

Guide to the WMO Integrated Global Observing System

2019 edition

WEATHER · CLIMATE · WATER



WORLD
METEOROLOGICAL
ORGANIZATION

WMO-No. 1165

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EDITORIAL NOTE

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WMO-No. 1165

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ISBN 978-92-63-11165-4

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INTRODUCTION

General

This is the second edition of the *Guide to the WMO Integrated Global Observing System* (WMO-No. 1165). The Guide was developed following the decision of the Seventeenth World Meteorological Congress for the WMO Integrated Global Observing System (WIGOS) to proceed to a preoperational phase (2016–2019), as well as the approval by the Seventeenth Congress of the *Technical Regulations* (WMO-No. 49), Volume I, Part I, and the *Manual on the WMO Integrated Global Observing System* (WMO-No. 1160), with effect from 1 July 2016. In essence, these two publications specify what is to be observed, as well as where, when and how, in order for Members to meet the relevant observational requirements.

To complement these activities, the Seventeenth Congress requested the Secretariat of the World Meteorological Organization (WMO) to publish a set of guidelines incorporated in an initial Guide, which would be progressively revised and enhanced through the WIGOS preoperational phase. This was formalized in a decision of the WMO Executive Council at its sixty-seventh session to re-establish the Intercommission Coordination Group on the WMO Integrated Global Observing System (ICG-WIGOS), which has as one of its terms of reference to complement WIGOS regulatory material with the necessary guidance information and technical guidelines incorporated in the *Guide to the WMO Integrated Global Observing System* (WMO-No. 1165). The first edition of the Guide was approved by the Executive Council at its sixty-ninth session via Resolution 2 (EC-69) – Initial version of the Guide to the WMO Integrated Global Observing System.

The initial Guide aimed to assist Members in complying with a number of new regulations that came into effect on 1 July 2016. It was developed by the Secretariat, in particular the WIGOS Project Office, with input from technical experts of the Inter-Commission Coordination Group on WIGOS (ICG-WIGOS) task teams and the lead technical commissions (Commission for Basic Systems and Commission for Instruments and Methods of Observation).

Purpose and scope

This edition of the Guide provides material relevant to some of the new WIGOS-related regulations. The topics cover the new system of WIGOS station identifiers, the new requirements to record and make available metadata as specified in the WIGOS Metadata Standard, the new Observing Systems Capability Analysis and Review (OSCAR) tool to be used by Members to submit metadata for WMO global compilation, the new observing network design principles, national WIGOS implementation, WIGOS data partnerships, Regional WIGOS Centres, and WIGOS Data Quality Monitoring System for surface-based observations.

Future versions of this Guide will provide detailed guidance and technical guidelines on how to establish, operate and manage WIGOS component observing systems to make observations in compliance with the *Technical Regulations* (WMO-No. 49), Volume I, Part I, and the *Manual on the WMO Integrated Global Observing System* (WMO-No. 1160). These versions will explain and describe WIGOS practices, procedures and specifications and will be 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 the many other relevant WMO Guides, technical documents and related publications. For example, the *Guide to Instruments and Methods of Observation* (WMO-No. 8) is the authoritative reference for all matters related to instrumentation and methods of observation. It should be consulted for more detailed descriptions and best practices. The subsequent step of how observations are to be encoded and reported 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 Global Observing System.

Procedures for amending the Guide

A detailed explanation of the procedures for amending WMO Guides that are under the responsibility of the Commission for Basic Systems can be found in the appendix to the General Provisions of the *Manual on the WMO Integrated Global Observing System* (WMO-No. 1160).

List of related publications

The development of this Guide takes a thin-layer approach, meaning that it aims only to publish additional, new material that complements the material in existing Guides. All guidance relating to observing systems in any of the WMO Guides or Manuals is effectively WIGOS guidance material.

Here is the list of publications related to the *Guide to the WMO Integrated Global Observing System* (WMO-No. 1165). The most relevant are indicated by an asterisk (*) following the publication name. Publications are also referenced within sections of this Guide where there is a very specific point to be highlighted. All these publications are available at <http://library.wmo.int/opac/index.php>. The search can be done by filling in either the "WMO/No." or "WMO/TD-No." fields with the corresponding publication number.

