Methods of Observation | **5-01 Source of observation (M)** | 5-11 Maintenance party (O) | 5-04 Instrument operating status (O) |
| **5-02 Measurement/observing method (M)** | *5-12 Geospatial location (C)* | *5-06 Configuration of instrumentation (C)* |
|  | **5-03 Instrument specifications (M)** | *5-15 Exposure of instrument (C)* | *5-07 Instrument control schedule (C)* |
|  | *5-05 Vertical distance of sensor (C)* |  | *5-08 Instrument control result (C)* |
|  |  |  | *5-09 Instrument model and serial number (C)* |
|  |  |  | *5-10 Instrument routine maintenance (C)* |
|  |  |  | 5-13 Maintenance Activity (O) |
|  |  |  | 5-14 Status of observation (O) |
| 6. Sampling | 6-03 Sampling strategy (O) | **6-05 Spatial sampling resolution (M)** | 6-01 Sampling procedures (O) |
|  | **6-07 Diurnal base time (M)** |  | 6-02 Sample treatment (O) |
|  | **6-08 Schedule of observation (M)** |  | **6-04 Sampling time period (M)** |
|  |  |  | **6-06 Temporal sampling interval (M)** |
|  |
| 7. Data Processing and Reporting | **7-03 Temporal reporting period (M)** | 7-02 Processing/analysis centre (O) | 7-01 Data processing methods and algorithms (O) |
| *7-04 Spatial reporting interval (C)* | 7-06 Level of data (O) | 7-05 Software/processor and version (O) |
|  | *7-11 Reference datum (C)* | **7-09 Aggregation period (M)** | **7-07 Data format (M)** |
|  |  | **7-10 Reference time (M)** | **7-08 Version of data format (M)** |
|  |  |  | 7-12 Numerical resolution (O) |
|  |  |  | **7-13 Latency (of reporting) (M)** |
| 8. Data Quality |  | *8-01 Uncertainty of measurement (C)* |  |
|  |  | *8-02 Procedure used to estimate uncertainty (C)* |  |
|  |  | **8-03 Quality flag (M)** |  |
|  |  | **8-04 Quality flagging system (M)** |  |
|  |  | *8-05 Traceability (C)* |  |
| 9. Ownership and Data Policy | **9-02 Data policy/use constraints (M)** | **9-01 Supervising organization (M)** |  |
| 10. Contact | **10-01 Contact (Nominated Focal Point) (M)** |  |  |

**ATTACHMENT 2.2**

**The WIGOS Information Resource (WIR)**

**Purpose of the WIR**

The WMO Integrated Global Observing System (WIGOS) Information Resource (WIR) is a tool designed to provide WIGOS 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 standard and recommended practices and procedures, best practices and procedures 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 standard 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, and 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/station metadata according to the WIGOS metadata standard described in the *Manual on WIGOS* (WMO-No. XXXX), 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 standard and recommended practices 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 Permanent Representatives with WMO.

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/stations they operate, including instrument, and platform/station metadata.

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

Current information can be seen at: <http://www.wmo.int/oscar>.

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**2.6. Quality Management**

Note 1: The *Technical Regulations* (WMO-No. 49), Volume IV – Quality Management, 2011 edition, provides provisions relating to the WMO Quality Management Framework, WMO QMF.

Note 2: Detailed guidance on how to develop and implement a quality management system (QMS) to ensure and enhance the quality of NMHS products and services 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 3: 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 within ISO 9000:2005, Quality Management Systems – Fundamentals and vocabulary.

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 standard and recommended practices and procedures associated with implementation of a QMS, in practice it is one or more organizations within the Member’s country that own and operate observing systems and provide observations and observational metadata, most notably the NMHSs. In practice, then, implementation of the WMO QMF relies on the Member making arrangements for such organizations to implement a QMS.

Note 5: The term “observations” include also “observational metadata” everywhere in the section 2.6.

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

Note: WIGOS practices and procedures enable Members to comply with the WMO QMF in relation to the quality of observations.

*Technical Regulations, Volume IV – Quality Management* (WMO-No. 49) provides provisions relating to the WMO Quality Management Framework, WMO QMF. Detailed guidance on how to develop and implement a quality management system (QMS) to ensure and enhance the quality of NMHS products and services is provided in the *Guide to the Implementation of a Quality Management System for National Meteorological and Hydrological Services* (WMO-No.1100, 2013 edition). Within this framework, WIGOS provides the procedures and practices with regard to the quality of observations and observational metadata. WIGOS practices and procedures enable Members to comply with the WMO QMF in relation to the quality of observations.

A QMS can only be implemented by the body that has the resources and the mandate to manage the observing system. The WMO QMF provides standards and recommended practices and procedures associated with implementation of a QMS. In practice, with a collaborative network like WIGOS, there often will be one or more organisations within a 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 making arrangements with all such organisations to implement a QMS.

WIGOS quality management strives for compliance of all components of WIGOS with international standards, such as ISO 9001:2008, and ISO 17025 where appropriate. Compliance with international standards is encouraged for all quality assurance (QA) procedures applied to the WIGOS observing components based on the standards and best practices described in the Regulatory Materials, such as the WIGOS Manual

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 within ISO 9000:2005, Quality Management Systems – Fundamentals and vocabulary.

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

**2.6.2.1 Quality Policy**

2.6.2.1.1 In the establishment and maintenance of WIGOS observing systems, Members should ensure optimum affordable quality for all observations.

2.6.2.1.2 Members should, through a process of continual improvement, pursue effective and efficient management and governance of observing systems.

As identified in Chapter 4 of the *WMO Guide to the Implementation of a Quality Management System for National Meteorological and Hydrological Services* (WMO-No. 1100), a quality policy is a statement of intent by senior management that provides the commitment of the organization to their quality management system. Such a quality policy may set specific imperatives and outcomes that are relevant to the organization and will be widely communicated within the organization in order to drive the full quality program.

Such a quality policy will directly influence the WIGOS observing systems managed by that organization. The policy should guide the management of the WIGOS observing systems to enable them to ensure optimum, affordable quality while supporting a process of continual improvement in the management and governance of observing systems.

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

2.6.2.2.1 Members should apply the eight Principles of Quality Management to the implementation of WIGOS as specified in Appendix 2.5.

Note: The eight principles of QM are specified in Volume IV of WMO the *Technical Regulations* (WMO‑No. 49).

Appendix 2.4 of the Manual on WIGOS lists the eight Principles of Quality Management that should be considered when applying quality management to WIGOS. These eight principles are also specified in *Volume IV of WMO Technical Regulations* (WMO-No. 49). The principles are provided below customized with specifics for WIGOS:

1. User/client focus: We must identify, document and understand the current and future needs of 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;
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. Managers of WIGOS observing systems should clearly define the goals and directions of their observing systems and create an environment that encourages staff 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 are described in Attachment 1.

**2.6.3.1 Determination and Maintenance of User Requirements**

Note: The WMO RRR process for compiling observation user requirements is described in section 2.2.4 and Appendix 2.3.

**2.6.3.2 Development and Documentation of Observing Systems Standards and Recommendations**

2.6.3.2.1 Through involvement in the work of technical commissions, Members should participate in the development of observing system standard and recommended practices and procedures.

**2.6.3.3 Training of Personnel and Capacity Development**

2.6.3.3.1 Members should ensure appropriate planning and implementation of training and capacity development activities.

**2.6.3.4 Performance Monitoring**

2.6.3.4.1 Members should use and respond to the results, advice and reports of designated monitoring centres and any subsequent advice of expert groups.

Further guidance:

* WMO-No. 8, Part III, Chapter 1, 1.6, 1.8
* WMO-No. 488; Part III, 3.1.3.14

**2.6.3.5 Feedback, Change Management and Improvement**

2.6.3.5.1 Members should ensure that inconsistencies (problems) identified by WIGOS Lead and Monitoring Centres are rectified in a timely manner and that a process for their documentation and rectification is implemented and maintained.

2.6.3.5.2 Members should, upon identification or notification of observation quality related inconsistencies, and problems analyze the detected problem and implement necessary improvements to operational practices and procedures so as to minimize their negative impacts and prevent their future reoccurrence.

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

Figure 1 of Attachment 1 in the WIGOS Manual 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 practise, the processes have more complex interrelationships and sequences than shown by the arrows. An extreme case is the capacity development (including training) process, which is not shown as a step in the sequence since it is an important component of most of the other processes.

**Determination of User Requirements --** The fundamental principle for the development and implementation of WIGOS control procedures and processes is to ensure that the requirements for WIGOS, as specified in the Rolling Review of Requirements (RRR), User Requirements are met. WMO Technical Commissions will be responsible for coordinating the WMO RRR process in consultation with Regional Associations and Members. One needs to beaware of and familiar with the WIGOS User Requirements and Members and endeavour to ensure that regulated and recommended practices and procedures associated with the WMO RRR process are complied with.

**Design, planning and evolution of WIGOS …**

**Development and documentation of standards for control and best practice for observing systems --** WMO Technical Commissions are responsible for coordinating with Regional Associations and Members, the development, maintenance and documentation of WMO standards and recommended practices and procedures within manuals, guides and other technical documents on WIGOS for the following aspects of WIGOS operations and observing systems:

* Observing system design
* Instruments and methods of observation
* Observing system network management
* Observations quality control
* Observations production and delivery
* Observations quality and systems performance monitoring

As these WIGOS standards for control and best practices for observing systems are available, they need to be translated into specific policies and procedures by organizations responsible for observational networks including observational data quality. Such specific policies and procedures enable the implementation of observing systems in compliance with WIGOS regulator material.

**Implementation of systems by owners/operators …**

**Observing system operation and maintenance including fault management and audit …**

**Observations Quality Control --** Based on the ISO definition of Quality Control, WIGOS observations must be subject to quality control that is focused on fulfilling quality requirements prior to the dissemination of observational data. …

**Observations and observational metadata delivery**

Members should ensure that requirements and regulations for provision of data on the WMO Global Telecommunications System are met.

*(Note: References to the Manual on the GTS, Manual on Codes, Manual on the GDPFS … should be here.)*

Members should ensure that planning processes and relevant agreements with third parties associated with the design and implementation of observing systems and the production of observational data ensure that such data is able to be made available to WMO Members and, if required, transmitted on the GTS in accordance with WMO Resolutions 25 and 40 [Reference].

**Performance monitoring (outputs and systems) –** WMO Technical Commissions may designate Lead and Monitoring Centres to perform monitoring of WIGOS observational data in support of WIGOS quality maintenance and improvement. In do so, the WMO Technical Commissions define the requirements for the monitoring and reporting practices and procedures of Lead and Monitoring Centres. The results, advice and reports of WIGOS Lead and Monitoring Centres is to be used as an integrated component of quality management practices in the operation of WIGOS observing systems.

The *Manual on the Global Data-processing and Forecasting System* (WMO-No. 485) provides specific information about the roles of lead and monitoring centres with respect (primarily) to meteorological data and especially the data supporting the weather forecasting system as established by the Commission for Basic Systems.

The Global Atmospheric Watch has five times of central facilities dedicated to six groups of measurement variables are operated by WMO Members which form the basis of quality assurance and data archiving for the GAW global monitoring networks. They include Central Calibration Laboratories (CCLs) that host primary standards (PS), Quality Assurance/Science Activity Centres (QA/SACs), World Calibration Centres (WCCs), Regional Calibration Centres (RCCs), and World Data Centres (WDCs) with responsibility for archiving and access to GAW data.

**User feedback and review of requirements –** Many users of WIGOS observational data will either specifically or implicitly define requirements for continuity of the making, provision and retention of observations. Members should be aware of such requirements and endeavour to ensure that systems are designed, implemented and maintained so as to optimally comply with such requirements.

Members should ensure that systematic issues identified by WIGOS Lead and Monitoring Centres 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.

Upon identification or notification of systematic issues that impact adversely on the quality of WIGOS observations, Members should 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. Members should ensure that a process for documentation of such changes is implemented and maintained.

**Capacity Development (including training) –** WMO Technical Commissions, Regional Associations and Members will endeavour to coordinate the development and provision of training materials and courses for Members that will have a focus on the implementation and maintenance of WIGOS quality management standards and recommended practices and procedures.

Staff responsible for operation of WIGOS observing systems need to be provided with access to relevant and necessary training materials and courses, including those offered or recommended by WMO.

Further guidance:

* WMO-No.8, Part I, Chapter 1, 1.3.4

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

Note: This section specifies requirements for the integration of WIGOS practices and procedures into the QMS of Members. The requirements are based on the eight clauses of the ISO 9001 standard. 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. The five subsections which follow correspond to the last five of the clauses, providing further details about the elements required in a QMS.

Based on the eight clauses of the ISO 9001 standard, this section provides guidance for the integration of WIGOS practices and procedures into the QMS of Members. Sec. 4.2 of 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. The first three clauses are introductory and set the context while the remaining five clauses provide the requirements as laid out in the ISO 9001 standard.

In order to fully implement a QMS, 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) are required references.

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

2.6.4.1.1 Members should identify their high level processes and their interactions that lead to the provision of observations.

Note: In addition to WIGOS specific provisions, there are many other general requirements for the content of a QMS which are not unique to WIGOS observations hence are not repeated here.

Clause 4 of the ISO 9001 standard provides the overall requirements for the content of an organizational QMS. It provides guidance on the requirements for documentation, for a quality manual, for the control of documents and for the control of records.

The quality manual will identify the high level processes and their interactions that lead to the provision of observations. It should provide a clear picture of the processes and their operation that yield observations for WIGOS. Sec. 4.3 of the *Guide to the Implementation of a Quality Management System for National Meteorological and Hydrological Services* (WMO-No.1100, 2013 edition) provides details regarding the recommended content of the quality manual. When developing the quality manual to meet these general requirements, specifics regarding WIGOS processes and procedures should be incorporated.

**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 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.

2.6.4.2.4 Members should establish and make known objectives for their future provision of observations 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.

Management commitment to the integration of WIGOS quality management practices within their QMS needs to be effectively demonstrated through the appropriate provision of resources for operation and implementation of the QMS, the development of policy and organizational QM objectives and the regular leadership of managerial review meetings. The organizational policy and QM objectives should be consistent with the WIGOS quality policy. The organizations published quality policy should incorporate measurable, meaningful and relevant outcomes that demonstrate the organizations commitment to the implementation of programs to deliver on WIGOS quality objectives. These objectives and outcomes are typically defined at different levels and for different functions (including, as appropriate, for different WIGOS component networks) to ensure they are relevant to staff across the organization and to users of all types of products and services.

User requirements for observations need to be carefully identified and routinely reviewed prior to attempting to meet their needs through the conduct of WIGOS observing programs. These user requirements are regularly updated to reflect changing needs and opportunities and enable the organization to continuously improve their objectives. As part of the on-going determination of user requirements, the satisfaction of users with existing observational programs should be routinely assessed.

In considering user requirements and their expected evolution, it is valuable to establish and make known objectives for the future provision of observations. This will provide guidance to stakeholders, users and clients concerning the expected evolution of and changes to the observing systems. This is important to all users but is of particular significance to any cooperating agencies that operate observing systems as a contribution to WIGOS. The organizational objectives should reflect the organizations ability and commitment to the WIGOS quality objectives.

To ensure the continued promotion and maintenance of the QMS, a quality manager is appointed. Depending on the size of the programmes provided, it may also be appropriate to identify an associate quality manager with specific responsibility for the WIGOS networks. Appendix 5 of the *Guide to the Implementation of a Quality Management System for National Meteorological and Hydrological Services* (WMO-No.1100, 2013 edition) provides a sample job description for such a quality manager.

**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 continuously improve the effectiveness and efficiency of their processes and procedures.

2.6.4.3.2 Members should define the competencies required for staff involved in the provision of observations.

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 required for the provision of observations.

Resources are defined to be inclusive of the finance, materials, staff and other assess required to operate, maintain and continuously improve operational programs and services and, in this case, specifically WIGOS networks. Sufficient resources need to be available to the operational organization to operate, maintain and continuously improve the effectiveness and efficiency of all processes and procedures.

A QMS provides a framework for a well documented system built upon sound management practices. This enables the organization to more effectively identify resource requirements to funding agencies that will enable the delivery of quality observations meeting client requirements and delivering upon WIGOS quality objectives. By seeking and achieving certification under ISO 9001, the organization may further strengthen their credibility and achieve appropriate and necessary resource allocations.

The staff (human resources) of an organization requires particular attention. The required competencies need to be identified for each position to achieve the organizational expectations of that position. Competency standards for meteorological personnel have been articulated by WMO and are included in *Technical Regulations (WMO-No. 49), Volume 1; Part II Sec. 5.*

Managers and supervisors should regularly evaluate the achievement of staff relative to job expectations and identify any competency shortcomings. Such evaluation may be conducted through routine observation of staff, based on client feedback or through the application of an exam or test. Actions must then be identified (e.g. training) to correct or mitigate the impact of such shortcomings. Records should be maintained concerning the evaluation process, the results and the corrective actions undertaken.

Policies and procedures to assure maintenance of the infrastructure required for the provision of observations should be prepared and followed. Such policies and procedures will need to cover the diverse requirements for such infrastructure ranging including physical infrastructure (e. g. building/site maintenance and repair), utilities (e.g. power, gas, water etc.), technology (computers, back-ups, network access), workplace (ergonomics) and any other conditions that might negatively affect the ongoing provision of WIGOS observations.

**2.6.4.4 Requirements related to the provision of observations** 2.6.4.4.1 Members should undertake sound planning for the provision of observations.

Note: Such planning includes the following activities and processes:

* Determination and continuous review of user and client requirements;
* The translation of user and client requirements into objectives and targets for observations and observing system design;
* Initial and ongoing allocation of adequate resources for all aspects of the design, implementation and maintenance processes of observing systems;
* 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 and client requirements; and,
* 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.

Note: The means for doing this include:

i. The WMO Rolling Review of Requirements (RRR) process, described in sections 2.2.4 and Appendix 2.3;

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.

2.6.4.4.3 Members should have a clear description of the requirements that are agreed upon.

Note: 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.

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

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

2.6.4.4.6 Members should use a formal change management process to ensure that all changes are assessed, approved, implemented and reviewed in a controlled manner.

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 therefore 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 WIGOS provisions covering methods of observation, calibration and traceability, operational practices, maintenance, and observational metadata.

2.6.4.4.9 Members should implement practices and procedures which ensure that observations remain accurate.

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

When planning for the provision of observations, it is appropriate to include the following activities and processes:

* Determination and continuous review of user/client requirements;
* The translation of user/client requirements into objectives and targets for observations and observing system design;
* Initial and ongoing allocation of adequate resources for all aspects of the design, implementation and maintenance processes of observing systems;
* 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,
* Appropriate and ongoing documentation of planning processes and their results.

To identify their users and establish and document users' requirements for observations, it is appropriate to use the following processes:

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.

When documenting users’ requirements, it is important to clearly document the agreed to requirements. Users may have aspirational requirements that an organization cannot commit to. It is valuable to record these as well but to carefully distinguish them from those requirements agreed to. The agreed to requirements are used to support the ongoing monitoring and measurement of conformance. Clear documentation of requirements assists both staff and clients in the delivery of the observational programs as it reduces mis-understanding and frustration.

It can also be valuable to clearly document the users’ priorities within the stated requirements – in some cases, some requirements will be significantly more important than others to a users application.

In agreeing to requirements, one must consider and adhere to statutory or regulatory requirements in relation to the provision of observations as well as the organizational capability (including resources) to deliver on those requirements. Once accepted and agreed to, one must then design and develop, or otherwise implement, observing systems to satisfy the agreed to user requirements.

The determination of user requirements and the delivery upon those is subject to continuing change. The actual user requirements may change; the statutory or regulatory material may change; the organizational capabilities may change; monitoring methods (including technology) may change. A formal change management process is developed to ensure that all changes are assessed, approved, implemented and reviewed in a controlled manner.

Observing systems often require large expenditure and are highly specialized, and 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.

The WIGOS provisions covering methods of observation, calibration and traceability, operational practices, maintenance, and observational metadata should be include in the QMS of all operating observation programs contributing to WIGOS. These should include the implemented practices and procedures which ensure that observations remain accurate. Observations need to be checked as they are produced to ensure they meet the agreed requirements. This is typically done in a number of ways including automated algorithms and manual inspection and oversight.

Further guidance:

* No.49, Vol. II, 2.2.4 & Note
* WMO-No. 1111

**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 (see 2.6.4.4) as a basis for defining and implementing appropriate measures of performance and success.

Note: It is important to gain a clear understanding of how satisfied users are with observations. 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.

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 results 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 is provided in the *Guide to the Implementation of a Quality Management System for National Meteorological and Hydrological Services* (WMO-No. 1100) 2013 edition, section “8.2.2 Internal audit”.

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

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 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.

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

2.6.4.5.9 Members should specify and implement procedure(s) that describe(s) 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 is provided in the *Guide to the Implementation of a Quality Management System for National Meteorological and Hydrological Services* (WMO-No. 1100) 2013 edition, section “8.2.3 and 8.2.4 Monitoring and measurement of processes and products”.

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 of 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.

The satisfaction of users of the observations should be routinely and systematically determined and assessed. One must monitor information regarding users perception and whether their expectations have been met.

The user requirements for observations (see 2.6.4.3) are used as a basis for defining and implementing appropriate measures of performance and success.

A wide variety of methods and techniques may be used to gather such information – ranging from formal survey processes through the informal gathering of information through routine meetings, conversations, etc. conducted with users. It is important to be systematic and deliberate; it is important to have recognized and specific processes to gather and analyse this information to assure real-time accuracy and long-term intercomparability. Staff need to be aware of the methods that are being employed for determining user perceptions and expectations and that, as required, they are being applied consistently.

Internal audits of WIGOS processes and procedures should be regularly conducted as part of the management processes of the observing system. The requirements for an internal audit process are provided in the Guide to the Implementation of a Quality Management System for National Meteorological and Hydrological Services (WMO-No.1100, 2013 edition), section 8.2.2.

Performance monitoring should be conducted against specific Key Performance Indicators and target levels of performance should monitor the degree of adherence to the defined processes and requirements for producing observations.

The fitness for purpose and the quality of the observations should be monitored as they are produced in order to compare their characteristics with the agreed requirements. The can be done by devising and implementing the routine analysis of manually or automatically generated Key Performance Indicators and their associated targets. As part of this, there should also be manual inspection and oversight of observational data.

Instances of non-conformity with requirements should be recorded and actions taken to rectify problems in a timely manner and given priority in accordance with requirements for the affected observational data. Such corrective actions should be documented.

Procedures should be specified and implemented to describe 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. A detailed explanation on the requirements of the corrective action process is provided in the Guide to the Implementation of a Quality Management System for National Meteorological and Hydrological Services (WMO-No.1100, 2013 edition), section “8.2.3 and 8.2.4 Monitoring and measurement of processes and products”.

Monitoring results should be regularly and routinely analyzed to detect any performance related changes, trends and deficiencies and use the results and analyses as input to activities aimed at continual improvement. Analysing trends and taking action prior to the occurrence of a case of non-conformity helps to prevent problems.

Documented preventive action procedures relevant to observing systems should be maintained and staff should be aware of and, if necessary, trained in their routine application. Consideration can be given to combining the preventive and the corrective action procedures for efficiency and to simplify overall processes.

**2.6.5 Compliance, Certification and Accreditation**

Note: 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.

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.

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 a accredited national Supervisory Authority; and,

iii) The reference testing and calibration laboratories (see CIMO Guide, 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 Centres [Reference to relevant section above].