- (a) *Technical Regulations* (WMO-No. 49), Volumes I–III*
- (b) Manuals:
 - (i) *Manual on Codes* (WMO-No. 306), Volumes I.1 and I.2
 - (ii) *Manual on the Global Telecommunication System* (WMO-No. 386)
 - (iii) *International Cloud Atlas* (WMO-No. 407)
 - (iv) *Manual on the WMO Information System* (WMO-No. 1060)
 - (v) *Manual on the WMO Integrated Global Observing System* (WMO-No. 1160)*
- (c) Guides:
 - (i) *Guide to Instruments and Methods of Observation* (WMO-No. 8)*
 - (ii) *Guide to Climatological Practices* (WMO-No. 100)*
 - (iii) *Guide to Agricultural Meteorological Practices* (WMO-No. 134)
 - (iv) *Guide to Hydrological Practices* (WMO-No. 168), Volume I*
 - (v) *Guide on the Global Data-processing System* (WMO-No. 305)
 - (vi) *Guide to the Global Observing System* (WMO-No. 488)*
 - (vii) *Guide to the Quality Management System for the Provision of Meteorological Service for International Air Navigation* (WMO-No. 1001)
 - (viii) *Guide to the Implementation of a Quality Management System for National Meteorological and Hydrological Services* (WMO-No. 1100)
 - (ix) *Guide to the WMO Information System* (WMO-No. 1061)
 - (x) *Guide to the Implementation of Education and Training Standards in Meteorology and Hydrology* (WMO-No. 1083), Volume I

- (xi) *Guide to Aircraft-based Observations* (WMO-No. 1200)
 - (d) Technical documents/technical notes:
 - (i) *Baseline Surface Radiation Network (BSRN), Operations Manual*, World Climate Research Programme Publication Series No. 121 (WMO/TD-No. 1274)
 - (ii) *Guide to the GCOS Surface Network (GSN) and GCOS Upper-air Network (GUAN)*, GCOS Report No. 144 (WMO/TD-No. 1558; 2010 update of GCOS-73)
 - (iii) *International Meteorological Tables* (WMO-No. 188, TP 94)*
 - (iv) *Manual on Sea Level Measurement and Interpretation*, JCOMM Technical Report No. 31 (WMO/TD-No. 1339), Volume IV
 - (v) *Note on the Standardization of Pressure Reduction Methods in the International Network of Synoptic Stations*, Technical Note No. 61 (WMO-No. 154, TP 74)
 - (vi) *WMO Global Atmosphere Watch (GAW) Implementation Plan: 2016–2023*, GAW Report No. 228*
 - (e) Guidelines and other related publications:
 - (i) *WIGOS Metadata Standard* (WMO-No. 1192)
 - (ii) *Technical Guidelines for Regional WIGOS Centres on the WIGOS Data Quality Monitoring System* (WMO-No. 1224)
 - (iii) *Aircraft Meteorological Data Relay (AMDAR) Reference Manual* (WMO-No. 958)
 - (iv) GAW reports
 - (v) *The GCOS Reference Upper-air Network (GRUAN) – Manual*, WIGOS Technical Report No. 2013-02, GCOS Report No. 170
 - (vi) *The GCOS Reference Upper-air Network (GRUAN) – Guide*, WIGOS Technical Report No. 2013-03, GCOS Report No. 171
 - (vii) Hydrology and Water Resources Programme (HWRP) manuals
 - (viii) JCOMM catalogue of practices and standards (WMO Manuals and Guides, and observation standards, such as manuals and guides of the Intergovernmental Oceanographic Commission)
 - (ix) Marine Meteorology and Oceanography Programme publications and documents
 - (x) *Sixth WMO Long-term Plan (2004–2011)* (WMO-No. 962)
-

1. INTRODUCTION TO THE WMO INTEGRATED GLOBAL OBSERVING SYSTEM

1.1 PURPOSE AND SCOPE

It is specified in the *Technical Regulations* (WMO-No. 49), Volume I, Part I, and the *Manual on the WMO Integrated Global Observing System* (WMO-No. 1160) that the WMO Integrated Global Observing System is a framework for all WMO observing systems and for WMO contributions to co-sponsored observing systems in support of WMO Programmes and activities.