**2.6.6 Documentation**

2.6.6.1 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 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, corrective actions and preventive actions.

2.6.6.3 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.

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

Note: More detailed information on Documentation requirements is provided in the *Guide to the implementation of a Quality Management System for National Meteorological and Hydrological Services* (WMO-No. 1100) 2013 edition, section “4.2 Documentation requirements”.

Detailed information on documentation requirements is provided in the *Guide to the implementation of a Quality Management System for National Meteorological and Hydrological Services (WMO-No.1100, 2013 edition), section 4.3*.

In fulfilling these documentation requirements, it is important to include the WIGOS quality policy and objectives in the required QMS Quality Manual. Further, documents that describe WIGOS procedures (including in particular those relating to control of non-conforming observations, corrective actions and preventive actions) should be included in the Quality manual. The quality manual should contain directly or provide an authoritative list of with access to all documents needed for effective planning, operation and control of WIGOS processes and procedures.

Further guidance:

* WMO-No. 1001, e.g. Clause 7.6; Chapter 8, 8.5, Clause 8.5, App. 1

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**APPENDIX 2.5**

**Eight Principles of Quality Management of the WMO Quality Management Framework applied to WIGOS**

1. User and 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.

Note: The means to achieve this includes participation in and the application of the WMO Rolling Review of Requirements (RRR) process (see section 2.2.4 and Appendix 2.3).

2. Leadership

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.

Note: 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.

3. Involvement of people

Experts from Member countries should be fully involved in the implementation of regulations pertaining to WIGOS quality management.

4. Process approach

Members should adopt a process-based approach to management of observing systems.

5. System approach to management

Members should identify, understand and manage WIGOS observing systems as sets of processes that may be operational, scientific or administrative, with the overall objective of producing the required observations outputs.

6. Continual improvement

Members should ensure that continual improvement is an integral and permanent component of WIGOS observing systems and is 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.

Note: The resulting outcome is the improvement of either the quality of observations or the efficiency of observing systems.

7. Factual approach to decision-making

Members should ensure that decisions, requirements and regulations associated with the design, development, implementation, operation, maintenance and evolution of WIGOS observing systems are based on scientifically, factually and analytically derived information.

Note: The above mentioned information is 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*” (WIGOS Technical Report No. 2013-4) and others. For further information see section 2.2.4, Appendix 2.3 and Attachment 2.2.

8. Mutually beneficial supplier relationships

Members should participate in, and share with each other and with suppliers, information and results of, tests, trials and intercomparisons of instruments and systems, for the mutual benefit of both WIGOS and suppliers.

Note: 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.

Guide: WMO-No. 100, Chapter 2; 2.1 Introduction

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**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.

2.7.1.4 When planning capacity development activities, Members should take a holistic approach considering institutional, infrastructural, procedural, and human resources requirements to support both the current and continuing resource requirements for installation, operation, maintenance, inspection, and training. For this purpose, Members should prepare specific capacity development plans with measurable objectives to enable effective implementation, monitoring, and assessment.

Note: Funds to meet these requirements should be planned well ahead, subject to national policies of Members, to assure long-term sustainable networks.

Guidance on approaches for capacity development is found in the WMO Capacity Development Strategy (CDS) and its Implementation Plan.

The purpose of the CDS is to provide a coordinated and cohesive approach to capacity development activities by WMO in assisting Members to meet their mandates and contribute to the goals of the WMO. The overall objective of the CDS is to foster effective capacity development assistance to WMO Members and facilitate sustainable development of their National Meteorological and Hydrological Services (NMHSs), particularly in developing countries, LDCs and SIDS. The CDS seeks to build upon existing capacities in NMHSs, reduce duplication and utilize opportunities to leverage investments in strategic partnerships and synergies, while integrating the roles and requirements of regional associations, technical commissions, WMO co-sponsored Programmes as well as WMO Programmes within the strategic priority areas in the provision of development assistance to Members.

The CDS recognizes that there are four types of NMHSs capacity: institutional, infrastructural, procedural and human resources. These four dimensions of capacities are distinct yet inter-related and must be considered holistically to achieve sustainable capacity development. The CDS also recognizes that WMO capacity development activities should be monitored and results evaluated for sustainability over time.

Capacity development begins with an accurate understanding of current and required capacities. The WMO provides the framework through the establishment of standards for measurement of geophysical observations as well as processing and standardization of related data within WIGOS; it provides a point of reference needed by National Meteorological and Hydrological Services (NMHSs) to understand the required capacities and to identify any deficiencies in current capacities.

National governments have a strong role in planning and sustaining the capabilities of the National Meteorological and Hydrological Services (NMHSs) in partnership with regional and global communities, and recognizing the importance of the NMHSs to public safety, security, national development and general social and economic benefits which flow from weather, water and climate services.

**Four Dimensions of Capacity**

The WMO Capacity Development Strategy recognizes that NMHSs capacities have four different dimensions: their human resource capacities, the infrastructural capacity, the procedural capacity and the institutional capacity. These four perspectives are needed to sustain capacity development, and are defined as:

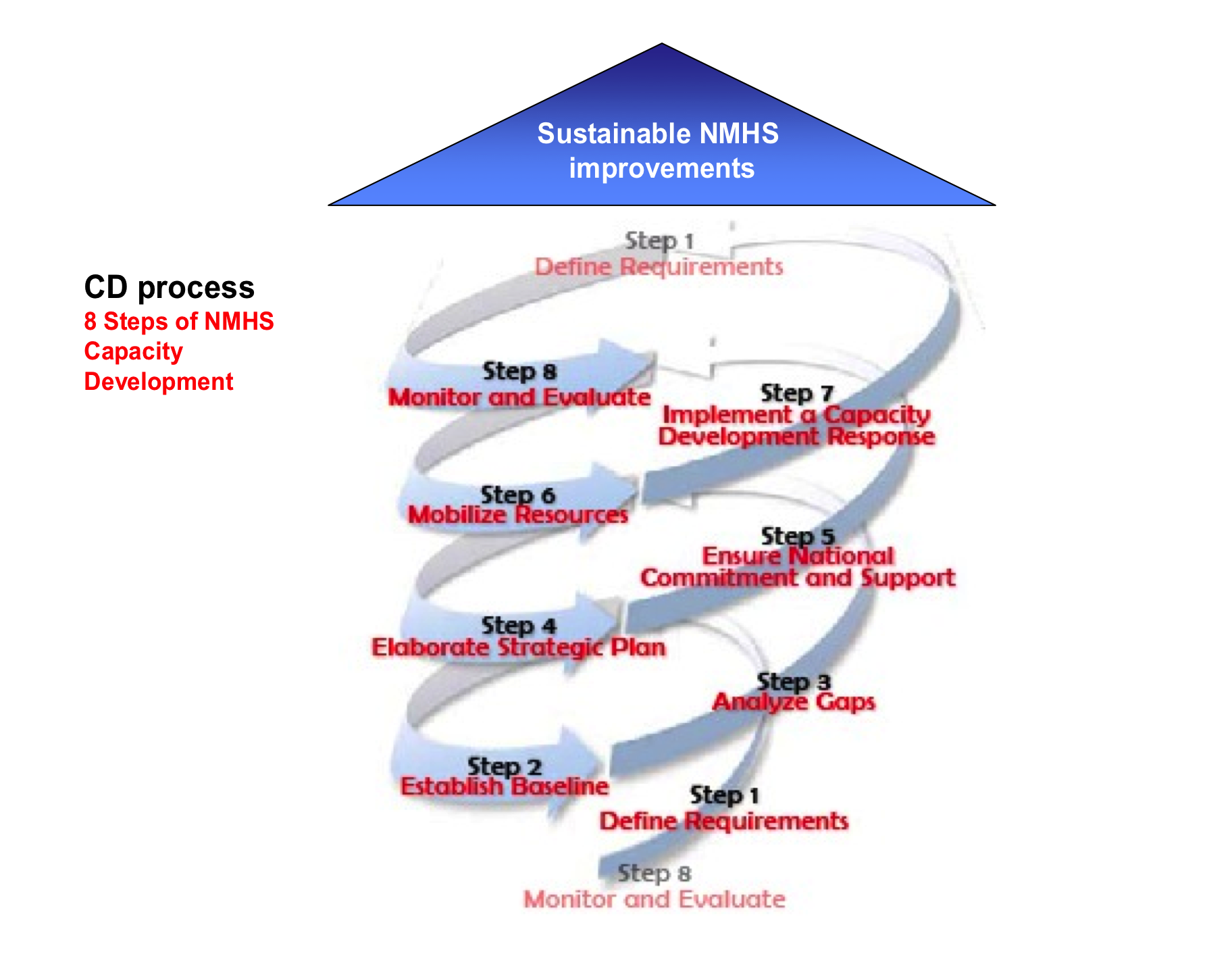
* Human resource capacity: Individuals equipped with the education, skills, information, knowledge and training to enable them to generate, communicate and use decision-relevant weather, water and climate information, and also to manage the process;
* Infrastructural capacity: Capability of NMHSs to access the resources that are needed to generate, archive and use weather, water and climate data and decision-relevant information, including observing networks, data management systems, computer hardware and software, internet, manuals and scientific literature;
* Procedural capacity: Capability of NMHSs to define and advance best practices for generating and using weather, water and climate information. The capacity includes the processes needed to implement and execute projects, programme or policy, and to monitor its implementation and evaluate results;
* Institutional capacity: Capability of NMHSs to articulate its mandate, elaborate its management structures or to envision the desired course of the organization; to develop a strategy, translate it into an actionable plan and prepare a budget; to engage with stakeholders to identify, and create consensus around capacity development issues, as well as related policies, regulations and laws, that enable effective provision of services.

These perspectives are distinct and yet inter-related. In considering capacity development, it is important to consider all four aspects and their inter-relationships in order to priorize investments and actions.

Efforts efforts in capacity development for WIGOS should be taken to ensure that observing systems comply with the standards and recommendations specified by the WMO Technical Regulations.

**Steps in Capacity Development**

The CDS identifies eight steps for capacity development:



(Ref: CDSIP-Annex3.doc)

**STEP 1: Define Requirements:** Describe what observations are needed at the global, regional and national level and what is needed to meet these requirements in terms of institutional organization and mandate, technical skill, infrastructure, and relationships with users and its ability to operate the infrastructure and to performs its functions. The requirements can be different in nature: technical systems, standards, or organizational, and can be expressed in a number of ways such as type of measurement, observational coverage and frequency, timeliness, resolution, staffing skill and budget. All relate to the capacities which are needed for providing the weather, climate, water and related environmental services, including observing systems, data management, prediction, communications and data exchange to stakeholders who require the information. Requirements can also refer the level of quality of services, usability, availability, reliability, supportability, testability and maintainability.

**STEP 2: Establish Baseline:** Assess existing capacities (procedures, institutions, human resources and infrastructure).

**STEP 3: Analyze Gaps:** Compare the baseline capacities with what is needed to meet national and international requirements. This step involves determining what capacities are lacking or require additional development in terms of institutional, infrastructural, procedural and/or human resources capacities.

**STEP 4: Develop a Strategic Plan:** A strategic plan to address the gaps is required to clarify the goals and specify the measures to be taken to fill the gaps and meet requirements. Strategic planning is the organization’s process of defining its strategy and helps making decisions on allocating its resources to pursue its strategy. Generally a strategic plan deals with the key questions *What do we do?* (= mission), *Where shall we be in the next three to five years?* (vision), and *How are we going to make it a success?* (strategy). Strategy shall include expected results (ERs) and SMART[[4]](#footnote-4) objectives. To ensure a sustainable approach, the strategic plan should be aligned with stakeholder priorities, including national development plans (see step 5) and linked to resource mobilization (see step 6). The strategy should lead to a budget for the activities in the plan and include sub-programmes (observations, communications, staffing, services) with targets for each sub-programme, staff requirements with salaries and training, capital equipment and operating funds (see step 7).

**STEP 5: Ensuring National Ownership and Support:** Through engagement with national governments and regional authorities and related institutions, integrate support for the service and the strategic plan into national priorities (and linked to regional and global priorities) to ensure sustainable development. As helpful as multilateral and bilateral assistance can be, ownership of the goals, priorities and long-term funding must be evident at the national level.

**STEP 6: Mobilize Resources:** Mobilize financial and in-kind resources towards meeting the requirements identified in Step 1 and prioritized in Step 4. National support means, to some extent, national funding. National funding may be sought from multiple agencies and, in many cases, funding arrangements for special services from the NMHSs to another department or to a private entity can be made by agreement or contract. In many countries a portion of funds received for aviation support from airlines are apportioned to NMHSs for aviation services. Multilateral and bilateral funding mechanisms exist and should be pursued as required to meet the identified requirements. International, inter-regional and bilateral cooperation, and volunteerism should be considered to extend the resources available. Strengthened partnerships within the UN system, development banks, NGOs and with regional organizations can provide opportunities to leverage resources and build on common interests.

**STEP 7: Implement a CD Response:** A capacity development response is developed to align the strategy with national and donor strategic priorities and the availability of resources. Goals, expected results and key performance indicators are incorporated into an implementation plan or national budget with clear responsibilities, funding sources and mechanisms for coordination and management of the process.

**STEP 8: Monitor and Evaluate:** Evaluation of capacity development promotes institutional arrangements, leadership, knowledge and accountability. Monitoring and evaluation of the overall capacity development strategy should occur not only at the end of an implementation phase but throughout the process at defined intervals.

Capacity development initiatives should be considered as long-term actions and investments; it is necessary that resources be available not only for the initial implementation of the strategy (e.g. observing infrastructure improvements, staff training) but also for the long-term operation and maintenance of the strategy (e.g the continued maintenance of the new observing infrastructure.) Considering the value of continuity of observational data, it is recommended that capacity development initiatives be considered for a ten year horizon. It is recommended that, when resources and funding are established for a strategy, they be established for a full ten years to include any initial installation and all ongoing operation and maintenance for the period.

**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 or 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.

The purpose of a training programme is to ensure that personnel are able to meet all the demands made of them. These include the administration and management of the station(s) and the effective operation of the observing programme as well as the implementation of new requirements or modifications to operating procedures that may be requested. Training of a recurring nature is therefore important.

Extensive provisions applicable to the education and training of personnel are defined in Part V and Part VI of these Technical Regulations, and its Annex VIII (Manual on the Implementation of Education and Training Standards in Meteorology and Hydrology (WMO-No. 1083, Volume I).

To effectively meet WIGOS standards and recommendations, it is necessary to have training at initial recruitment of new staff as well as continuing professional development training. The tasks required to comply with the WIGOS standards and recommendations are evaluated to develop the necessary training materials, plans etc. for both initial and continuing training activities. As infrastructure is renewed, requirements are revised and/or procedures/methods are updated, professional development training is scheduled in advance of the implementation of the new systems/methods. An assessment should be made of the qualifications, competencies, skills and numbers of personnel and contractors required to comply with WIGOS standards and recommendations to determine the scale/scope of the necessary training programs.

Maintenance training is required for personnel responsible for preventive and corrective maintenance of the system. In order to understand adequately the operation of electronic and electro-mechanical devices, and to maintain them, it is necessary to understand the theory on which they are based. The theory provides the foundation for understanding the operation of present-day and proposed operational observational equipment.

A variety of training opportunities are often available at local or regional universities, technical schools, or factories producing specialized observational equipment. On-the-job training should be arranged either at a local facility or at another which performs the same function. On-the-job-training in the use of complex equipment is sometimes provided upon the successful conclusion of formal schooling instead of classroom study. Non-technical training is as important as technical training as a basis for achieving operational efficiency of the facilities.

Further guidance:

* WMO-No. 1114; (This publication is intended for those involved in providing training for staff in a National Meteorological and Hydrological Service (NMHS) or related agencies. In particular, it aims to strengthen training departments and enhance the expertise of trainers by providing a reference manual and introductory guide. It includes guidance on the options available to ensure positive learning experiences for individuals and organizations.)
* Members should maintain records of the education and training of their personnel as part of their Quality Management System, for their human resource development activities and for auditing purposes, where appropriate, in accordance with the *Manual on the Implementation of Education and Training Standards in Meteorology and Hydrology* (WMO- No.1083), Volume I).
* WMO-No. 100, Chapter 2, 2.6.5;

**2.7.3 Infrastructural Capacity Development**

2.7.3.1 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.

The RRR process and the resulting priorities for the evolution of observing systems will provide fundamental information for Step 1 of the capacity development process described in 2.7.3. As part of this process, a regular assessment of observing infrastructure should be undertaken so that observing systems can appropriately address the evolving requirements of the RRR process as well as additional regional or national priorities. As the CD process is undertaken, it will become clear in Step 3 if infrastructural capacity development is a requirement.

**References and Further Reading**

World Meteorological Organization, 2006 (2nd edition): *Guide on Meteorological Observing and Information Distribution Systems for Aviation Weather Services* – (WMO, No. 731)

World Meteorological Organization, 2008: *Guide to Hydrological Practices, Volume I: Hydrology – From Measurement to Hydrological Information:* – (WMO, 168)

World Meteorological Organization, 2008 edition updated in 2010: *Guide to Meteorological Instruments and Methods of Observation: (CIMO guide)* – (WMO, No. 8)

World Meteorological Organization, 2010 edition updated in 2013: *Guide to the Global Observing System:*  – (WMO, No. 488)

World Meteorological Organization, 2013: *Guide to the Implementation of a Quality Management System for National Meteorological and Hydrological Services* – (WMO, No. 1100)

World Meteorological Organization: *A Practical Guide for the Implementation of a Quality Management System for National Meteorological and Hydrological Services:* – (Version 10, draft) (available at: <http://www.wmo.int/pages/prog/hwrp/qmf-h/documents/ext/QM_Guide_NMHSs_V10.pdf> )

World Meteorological Organization, 2013: *Guidelines for Implementing a Quality Management System in Hydrology:* – available at: <http://www.wmo.int/pages/prog/hwrp/qmf-h/documents/Doc_3_GuidelinesQualityManagementSystem_17092013.pdf>

World Meteorological Organization: *Observing Systems Capability Analysis and Review Tool (OSCAR)* – Online resource available at: <http://www.wmo-sat.info/oscar/>

World Meteorological Organization: *Requirements for Observational Data: The Rolling Review of Requirements* – Online resource available at: <http://www.wmo.int/pages/prog/www/OSY/Documentation/RRR-process.pdf>

World Meteorological Organization, 2009: *Vision for the GOS in 2025*. An online resource available at: <http://www.wmo.int/pages/prog/www/OSY/WorkingStructure/documents/CBS-2009_Vision-GOS-2025.pdf>

World Meteorological Organization: *WIGOS Operational Information Resource (WIR)* – Online resource available at: <http://www.wmo.int/pages/prog/www/wigos/wir/index_en.html>

World Meteorological Organization: *WMO Quality Management Framework – Hydrology:* –available at: <http://www.wmo.int/pages/prog/hwrp/qmf-h/documents/Doc_1_WMO_Quality_Management_Framework17092013.pdf> )

World Meteorological Organization: *WMO Capacity Development Strategy.* Online resource available at: <http://www.wmo.int/pages/prog/dra/CDS.html>

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**3.** **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.

The observational user requirements of WMO Application Areas are expressed in a technology free manner and determined through the RRR process. These requirements apply to all of WIGOS in common, not only to a specific sub-system. Thus, the provisions of section 2.1 apply across all WIGOS sub-systems.

The WIGOS surface-based sub-system is composed of stations/platforms within the WIGOS component networks (i.e. GOS, GAW, GCW, and WHOS) as described in the Manual on WIGOS. This is a wide-ranging system of stations/platforms including surface synoptic stations, upper-air synoptic stations, aircraft meteorological stations, manned and automatic sea stations and, aeronautical meteorological stations, research and special-purpose vessel stations, climatological stations, agricultural meteorological stations, hydrometric stations, groundwater stations, hydrological stations for specific purposes, and GAW stations in one or more of the focal areas (aerosols, greenhouse gases, selected reactive gases, ozone, UV radiation and precipitation chemistry (or atmospheric deposition).)

The establishment and operation of the surface-based sub-system should be considered as a single composite system of observing stations/platforms. While each individual set of stations serves specific purposes, it is valuable for efficiency and effectiveness to establish, operate and manage the full WIGOS surface-based sub-system as a composite system. By doing so, it will become more apparent where individual stations provide support to multiple purposes thereby increasing the value of the stations to all users. It will also become more apparent what adjustments and changes are necessary to the network considering all user requirements and all surface-based observations. When managed as a composite system, there will also be opportunities to enhance reliability and effectiveness across the network through the use of common equipment, hardware, and software etc. systems. Consideration should also be given to the opportunity present by having staff trained to maintain multiple station types.**Observational requirements**

The RRR process is conducted to produce user-specified observational requirements. Maintained by the WMO Space Programme, the Observing Systems Capabilities Analysis and Review tool (OSCAR) is a component of the Rolling Requirements Review process for recording observational requirements and observing capabilities (both space-based and surface-based), and conducting critical reviews of how well the capabilities address the requirements.

The observational user requirements component of OSCAR (OSCAR/Requirements -- http://www.wmo-sat.info/oscar/observingrequirements) provides a record of observational user requirements formulated by WMO and co-sponsored programmes: GCOS, GOOS, WCRP. The requirements are regularly reviewed by groups of experts nominated by these organizations and programmes. For WMO, this process is conducted by the Inter-Programme Expert Team on Observing System Design and Evolution (IPET-OSDE) and its designated focal points for each of the WMO application areas (e.g. Global NWP, High-resolution NWP, Synoptic meteorology, Nowcasting and Very Short Range Forecasting, Seasonal to Inter-annual Monitoring, Atmospheric chemistry, Aeronautical meteorology, Agricultural meteorology, Hydrology and water resources).

Requirements are expressed for geophysical variables in terms of 5 criteria: horizontal resolution, vertical resolution, observing cycle, timeliness and uncertainty. For each of these criteria the table indicates 3 values determined by experts:

- the “threshold” is the minimum requirement to be met to ensure that data are useful

- the “goal” is an ideal requirement above which further improvements are not necessary

- the “breakthrough” is an intermediate level between “threshold” and “goal“ which, if achieved, would result in a significant improvement for the targeted application. The breakthrough level may be considered as an optimum, from a cost-benefit point of view, when planning or designing observing systems.

Information on surface-based observing capabilities are planned to be made available through the surface-based component of OSCAR (OSCAR/Surface). This component is currently under development and surface-based observing capabilities therefore not available for the time being. However, some information on surface based observing systems capabilities can be obtained through the following websites:

World Weather Watch Operational Information Service (OIS):

<http://www.wmo.int/pages/prog/www/ois/ois-home.html>

Global Atmosphere Watch (GAW) Station Information System (GAWSIS):

<http://gaw.empa.ch/gawsis>

World Hydrological Cycle Observing System (WHYCOS):

<http://www.whycos.org/whycos/>

JCOMM in situ Ocean Observations Programme Support Centre (JCOMMOPS):

<http://www.jcommops.org/>

The full surface-based observing network is established, operated and maintained to meet the observing requirements of users.

**3.2. Design, planning and evolution**

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

3.2.1.1 The WIGOS surface-based sub-system **shall** be composed of surface stations within the component networks (i.e. GOS, GAW, WHOS, GCW).

3.2.1.2 Members should implement elements of the WIGOS surface-based sub-system under the coordination of regional associations when appropriate.