1.2 WIGOS COMPONENT OBSERVING SYSTEMS

The component observing systems of WIGOS are the Global Observing System of the World Weather Watch Programme, the observing component of the Global Atmosphere Watch Programme, the WMO Hydrological Observing System of the Hydrology and Water Resources Programme and the observing component of the Global Cryosphere Watch, including their surface-based and space-based networks.

The above component systems include all WMO contributions to the co-sponsored systems, to the Global Framework for Climate Services and to the Global Earth Observation System of Systems. The co-sponsored observing systems are the Global Climate Observing System and the Global Ocean Observing System, both joint undertakings of WMO and the Intergovernmental Oceanographic Commission of the United Nations Educational, Scientific and Cultural Organization, the United Nations Environment Programme and the International Science Council.

1.3 GOVERNANCE AND MANAGEMENT

Implementation and operation of WIGOS

The implementation of WIGOS is an integrating activity for all WMO and co-sponsored observing systems: it supports all WMO Programmes and activities. The Executive Council and regional associations, supported by their respective working bodies, have a governing role in the implementation of WIGOS. Technical aspects of WIGOS implementation are guided by the technical commissions, with leadership provided through the Commission for Basic Systems and the Commission for Instruments and Methods of Observation.

The WIGOS framework implementation phase occurred in the period 2012–2015. Implementation plans and activities followed a structure based on ten key activity areas which are listed below and represented schematically in Figure 1.1:

- (a) Management of WIGOS implementation;
- (b) Collaboration with the WMO co-sponsored observing systems and international partner organizations and programmes;
- (c) Design, planning and optimized evolution;
- (d) Observing system operation and maintenance;
- (e) Quality management;

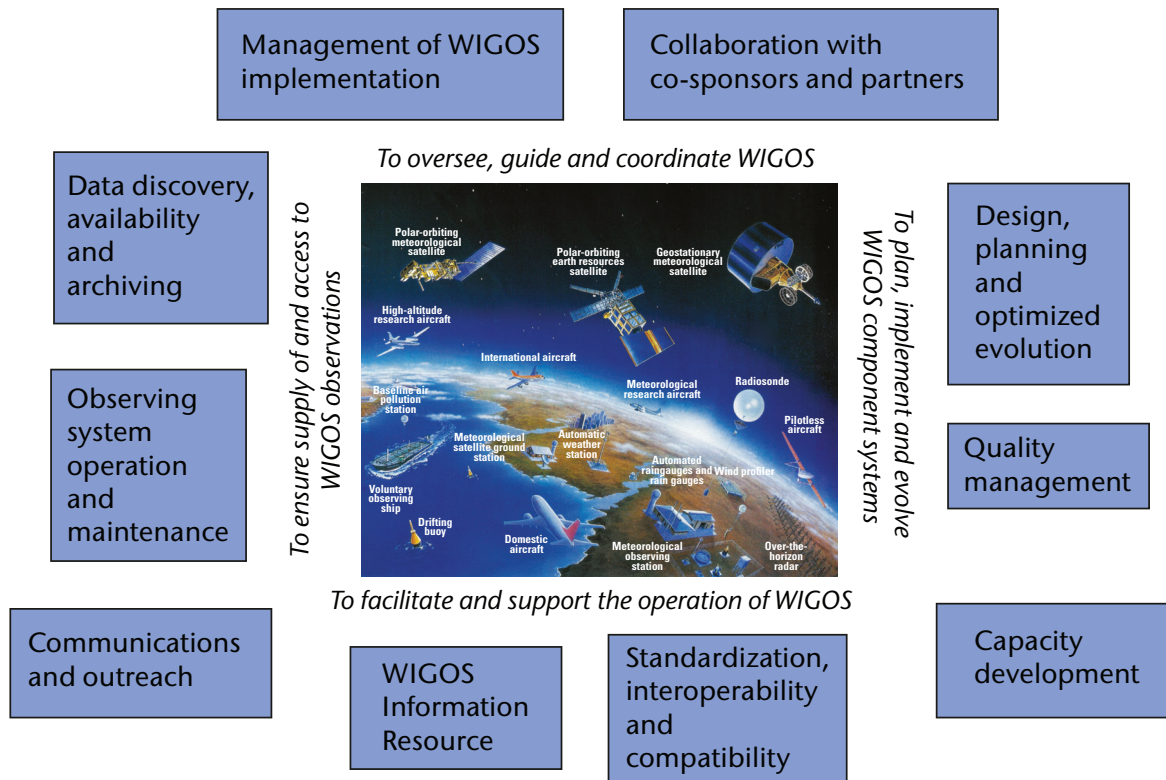


Figure 1.1. Ten key activity areas for the WIGOS framework implementation and how they relate

- (f) Standardization, interoperability and data compatibility;
- (g) The WIGOS Information Resource;
- (h) Data discovery, availability (of data and metadata) and archiving;
- (i) Capacity development;
- (j) Communications and outreach.

Building on the WIGOS framework, the five priority areas of the WIGOS preoperational phase, which support the delivery of the WMO strategic priorities, are being addressed in the period 2016–2019. The five priority areas are listed below and are represented schematically in Figure 1.2:

- (a) National WIGOS implementation;
- (b) WIGOS regulatory and guidance material;
- (c) WIGOS Information Resource;
- (d) WIGOS Data Quality Monitoring System;
- (e) Regional WIGOS centres.

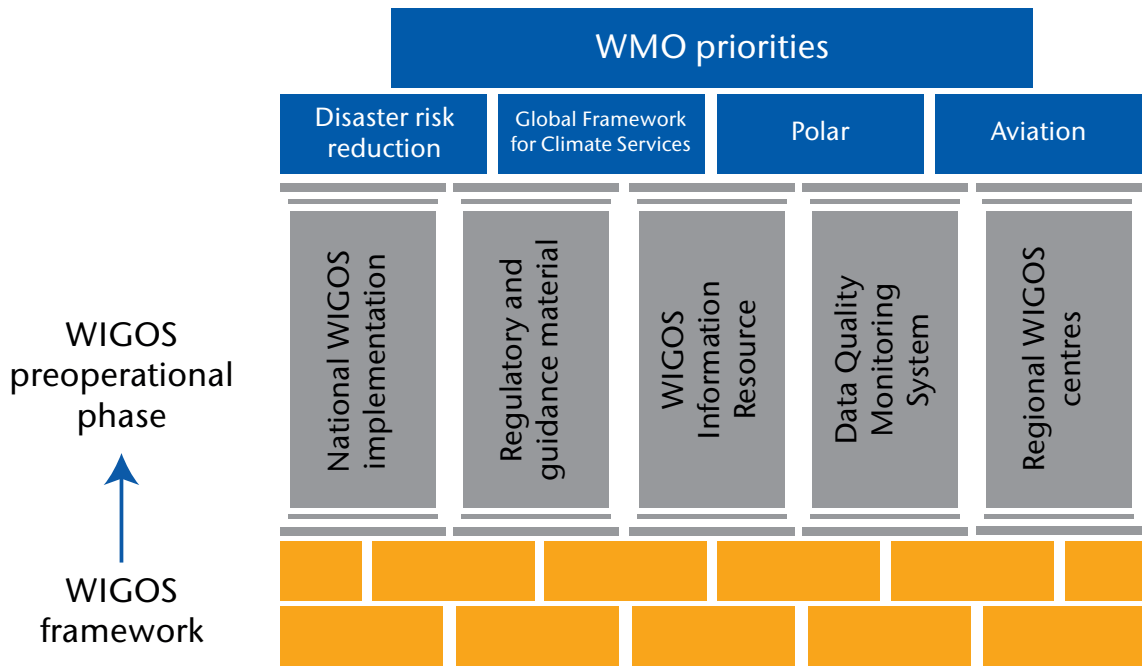


Figure 1.2. The five priority areas of the WIGOS preoperational phase

2. WIGOS STATION IDENTIFIERS

2.1 FUNDAMENTALS

2.1.1 System of WIGOS identifiers

The system of WIGOS identifiers¹ is defined in the *Manual on the WMO Integrated Global Observing System* (WMO-No. 1160), Attachment 2.1.

Each observing station must have at least one WIGOS station identifier. The station identifier(s) link(s) the station to its WIGOS metadata.