Note: Information regarding the current capabilities of the surface-based subsystem is to be available through the Observing Systems Capability Analysis and Review Tool (OSCAR) at: http://[www.wmo.int/oscar](http://www.wmo.int/oscar).

The planning, implementation, operation and maintenance of national networks and observing programmes should be based on the standard and recommended practices and procedures as stated in the WMO Technical Regulations, including the Manual on WIGOS. Such actions must also take into account the various plans and strategies developed by WMO, for WIGOS and the component observing systems.

In some cases, it will be appropriate to cooperate to address regional implementation of observing networks/systems. This may occur at the full regional level but it may also occur as a bi-national or multi-national cooperative initiative.

As discussed in 3.1, it is valuable to adopt a composite network approach to networks to deliver the most efficient and effective network to meet user requirements. and include observations from a range of sources, including NMHSs and other government agencies, the commercial sector and members of the public. The composite network approach means the use of various types of observing systems or sources of observations to deliver a combined set of observations.

**3.3. Instrumentation and Methods of Observation**

**3.3.1 General Requirements**

3.3.1.1 Members **shall** classify their surface meteorological and climatological observing stations on land.

Note 1: The *Guide to Meteorological Instruments and Methods of Observation* (WMO-No. 8), Part I, Chapter 1, (1.1.2), Annex 1.B provides guidelines on the classification of surface observing sites on land to indicate their representativeness for the measurement of different variables.

Note 2: The content of Annex 1.B will be included as an Appendix in a future edition.

Standards and recommendations with respect to instruments and methods of observation for all WIGOS surface-based sub-systems are specified in Technical Regulations (WMO-No. 49), Vol. I - III, and detailed in the Manual on WIGOS and the other relevant WMO regulatory material.

The *Guide to Meteorological Instruments and Methods of Observation* (WMO-No. 8), Part 1 provides an extensive reference guide regarding instrumentation and methods of observation for meteorological observations. Some specific elements for reference include:

* Classification of surface meteorological and climatological observing stations -- *Guide to Meteorological Instruments and Methods of Observation (WMO-No. 8)*, Part 1, Chapter 1, (1.1.2) with more details available at: <http://www.wmo.int/pages/prog/www/IMOP/SitingClassif/SitingClassif.html>
* Use of the World Geodetic System 1984 (WGS-84) Earth Geodetic Model 1996 (EGM96) to refer to the position of a station (not including hydrology) -- *Guide to Meteorological Instruments and Methods of Observation (WMO-No. 8)*, Part I, Chapter 1 (1.3.3.2).
* Defining the elevation of a station -- *Guide to Meteorological Instruments and Methods of Observation (WMO-No. 8)*, Part I, Chapter 1, (1.3.3.2(c))
* Defining the elevation of a station at an aerodrome -- WMO Technical Regulation (WMO-No. 49), Vol. II, [C.3.3.], Appendix 3, 4.7.2)
* Operations and functions of a Regional Instrument Centre -- *Guide to Meteorological Instruments and Methods of Observation (WMO-No. 8)*, Part I, Annex 1.A

Further guidance on the use of automatic meteorological observing systems for the aviation services is given in the ICAO Manual on Automatic Meteorological Observing Systems at Aerodromes (Doc 9837): Chapters 3-9; Appendix A, Appendix B;

3.3.1.2 Members should locate each observing station at a site that permits instrument exposure against the requirements of the particular applications and enables satisfactory non-instrumental observations.

Note 1: The *Guide to Meteorological Instruments and Methods of Observation* (WMO-No. 8), Part I, Chapter 1, Annexes 1.B and 1.C provides further guidelines.

Note 2: Requirements for GAW stations are formulated in section 6.

Further guidance:

* WMO-No. 8, Part I, Chapter 1, 1.3.3
* Specifications concerning the siting of equipment and installations on operational areas, aimed at reducing the hazard to aircraft to a minimum, are contained in ICAO Annex 14, Volume I, Chapter 9.
* WMO-No. 100, Chapter 2, 2.4

3.3.1.3 Members **shall** accurately know and refer the position of a station to the World Geodetic System 1984 (WGS-84) and its Earth Geodetic Model 1996 (EGM96)

Note 1: Guidelines are provided in the *Guide to Meteorological Instruments and Methods of Observation* (WMO-No. 8), Part I, Chapter 1 (1.3.3.2).

Note 2: This geodetic system is currently not in general use in hydrology.

Note 3: Its description will be included as an Appendix in a future edition.

3.3.1.4 Members **shall** define the elevation of the station.

Note 1: The *Guide to Meteorological Instruments and Methods of Observation* (WMO-No. 8), Part I, Chapter 1, (1.3.3.2(c)) provides guidelines on defining the elevation of a station.

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

3.3.1.5 If a station is located at an aerodrome, Members **shall** specify the official elevation of the aerodrome in accordance with the WMO *Technical Regulation* (WMO-No. 49), Volume II, [C.3.1.], Appendix 3, 4.7.2).

3.3.1.6 Members operating Regional Instrument Centres should follow the guidelines concerning capabilities and corresponding functions.

Note 1: The *Guide to Meteorological Instruments and Methods of Observation* (WMO-No. 8), Part I, Annex 1.A provides guidelines concerning capabilities and corresponding functions.

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

3.3.1.7 Members operating Regional Marine Instrument Centres should follow the guidelines concerning capabilities and corresponding functions.

Note 1: The Guide to Meteorological Instruments and Methods of Observation (WMO-No. 8), Part II, Chapter 4, Annex 4.A provides guidelines concerning capabilities and corresponding functions for operating Regional Marine Instrument Centres.

Note 2: The content of Annex 4.A will be included as an Appendix in a future edition.

**3.3.2 Requirements on Sensors**

3.3.2.1 Members **shall** avoid the use of mercury in their observing systems. Where mercury is still in use, Members **shall** obey the safety precautions provided.

Note 1: The *Guide to Meteorological Instruments and Methods of Observation* (WMO-No. 8), Part I, Chapter 3 (3.2.7) provides safety precautions

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

3.3.2.2 For inflation of meteorological balloons, Members should prefer helium over hydrogen. If hydrogen is used, however, Members **shall** obey to the safety precautions provided.

Note 1: The *Guide to Meteorological Instruments and Methods of Observation* (WMO-No. 8), Part II, Chapter 10 (10.5-10.6) provides safety precautions.

Note 2: This material will be included as 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 World Standard Group and a likely uncertainty of calibration equal to or better than the pyrheliometer being calibrated.

Note: The *Guide to Meteorological Instruments and Methods of Observation* (WMO-No. 8), Part I, Chapter 7 (7.2.1.4) provides the detailed guidelines.

3.3.2.4 Members **shall** compare, calibrate and maintain barometers according to the guidelines.

Note 1: The *Guide to Meteorological Instruments and Methods of Observation* (WMO-No. 8), Part I, Chapter 3 (3.10), provides guidelines on the comparison, calibration and maintenance of barometers.

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

The *Guide to Meteorological Instruments and Methods of Observation (WMO-No. 8)*, Part I provides guidance regarding requirements for meteorological sensors. Some specific elements include:

* Safety precautions for mercury – *Guide to Meteorological Instruments and Methods of Observation (WMO-No. 8)*, Part I, Chapter 3 (3.2.7)
* Safety precautions for hydrogen – *Guide to Meteorological Instruments and Methods of Observation (WMO-No. 8)*, Part I, Chapter 10 (10.6.1)
* Calibration of pyrheliometers – *Guide to Meteorological Instruments and Methods of Observation (WMO-No. 8)*, Part I, Chapter 7 (7.2.1.4)
* Calibration and maintenance of barometers – *Guide to Meteorological Instruments and Methods of Observation (WMO-No. 8)*, Part I, Chapter 3 (3.10)

**3.4. Operations**

**3.4.1 General Requirements**

3.4.1.1 Members operating surface-based observing systems **shall** follow the provisions of the section 2.4.1.

Within a country, frequently the NMHS is the primary operator of WIGOS networks but there may be a number of organizations (governmental and non-governmental) that are system owners/operators or custodians. To maintain the overall integrity of the WIGOS network, these organizations need to understand and be assisted (as required) to ensure they operate and maintain their systems in compliance with the technical regulations of the WMO.

The WMO Member for a country will work with relevant international organizations (WMO typically but also IOC, IMO, ITU and other organizations as necessary) to obtain and assign a unique identifier for each observing station/platform within their country. Frequently, this is done from the allocation of identifiers made by the international organization to the specific country. This is applicable to stations operated specifically by the Member and to all collaborating organizations within the country that provide observations for the WIGOS network.

When a new station/platform is established or changes are made to an existing station/platform, the metadata for this station should be changed as early as practical (and before the platform becomes operational) by providing the revised metadata to the organizations or centres in charge of their collection.

**3.4.2 Observing Practices**

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

3.4.2.2 Members **shall** determine a reference height for at each surface observing station or system.

Note: A reference height is defined as follows:

1. Elevation of the station. It is the datum level to which barometric pressure reports at the station refer; such current barometric values being termed "station pressure" and understood to refer to the given level for the purpose of maintaining continuity in the pressure records; or

2. For stations not located on aerodromes: elevation of the ground (height above mean sea level of the ground on which the raingauge stands or, if there is no raingauge, the ground beneath the thermometer screen. If there is neither raingauge nor screen, it is the average level of terrain in immediate vicinity of station) in metres rounded up to two decimals; or

3. For stations located on aerodromes it is an official altitude of the aerodrome.

The exposure of instruments, platforms and sites may significantly affect the observation of the various observed parameters. Standards should be researched, developed and adopted to document the preferred and required exposures for the various instruments that are part of a site. These standards should provide for similar exposure across the observing network for each parameter to enable compatibility of the observations.

**3.4.3 Quality Control**

3.4.3.1 Members operating surface-based observing systems **shall** follow the provisions of the section 2.4.3.

**3.4.4 Data and Metadata Reporting**

3.4.4.1 Members operating surface-based observing systems **shall** follow the provisions of the section 2.4.4.

**3.4.5 Incident Management**

3.4.5.1 Members operating surface-based observing systems **shall** follow the provisions of the section 2.4.5.

**3.4.6 Change Management**

3.4.6.1 Members should compare observations from new instruments over an extended interval before the old measurement system is taken out of service or 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 stations and among the exceptions are hydrological stations.

Note 2: Further details can be found in the *Guide to Climatological Practices* (WMO-No. 100), including the required minimum intervals for such comparison.

Changes to a WIGOS observing network (whether network wide or individual stations) should be planned to (where possible/reasonable) enable an inter-comparison of the observations. Such changes may include a change in instruments, a change in station location, a change in exposure, etc. Typically, it is preferable to compare the observations over an extended period of time to be assured of the continued reliability of the observations. In some cases or some networks (e.g. hydrology), this strategy is impractical for a number of reasons. In these cases, one can consider comparisons at selected representative sites or comparisons at special inter-comparison sites or comparisons in controlled conditions (e.g. a lab or tank.) Further details for some parameters can be found in the *Guide to Climatological Practices (WMO-No. - 100),* including the required minimum intervals for such comparison.

**3.4.7 Maintenance**

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

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), Part I, Chapter 1, 1.3.5.2 *and more specific guidance for different instruments in other Chapters of Part I, Part II, Chapter 1, 1.6,Chapter 9, 9.8.2, Chapter 12, 12.10, as well as in some other Chapters of Part II, Part III, Chapter 1, 1.6*, the *Guide to Hydrological Practices* (WMO-No. 168, 2008) and the *Manual on Stream Gauging* (WMO-No. 1044, 2010).

Detailed guidance on the maintenance of observing sites, observing systems and instruments is provided 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 Members **shall** 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 sections 5-8 for the frequency intervals specified for the different types of WIGOS surface observing stations.

Note 2: Detailed guidance on the inspection, including the frequency, is given in the *Guide to Meteorological Instruments and Methods of Observation* (WMO-No. 8), Part I, Chapter 1, 1.3.5, Part II, 1.7, Part III, Chapter 1, 1.6, 1.10.1; Chapter 4, 4.3.5 *with some more detailed guidance throughout the Part I, e.g. 2.3.7, 3.10.3.2*.