The structure of a WIGOS identifier is:

WIGOS identifier series (number)	Issuer of identifier (number)	Issue number (number)	Local identifier (characters)
-------------------------------------	----------------------------------	--------------------------	----------------------------------

Only the WIGOS identifier series 0 has been defined. This series is used to identify observing stations.

2.1.2 Advice for users of WIGOS identifiers

WIGOS identifiers do not have meaning in themselves. Users must not interpret any patterns they see in these identifiers; for WIGOS station identifiers, users should use [OSCAR/Surface](#) to look up the metadata for the station associated with the identifier.

2.1.3 Recording the WIGOS station identifier in observation reports (in the standard WMO reporting formats)

WIGOS station identifiers cannot be represented in the traditional alphanumeric code forms, such as FM-12 SYNOP or FM-35 TEMP. The Table Driven Code Form equivalents have to be used (FM-94 BUFR or FM-95 CREX, or, in the future, model driven code forms). Further information on representing the WIGOS station identifier in BUFR/CREX is available in [section 2.2](#).

Centres that are unable to process Table Driven Code Forms will not be able to access the reports from stations that only have WIGOS station identifiers.

2.1.4 Advice for people responsible for allocating WIGOS identifiers

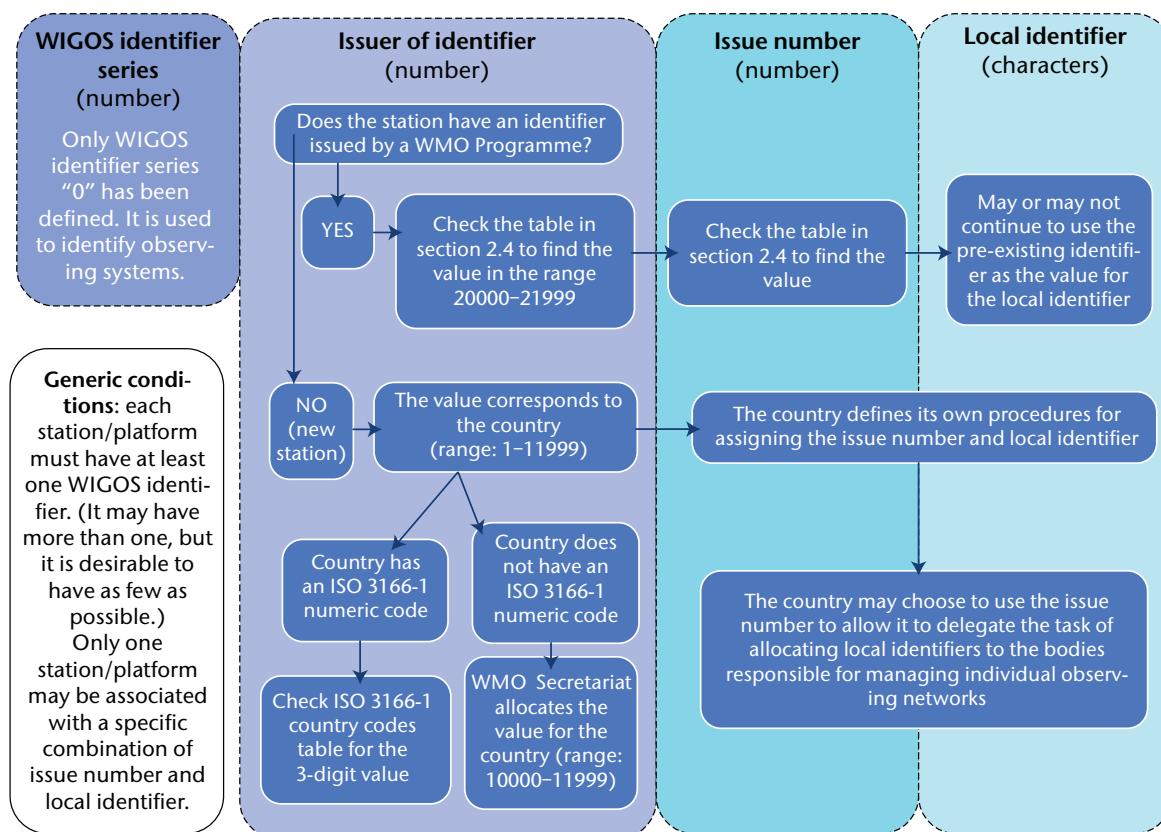
As mentioned above, all observing stations must be associated with at least one WIGOS station identifier. A WIGOS station identifier can only be associated with one observing station. If you need additional help after reading this guidance, please contact the Secretariat at wigos-help@wmo.int.