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

3.4.8.2 Members **shall** ensure that inspection is performed by qualified and adequately trained staff.

3.4.8.3 When performing inspection, 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 of the Guide, the *Guide to Hydrological Practices* (WMO-No. 168) and the *Manual on Stream Gauging* (WMO-No. 1044).

Inspection of surface observing sites/stations/systems is conducted sufficiently frequently 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.

Reference is made to the Sections 5-8 of the Manual on WIGOS for the frequency intervals specified for the different types of WIGOS surface observing stations. Detailed guidance on the inspection including the frequency is given in the Guide to Meteorological Instruments and Methods of Observation (WMO-No. 8), Part III, Chapter 1.

Reference is also made to the Technical Regulations (WMO-No. 49), Volume II for provisions on the inspection of aeronautical meteorological stations including its frequency.

When performing inspection, the qualified and adequately trained staff should verify that:

1. The siting, selection and installation, as well as exposure when applicable, of instruments are known, recorded and acceptable;
2. Instruments have approved characteristics, are in good order and regularly verified against relevant standards;
3. There is uniformity in the methods of observation and in the procedure for reduction of observations.

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).

Further guidance:

* WMO-No. 100, 2.4, 2.6.6

**3.4.9 Calibration Procedures**

3.4.9.1 Members operating surface-based observing systems **shall** follow the provisions of the section 2.4.9.

Further guidance:

* WMO-No. 8, Part II, Chapter 1, 1.7, Chapter 9, 9.8.1; Part III, Chapter 1, 1.6;
  1. **Observational Metadata**

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, 3.3.3, 3.3.9; *Guide to the Global Observing System* (WMO-No. 488), Appendix III.3, and the *Guide to Hydrological Practices* (WMO-No. 168), Volume I, Chapter 10.

3.5.1 Members operating surface-based observing systems **shall** follow the provisions of the section 2.5.

Note: Further provisions specific to the WIGOS component observing system appear in sections 5, 6, 7 and 8.

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), Volume I, Chapter 10.

Further guidance specific to the WIGOS component observing system appear in sections 2, 5, 6, 7 and 8 of this Guide.

**3.6. Quality Management**

3.6.1 Members operating surface-based observing systems **shall** follow the provisions of the section 2.6.

Note: Further provisions specific to the WIGOS space-based sub-system appear in section 4; specific to the WIGOS component observing system appear in sections 5, 6, 7 and 8.

Further guidance:

* ICAO/Doc 9837; Chapter 12;

**3.7. Capacity Development**

3.7.1 Members operating surface-based observing systems **shall** follow the provisions of the section 2.7.

Note: Further provisions specific to the WIGOS space-based sub-system appear in section 4; specific to the WIGOS component observing system appear in sections 5, 6, 7 and 8.

**References and Further Reading**

World Meteorological Organization, 2008 edition updated in 2010: *Guide to Meteorological Instruments and Methods of Observation: (CIMO guide)* – (WMO, No. 8)

World Meteorological Organization, 2008: *Guide to Hydrological Practices, Volume I: Hydrology – From Measurement to Hydrological Information:* – (WMO, 168)

*[GCOS Upper-Air reference Network (GRUAN) – Guide](http://library.wmo.int/pmb_ged/gcos_171.pdf)* [(WIGOS Technical Report No. 2013-03, GCOS-171)](http://library.wmo.int/pmb_ged/gcos_171.pdf)  (2013)

World Meteorological Organization, 2010 edition updated in 2013: *Guide to the Global Observing System:*  – (WMO, No. 488)

World Meteorological Organization, 2006 (2nd edition): *Guide on Meteorological Observing and Information Distribution Systems for Aviation Weather Services* – (WMO, No. 731)

World Meteorological Organization, 2013: *Guide to the Implementation of a Quality Management System for National Meteorological and Hydrological Services* – (WMO, No. 1100)

World Meteorological Organization: *Observing Systems Capability Analysis and Review Tool (OSCAR)* – Online resource available at: <http://www.wmo-sat.info/oscar/>

World Meteorological Organization: *WIGOS Operational Information Resource (WIR)* – Online resource available at: <http://www.wmo.int/pages/prog/www/wigos/wir/index_en.html>

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

**4.1.** **Requirements**

* + 1. **General**

4.1.1.1 Members **shall** strive to develop, implement and operate a space-based environmental observing system in support of WMO Programmes as described in Attachment 4.1.

Note: The space-based sub-system of WIGOS is established through dedicated satellites, remotely observing the characteristics of the atmosphere, the earth and the oceans.

**References**

Guide to Meteorological Instruments and Methods of Observation (WMO-No. 8);

Guide to the Global Observing System (WMO-No. 488);

Guide on Meteorological Observing and Information Distribution Systems for Aviation Weather Services – (WMO-No. 731)

* + 1. World Meteorological Organization: WMO Space Programme. An online resource available at: <http://www.wmo.int/pages/prog/sat/index_en.php>**Observed Variables**

4.1.2.1 This sub-system **shall** provide quantitative data enabling, independently or in conjunction with surface-based observations, the determination of variables including but not limited to:

(a) Three-dimension fields of atmospheric temperature and humidity;

(b) Temperature of sea and land surfaces;

(c) Wind fields (including ocean surface winds);

(d) Cloud properties (amount, type, top height, top temperature, and water content);

(e) Radiation balance;

(f) Precipitation (liquid and frozen);

(g) Lightning;

(h) Ozone concentration (total column and vertical profile);

(i) Greenhouse gas concentration;

(j) Aerosol concentration and properties;

(k) Volcanic ash cloud occurrence and concentration;

(l) Vegetation type and status and soil moisture;

(m) Flood and forest fire occurrence;

(n) Snow and ice properties;

(o) Ocean colour;

(p) Wave height, direction and spectra;

(q) Sea level and surface currents;

(r) Sea ice properties;

(s) Solar activity;

(t) Space environment (electric and magnetic field, energetic particle flux, electron density).

Note: Information regarding the current capabilities of the space-based subsystem is available through the Observing Systems Capability Analysis and Review Tool (OSCAR) at: http://[www.wmo.int/oscar](http://www.wmo.int/oscar).

* + 1. **Observing performance requirements**

4.1.3.1 Satellite operators providing observational data to WIGOS **shall** strive to meet, to the extent possible, the uncertainty, timeliness, temporal and spatial resolution, and coverage requirements of WIGOS as defined in the WIGOS Information Resource (WIR), based on the Rolling Requirements Review process described in section 2.

Note 1: The term “satellite operators” is used in the *Manual on WIGOS* (WMO-No. XXXX) to refer to “Members or coordinated group of Members operating environmental satellites”.

Note 2: A coordinated group of Members operating environmental satellites is a group of Members acting jointly to operate one or more satellites through an international space agency such as the European Space Agency or EUMETSAT

Note 3: These requirements are recorded and maintained in the requirements database: <http://www.wmo.int/oscar>.

* + 1. **Global planning**

4.1.4.1 Satellite operators **shall** cooperate to ensure that a constellation of satellite systems is planned and implemented to guarantee the continuous provision of space-based observations in support of WMO Programmes.

Note: Collaboration is pursued within the Coordination Group for Meteorological Satellites, which includes all Members operating space-based observation systems in support of WMO Programmes.

* + 1. **Continuity**

4.1.5.1 Satellite operators working together under the auspices of the Coordination Group for Meteorological Satellites or otherwise, should ensure the continuity of operation, and of the data dissemination and distribution services of the operational satellites within the sub-system through appropriate contingency arrangements and re-launch plans.

* + 1. **Overlap**

4.1.6.1 Satellite operators should ensure an adequate period of overlap of new and old satellite systems in order to determine inter-satellite instrumental biases and maintain the homogeneity and consistency of time series observations, unless reliable transfer standards are available.

* + 1. **Interoperability**

4.1.7.1 Satellite operators **shall** achieve the greatest possible interoperability of their different systems.

4.1.7.2 Satellite operators **shall** make available sufficient technical details about the instruments, data processing, transmissions, and the dissemination schedules for Members to fully exploit the data.

**4.2.** **Design, planning and evolution**

Note: The space-based sub-system is composed of:

a. An Earth observation space segment;

b. An associated ground segment for data reception, processing, dissemination, and stewardship;

c. A user segment.

**4.2.1** **Space segment architecture**

Note: The overall architecture of the space segment is described in Attachment 4.1.

It is defined and evolves in consultation with the Coordination Group for Meteorological Satellites.

It includes:

* A constellation of geostationary satellites;
* A core constellation of sun-synchronous satellites distributed over three separated orbital planes;
* Other operational satellites operated on either sun-synchronous orbits or other appropriate Low-Earth orbits;
* Research and Development satellites on appropriate orbits.

**4.2.2 Space programme life cycles**

4.2.2.1 Satellite operators **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.

**4.3. Instruments and Methods of Observation**

Note 1: Space-based observation relies on a wide range of sensor types, e.g. active or passive, operating in various spectral ranges, with various scanning or pointing modes. 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 to Instruments and Methods of Observation*, (WMO-No. 8), Part III.

Note 2: Detailed characteristics of current and planned systems of environmental satellites are available in the satellite module of the Observing System Capabilities Analysis and Review tool (OSCAR), which is available on line (<http://www.wmo.int/oscar/space>). It also contains an indication of the main instruments that are relevant for each specific variable observable from space, with their potential performance for the respective variables.

**4.3.1 Calibration and Traceability**

4.3.1.1 Satellite operators **shall** perform a detailed instrument characterization before launch.

Note: Members must strive to follow the pre-launch instrument characterization guidelines recommended by the Global Space-based Inter-calibration System.

4.3.1.2 After launch, satellite operators **shall** calibrate all instruments on a routine basis against reference instruments or calibration targets.

Note 1: Advantage should be taken of satellite collocation to perform on-orbit instrument intercomparison and calibration.

Note 2: Calibration must be done in accordance with established and documented methodologies by the Global Space-based Inter-calibration System and the Committee on Earth Observation Satellites (CEOS) Working Group on Calibration and Validation.

4.3.1.3 Satellite operators **shall** ensure traceability to International Standards (SI) according to international approved standards.

Note: The Implementation Plan for the Global Climate Observing System (WMO/TD-No. 1253) calls for sustained measurement of key variables from space traceable to reference standards, and recommends implementing and evaluating a satellite climate calibration mission.

4.3.1.4 To ensure traceability to International Standards (SI), satellite operators **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 Satellite operators should implement an operational constellation of satellites in geostationary orbit as described in Attachment 4.1.

4.4.1.2 Satellite operators **shall** ensure that the constellation of satellites in geostationary orbit provides full disc imagery at least every 15 minutes, and achieves coverage of all longitudes, throughout a field of view between 60° S and 60° N.

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

4.4.1.3 Satellite operators should implement rapid-scan capabilities where feasible.

4.4.1.4 For the imagery mission in geostationary orbit, satellite operators should ensure an availability rate of rectified and calibrated data of at least 99 percent as a target.

4.4.1.5 To meet the essential requirement for continuity of data delivery, satellite operators, **shall** strive to implement contingency plans, involving the use of in-orbit stand-by flight models and rapid call-up of replacement systems and launches.

**4.4.2 Core operational constellation on sun-synchronous Low Earth Orbits (LEO)**

4.4.2.1 Operators of LEO satellites should implement a core operational constellation of satellites in three regularly distributed sun-synchronous orbits as described in Attachment 4.1.

4.4.2.2 Operators of the core constellation of environmental LEO satellites on three sun-synchronous orbital planes in early morning, mid-morning and afternoon orbit, **shall** strive to ensure a high level of robustness allowing the delivery of imagery and sounding data from at least three polar orbiting planes, on not less than 99 percent of occasions.

Note: This implies provisions for a ground segment, instrument and satellite redundancy, and rapid call-up of replacement launches or on orbit spares.

**4.4.3 Other capabilities on Low Earth Orbits**

4.4.3.1 Operators of environmental LEO satellites should implement capabilities in appropriate orbits as described in Attachment 4.1.

**4.4.4 Research and Development satellites**

4.4.4.1 Operators of Research and Development satellites **shall** consider providing the following observing capabilities:

1. Advanced 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.

Note: For WMO, the main benefits of Research and Development satellite missions are:

* Support of scientific investigations of atmospheric, oceanic, and other environment related processes,
* Testing or demonstration of new or improved sensors and satellite systems in preparation for new generations of operational capabilities to meet WMO observational requirements.

4.4.4.2 Members **shall** strive to optimize the usefulness of observations from Research and Development satellites for operational applications. In particular, operators of Research and Development satellites **shall** make provisions, where possible, to enable near real-time data availability to promote the early use of new types of observations for operational applications.

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: Although 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 Satellite operators **shall** make observational data available to Members over the WMO Information System (WIS) in accordance with the provisions in the *Manual on the WMO Information System* (WMO-No. 1060). Satellite operators **shall** inform Members of the means of obtaining these data through catalogue entries and **shall** provide sufficient metadata to enable meaningful use of the data.

4.5.1.2 Satellite operators **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.

4.5.1.3 Satellite operators **shall** strive to ensure that data from polar-orbiting satellites are acquired on a global basis, without temporal gaps or blind orbits, and that data latency meets WMO timeliness requirements.

**4.5.2 Data dissemination**

4.5.2.1 Satellite operators **shall** ensure near real-time data dissemination of the appropriate data sets, per the requirement of Members, either via an appropriately designed ground segment, by direct broadcast, or by re-broadcast via telecommunication satellites.

4.5.2.2 In particular, operators of operational sun-synchronous satellites providing the core meteorological imagery and sounding mission should ensure inclusion of 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 subsequent evolution, to provide meteorological centres 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 Satellite operators **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, to non-satellite data and to geophysical data products.

4.5.2.4 Operators of operational geostationary meteorological satellites with rapid-scan capabilities **shall** strive to provide meteorological centres with data in near-real time as required for nowcasting, numerical weather prediction (NWP) and other real-time applications.

**4.5.3 Data Stewardship**

4.5.3.1 Satellite operators **shall** provide full descriptions of all processing steps taken in the generation of satellite data products, including algorithms, characteristics, and outcomes of validation activities.

4.5.3.2 Satellite operators **shall** preserve long-term raw data records and ancillary data required for their calibration, reprocessing as appropriate, with the necessary traceability information to achieve consistent Fundamental Climate Data Records.

4.5.3.3 Satellite operators **shall** maintain Level 1B satellite data archives including all relevant metadata pertaining to the location, orbit parameters and calibration procedures used.

4.5.3.4 Satellite operators **shall** ensure that their archiving system is capable of providing on-line access to the archive catalogue with a browsing facility, provides adequate description of data formats, and will allow users to download data.

**4.5.4 Data collection systems**

4.5.4.1 Satellite operators with a capability to receive data and/or products from Data Collection Platforms (DCP) **shall** maintain technical and operational coordination under the auspices of CGMS in order to ensure compatibility.

4.5.4.2 Satellite operators **shall** maintain a number of “international” DCP channels identically on all geostationary satellites to support the operation of mobile platforms moving across all individual geostationary footprints.

4.5.4.3 Satellite operators **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 Operators of research and development satellites **shall** implement capabilities enabling Members to access the data in one of the following ways: via downloading data from server(s), via receiving data from a re-broadcasting service, or via receiving from a direct broadcast capability.

4.5.5.2 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.

4.5.5.3 Where appropriate, Members should 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**

4.6.1 For each space-based system they operate, satellite operators **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**

4.7.1.1 Satellite operators **shall** include appropriate quality indicators in the metadata for each datasets, in accordance with the provisions of section 2.5.

**4.8.** **Capacity Development**

**4.8.1 Centres of Excellence**

4.8.1.1 Satellite operators, 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 or other training institutes designated as Centres of Excellence in satellite meteorology, in order to build up expertise and facilities at a number of regional growth points.

**4.8.2 Training strategy**

4.8.2.1 Satellite operators should focus their assistance, to the extent possible, on one or more of these Centres of Excellence within their service areas and contribute to the Virtual Laboratory for Training and Education in Satellite Meteorology.

Note: The aim of the Education and Training strategy implemented through the Virtual Laboratory 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 for new systems**

4.8.3.1 In order to facilitate a smooth transition to new satellite capabilities, satellite operators should make provisions for appropriate preparation of the users through training, guidance to necessary upgrades of receiving equipment and processing software, and information and tools to facilitate the development and testing of user applications.

4.8.3.2 In addition to working through the Virtual Laboratory, 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 Data Providers**

4.8.4.1 In order to achieve the most effective utilization of satellite data, Members should pursue the close engagement between users and data providers at a regional level.

4.8.4.2 Working with their regional association, Members should follow systematic steps to document the regional requirements for satellite data access and exchange.

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**ATTACHMENT 4.1**

**CGMS BASELINE FOR THE OPERATIONAL CONTRIBUTION TO THE GOS**

*(adopted by CGMS-39 on 6 October 2011)*

**FUTURE SATELLITE MISSIONS TO BE PERFORMED   
ON OPERATIONAL/SUSTAINED BASIS**

**Introduction**

In support of the programmes coordinated or co-sponsored by WMO for weather and climate, CGMS Members plan to maintain the operational capabilities and services described below, that constitute the “CGMS baseline for the operational contribution to the GOS”.

While this particular document focuses on missions that are decided and managed in an operational or sustained framework, with a perspective of long-term follow-on, this in no way precludes the importance of other missions undertaken e.g. on a research or demonstration basis. First of all, because today’s research and development are the foundation of tomorrow’s operational missions. Furthermore, because many missions initiated in an R&D framework for a limited duration are eventually extended well beyond their design life time and provide longstanding support to both scientific and operational activities.

This baseline defines a constellation of geostationary satellites, a core meteorological mission on three sun-synchronous orbits, other missions in sun-synchronous orbits, missions in other Low Earth Orbits, and contains cross-cutting considerations on contingency planning, inter-calibration, data availability and dissemination.

**I. Constellation in geostationary orbit**

At least six geostationary satellites **shall** be operated at evenly distributed locations with in orbit

redundancy, and perform the following missions:

1. Advanced visible and infrared imagery (at least 16 spectral channels, 2km resolution) over the full disc at least every 15 minutes
2. Infrared sounding (hyperspectral on some positions)
3. Lightning detection
4. Data collection
5. Space environment monitoring

On selected positions, the following missions **shall** be performed:

1. Earth Radiation Budget monitoring
2. High spectral resolution UV sounding
3. Solar activity monitoring

**II. LEO sun-synchronous missions**

Operational sun-synchronous satellites **shall** be operated around three orbital planes in mid-morning (“am”, nominally 09:30 descending, 21:30 ascending ECT), afternoon (“pm”, nominally 13:30 ascending ECT) and early morning (nominally 05:30 descending, 17:30 ascending ECT) and, as a constellation, **shall** perform the following missions:

1) Core meteorological mission nominally on 3 orbital planes

1. Multispectral visible and infrared imagery
2. Infrared hyperspectral sounding (at least am and pm)
3. Microwave sounding
4. Microwave imagery

2) Other missions on sun-synchronous orbits

1. Wind scatterometry over sea surfaces (at least two orbital planes)
2. Ocean surface topography by radar altimetry (at least on am and pm orbits, supplemented by a reference mission on a high-precision, inclined orbit)
3. Radio-occultation sounding (at least am and pm, supplemented by a constellation in specific orbits)
4. Broadband VIS/IR radiometer for Earth Radiation balance (at least am and pm)
5. Total Solar Irradiance (at least one)
6. Contribution to atmospheric composition observations (at least am and pm)
7. Narrow-band Vis/NIR imagers (at least one sun-synchronous, am spacecraft) for ocean colour, vegetation and aerosol monitoring
8. High-resolution multi-spectral Vis/IR imagers (constellation of sun-synchronous satellites, preferably in am)
9. IR dual-angle view imagery for high-accuracy SST (at least one am spacecraft)
10. Particle detection and/or electron density (at least am and pm)
11. Magnetic field (at least am and pm)
12. Solar activity (at least two)
13. Data collection

**III. Other LEO missions**

The following missions **shall** be performed on an operational basis by Low Earth Orbit satellites on appropriate orbits:

1. Ocean surface topography by radar altimetry (A reference mission on high-precision, inclined orbit, complementing two instruments on sun-synchronous am and pm orbit)
2. Radio-Occultation sounding (dedicated constellation of sensors on appropriate orbits)

**IV. Contingency Planning**

The CGMS baseline is associated with contingency plans for geostationary and polar-orbiting satellite systems, which are detailed in the CGMS Global Contingency Plan[[5]](#footnote-5).

**V. Inter-calibration**

Instruments should be inter-calibrated on a routine basis against reference instruments or calibration sites. The routine and operational inter-calibration and corrections **shall** be performed in accordance with standards as agreed by the Global Space-based Inter-calibration System (GSICS).

**VI. Data availability and dissemination**

VI.1. Data open availability with suitable timeliness

All operational environmental observation satellite systems should be designed to ensure the provision of data with suitable timeliness, as appropriate for their intended applications. Data should be preserved for the long term and documented with metadata allowing their interpretation and utilization. The satellite operators should establish dissemination contents and schedules that take into account the data requirements of users. Re-broadcast via telecommunication satellites should complement and supplement direct broadcast services, which allows cost-efficient access to integrated data streams including data from different satellites, non-satellite data and geophysical products. The dissemination systems should utilize all-weather resilient telecommunication means.

VI.2. Direct broadcast for core meteorological missions in LEO

The core meteorological satellite systems in LEO orbits, and other operational observation satellite systems when relevant, should ensure near real-time data dissemination of imagery, sounding, and other real-time data of interest to Members by direct broadcast. Direct broadcast frequencies, modulations, and formats for polar-orbiting satellites should allow a particular user to acquire data from either satellite by a single antenna and signal processing hardware. Direct Broadcast should use allocations in all-weather resilient frequency bands.

**VII. Note**

The present update of the CGMS baseline is adopted in the light of satellite mission plans as they are known in October 2011.

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**5 ATTRIBUTES SPECIFIC TO THE GLOBAL OBSERVING SYSTEM OF THE WORLD WEATHER WATCH**

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

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

Guide to the Global Observing System (WMO-No. 488);

**6 ATTRIBUTES SPECIFIC TO THE OBSERVING COMPONENT OF THE GLOBAL ATMOSPHERE WATCH**

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

**6.1. Requirements**

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

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

Note 1: 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. The RRR process is described in section 2.2.4 and Appendix 2.3.

Note 2: Scientific Advisory Groups exist for the six GAW focal areas and their terms of reference are defined by the Commission for Atmospheric Sciences.

6.1.3 Members should follow the Data Quality Objectives specified by the GAW Programme for the individual variables observed.

6.1.4 Members should establish and operate their GAW stations such that they satisfy the station requirements specified in Attachment 6.1.

6.1.5 Members operating GAW stations **shall** undertake long-term and uninterrupted operation with stability and continuity of data collection that is adequate for purpose outlined in 6.2.1.

**6.2. Design, Planning and Evolution**

6.2.1 Members should design, plan and further evolve their GAW observing network and stations to address the user requirements and, in particular those that concern key environmental issues and application areas, including but not limited to 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 reactive gases, and aerosols.

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

6.2.2 Members should contribute observations through operating or supporting suitable platforms at GAW stations and/or through contributing networks.

6.2.3 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.

6.2.4 Members operating a contributing network **shall** provide a description of the network and register the stations in GAWSIS and provide corresponding metadata.

6.2.5 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 in section 6.2.1.

**6.3. Instrumentation and Methods of Observation**

**6.3.1 General requirements of Instruments**

6.3.1.1 Members should use recommended types of instruments or methods of observation for variables observed at their stations, and follow further guidance available.

Note 1: Guidance is provided in the Standard Operating Procedures (SOPs) and Measurement Guidelines (MG).

Note 2: Instruments suitable for use at GAW sites are defined by the Scientific Advisory Groups for each parameter, in terms of stability, precision and accuracy.

Note 3: SOP describe the standard approach to operate this kind of instrument.

Note 4: MG describe the standard approach for this kind of measurement regardless of the instrument.

**6.3.2 Calibration and Traceability**

6.3.2.1 Members **shall** perform calibrations and maintain traceability to the GAW primary standards, where available.

Note 1: GAW primary standard is a single network standard, assigned by WMO. In the case of contributing networks the network observations are traceable to the network standard, which in turn is traceable to GAW primary standard.

Note 2: Details on calibrations are specified by the Standard Operating Procedures and Measurement Guidelines.

6.3.2.2 Members should utilize GAW central facilities to sustain the global compatibility of observations.

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

**6.4. Operations**

**6.4.1 Observing system implementation monitoring**

6.4.1.1 Members **shall** monitor the operation of GAW stations for which they are responsible and ensure that they follow the relevant procedures for quality assurance and data submission. Members **shall** 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 GAW are determined within the Commission for Atmospheric Sciences (CAS) in consultation with the participating Members.

6.4.1.2 Members should systematically monitor compliance with GAW regulations, 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.

**6.4.2 Quality Assurance**

6.4.2.1 Members should follow specified quality assurance practices and procedures.

Note: Details are given in the GAW Standard Operational Procedures and Measurement Guidelines, and further documents provided by the Scientific Advisory Groups and Central Facilities.

6.4.2.2 Members **shall** maintain detailed metadata records in accordance with procedures and practices specified in this Manual.

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

6.4.2.4 Members **shall** permit World Data Centres to perform independent evaluation of the data quality of their observations.

**6.4.3 Data and Metadata representation and format**

6.4.3.1 Members **shall** submit their observational data and associated metadata to the relevant GAW World Data Centres for the variables observed at the station within agreed time limits.

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

**6.5. Observational Metadata**

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

6.5.1 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.

6.5.2 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.

**6.6. Quality Management**

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

**6.7. Capacity Development**

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

6.7.1 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 Scientific Advisory Group (SAGs).

6.7.2 Members should use the GAW Training and Education Centre (GAWTEC) programme, as available for capacity building and staff training in measurement of the specific GAW variables.

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**ATTACHMENT 6.1**

**General requirements for GAW stations**

**Essential characteristics of GAW Regional Stations**:

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, and 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, typically 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 recommended to be made with known quality.

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 essential characteristics of Regional 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. 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 Networks**

GAW contributing networks involve observations from multiple stations. The stations comprising contributing networks 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 standards different from the WMO standards, 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. A station designation of global or regional, if it already exists for individual stations, always takes precedence. To be used in global assessments data from the contributing stations must be submitted to the GAW World Data Centres.

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**7. ATTRIBUTES SPECIFIC TO THE WMO HYDROLOGICAL OBSERVING SYSTEM**

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

**7.1 Requirements**

7.1.1 Members **shall** establish and operate a hydrological observing system according to its national requirements.

7.1.2 Members should also operate their hydrological observing systems to address the requirements of the RRR process, in particular 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 the *Technical Regulations*, Volume I, Part II and the *Manual on WMO Information System* (WMO-No. 1060) and the *Manual on Global Telecommunication System* (WMO-No. 386), Volume I.

7.1.3 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.

7.1.4 Members should also provide additional hydrological data and products where available, which are required by WMO Programmes and its Members as specified in 7.1.2.

7.1.5 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 making such observations publically available on the Internet.

7.1.6 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.

**7.2 Design, planning and evolution**

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

7.2.1 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 2.2.4.

**7.3 Instrumentation and Methods of Observation**

**7.3.1 General Requirements of Instruments**

7.3.1.1 Members should equip their 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 address the needs of hydrology and other applications areas.

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.

7.3.1.2 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.

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

Note: 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.

7.3.2.1 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 1: 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.

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.

7.3.2.2 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.

**7.3.3 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.

7.3.3.1 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* (WMO-No. 168), Volume I, and the *Manual on Stream Gauging* (WMO-No. 1044).

**7.4 Operations**

**7.4.1 Observing Practices**

7.4.1.1 Members should collect and preserve their hydrological records.

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

7.4.1.3 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.

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

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

7.4.1.6 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.

7.4.1.7 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.

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

7.4.1.9 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.

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

**7.4.2 Quality Control**

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

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

7.4.2.3 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.

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

7.4.2.5 With accelerating developments in technology, Members should ensure that data-processing and quality control systems are well-organized and that the relevant staff are trained to understand and use them.

Note: 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.

7.4.2.6 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.

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

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

**7.4.3 Observations and Observational Metadata Reporting**

7.4.3.1 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.

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

7.4.3.3 In order to make data globally available for real-time exchange and for discovery, access and retrieval, Members should report stage and discharge observations in compliance with WMO Information System (WIS) metadata 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 forms, are specified in the *Manual on Codes* (WMO-No. 306), Volume I).

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

**7.4.4 Incident Management**

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

**7.4.5 Change Management**

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

**7.4.6 Maintenance**

7.4.6.1 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 uncertainty 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.

7.4.6.2 Members should schedule periodical visits to the station to recalibrate the equipment or the measurement equations.

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

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

7.4.6.5 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 7.4.6.8 and 7.4.6.9.

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.

7.4.6.6 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.

7.4.6.7 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.

7.4.6.8 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.

7.4.6.9 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).

7.4.6.10 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, Members should train this person to check for these problems and communicate them to the regional or local office.

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

7.4.6.12 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.

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

(a) Upgrade site access (helipad, if necessary);

(b) Equip a temporary campsite with provisions;

(c) Store and check gauging equipment; and

(d) Flood-proof instrumentation such as stage recorders.

7.4.6.14 Following the recession of floodwaters, 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.

**7.4.7 Calibration procedures**

Note: Determination of a rating curve is described in section 7.3.2. Calibration procedures for current meters, is described in section 7.3.3.

**7.5 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 Appendix 2.4including WIGOS 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.

7.5.1 In addition to the provisions in section 2.5, Members should record, retain and make available the WIGOS observational metadata and also the additional observational metadata specified in the Appendix 2.4.

7.5.2 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 Appendix 2.4.

7.5.3 Members should collect and record additional detailed observational metadata identifying the purpose of the station in accordance with provisions in section 2.5.

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

**7.6 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.

Further guidance:

WMO-No. 1113

**7.7 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.

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

7.7.2 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.

7.7.3 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 Acoustic Doppler Current Profiler (ADCP) and mechanical current meters.

7.7.4 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.

7.7.5 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.

7.7.6 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.

Further guidance:

* WMO-No. 258; volume 2

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**8. ATTRIBUTES SPECIFIC TO THE OBSERVING COMPONENT OF THE GLOBAL CRYOSPHERIC WATCH**

Note: The provisions of sections 1, 2, 3 and 4 are common to all WIGOS component observing systems including the GCW. The further provisions of section 8 are specific to the GCW.

8.1 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 standard and recommended practices and procedures, 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 standardized core observing network, is to promote the addition of cryospheric observations taken according to GCW standard and recommended practices and procedures, guidelines and best practices, at existing sites rather than creating new sites. The development of GCW includes the development of a CryoNet Guide.

8.2 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 standard and recommended practices and procedures for cryospheric observation.

8.3 CryoNet **shall** be structured in two different classes of observational sites: Basic Sites and Integrated Sites with the following requirements:

* Basic Sites **shall** monitor single or multiple components of the cryosphere (glaciers, ice shelves, ice sheets, snow, permafrost, sea ice, river/lake ice, and solid precipitation) and **shall** observe multiple variables of each component. They **shall** measure auxiliary meteorological variables, **shall** comply with GCW agreed practices, **shall** be currently active, **shall** have long term financial commitment and **shall** make data freely available, whenever possible in (near) real time. Basic Sites should be suitable for the assessment of long-term changes of the cryosphere as well as for the validation of satellite data and related models.
* CryoNet Integrated Sites **shall** promote, through worldwide scientific collaboration, progress in the scientific understanding of the processes that change the cryosphere. These sites **shall** integrate in situ and space-based observations and create platforms of cryospheric observatories. In addition to the requirements for Basic Sites, CryoNet Integrated Sites **shall** monitor at least one of the other spheres (such as, hydrosphere, biosphere and atmosphere), have a broader research focus, have supporting staff and have training capability. Integrated Sites are particularly important for the study of feedbacks and complex interactions between the atmosphere, cryosphere, biosphere and ocean.
* CryoNet Sites contain one or more CryoNet Stations:
  + Primary Stations **shall** have target of long-term operation and a four (4) year initial commitment.
  + Baseline stations **shall** have long-term operational commitment and long-term (more than 10 years) records.

8.4 For inclusion of a GCW surface measurement site or station into CryoNet, Members and partners **shall** meet defined criteria. The minimum requirements are in Attachment 8.1.

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**ATTACHMENT 8.1**

**The minimum requirements for inclusion of a GCW surface measurement site or station in CryoNet**

1. The site location is chosen such that, for the cryospheric components measured, it is representative for the surrounding region.

2. User needs have been considered in the observation design process.

3. CryoNet sites have to be active and perform sustained observations according to CryoNet best practices. There **shall** be a commitment to continue measurements for a minimum of four (4) years.

4. Personnel are trained in the operation and maintenance of the site.

5. The responsible agencies are committed, to the extent reasonable, to sustaining long-term observations of at least one cryosphere component, including auxiliary meteorological variables.

6. The relevant CryoNet observations are of documented quality. The measurements are made and quality controlled according to CryoNet best practices.

7. Associated standard meteorological in situ observations, when necessary for the accurate determination and interpretation of the GCW variables, are made with documented quality.

8. A logbook for observations and activities that may affect observations is maintained and used in the data validation process.

9. The data and metadata including changes in instrumentation, traceability, observation procedures are submitted in a timely manner to a data centre that is interoperable with the GCW portal.

10. The station characteristics and observational programme information are kept up-to-date in the GCW station information database. Station metadata are also provided to the WIGOS Information Resource (WIR) and maintained regularly.

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1. The co-sponsored observing systems are the WMO-IOC-UNEP-ICSU Global Climate Observing System (GCOS), the WMO-IOC-UNEP-ICSU Global Ocean Observing System (GOOS) and the WMO-IOC-UNEP-ICSU Global Terrestrial Observing System (GTOS). [↑](#footnote-ref-1)
2. a suitable period of dual operations, under the same climatic conditions, of the current and new observing systems, which is adequate to identify and record any impact of the change [↑](#footnote-ref-2)
3. Ambler Thompson and Barry N. Taylor (2008), *Guide for the Use of the International System of Units (SI)* NIST Special Publication 811, 2008 Edition (version 3.0). [Online] Available: http://physics.nist.gov/SP811 [Tuesday, 29-Apr-2014 13:21:55 EDT]. National Institute of Standards and Technology, Gaithersburg, MD. [↑](#footnote-ref-3)
4. *SMART* : Specific, Measurable, Achievable, Realistic and Time-related [↑](#footnote-ref-4)
5. The Global Contingency Plan (http://www.wmo.int/pages/prog/sat/documents/CGMS\_Contingency-Plan-2007.pdf) should be updated accordingly. It should indicate that in case of potential gaps on core sun-synchronous missions, absolute priority should be given to observation from mid-morning and early afternoon orbits, in order to maintain the continuity of these datasets. [↑](#footnote-ref-5)