2.1.5 Assigning WIGOS identifiers to observing stations

The process for allocating a WIGOS station identifier is illustrated in the figure in this section.

Observing stations that had been allocated identifiers by a WMO Programme before the introduction of WIGOS station identifiers (that is, before 1 July 2016) may continue to use those

¹ The expression “WIGOS identifiers” is used in this chapter as an abbreviation of “WIGOS station identifiers”.



Outline of procedure for allocating a WIGOS station identifier

identifiers and are not required to have additional ones created for them. For these observing facilities, the WIGOS station identifier can be deduced from the pre-existing identifier using the tables below. Further, should the station take on new responsibilities (such as an aviation station starting to report World Weather Watch synoptic information), the WIGOS identifier can also be used in that new context, even though it was derived from a station identifier associated with a different programme (in this example, the synoptic report could use the WIGOS station identifier derived from the [International Civil Aviation Organization \(ICAO\) location indicator](#)²).

Although an observing station can have more than one WIGOS station identifier, it is desirable to associate as few identifiers as possible with one station. Therefore, if an observing station is already associated with a WIGOS identifier, or is associated with an identifier issued by a WMO or partner programme, an additional WIGOS station identifier should not be issued.

A Member for which there is an ISO 3166-1 numeric country code can assign its country code as the issuer of identifier value for its newly established observing stations. For example, the Korea Meteorological Administration can use "410" as the issuer of identifier number. This structure provides for an open range of station numbers that can be defined and allocated by the Republic of Korea to its expanding network (i.e. 0-410-0-XXXX).

Table 2.1 lists the issuer of identifier values that have been allocated for use for observing stations.

² The location indicators and their meanings are published in ICAO Location Indicators (Doc 7910).

Table 2.1. Issuer of identifier values allocated for observing stations

<i>Range</i>	<i>Category of issuer</i>	<i>Allocation method</i>	<i>Procedures for assigning issue number and local identifier</i>
0	Reserved for internal use by OSCAR	OSCAR allocates the value	Determined by OSCAR
1–9999	Member State or Territory for which there is an ISO 3166-1 numeric country code	Use of ISO 3166-1 three-digit numeric country code (by convention, leading zeroes are not shown in WIGOS identifiers). See the ISO website .	Issuer determines its own procedures. Further guidance is available in section 2.3 .
10000–11999	Member State or Territory for which there is no ISO 3166-1 numeric country code	WMO Secretariat allocates an available number on request	Issuer determines its own procedures. Further guidance is available in section 2.3 .
12000–19999	Reserved for future use	To be determined	To be determined
	<i>Identifiers in the ranges 20000–21999 and 22000–39999 are intended to be used only to allocate WIGOS identifiers to observing facilities that have one or more pre-existing identifiers.</i>		
20000–21999	WMO Secretariat for identifiers associated with WMO Programmes	Details are provided in section 2.4 .	Details are provided in section 2.4 .
22000–39999	WMO Secretariat for identifiers associated with programmes of partner organizations	Details are provided in section 2.5 .	Details are provided in section 2.5 .
40000–65534	Reserved for future use	To be determined	To be determined
65535	Missing value (reserved value in Table Driven Code Forms)		

2.2 WIGOS-ID-BUFR

This section explains how to represent the WIGOS station identifier in WMO standard code forms.

2.2.1 Reducing ambiguity through systematic use of WIGOS station identifiers

An observing facility may have several WIGOS station identifiers. Using OSCAR, it is possible to discover all the WIGOS station identifiers associated with that facility. In theory, this allows any of the possible WIGOS identifiers to be used in a report of an observation, but in practice, doing so would result in a lot of additional work for all users of the observation. A disciplined approach to using WIGOS station identifiers in a report will reduce the work for end-users.

2.2.2 Choosing which WIGOS station identifier to use

The following practices will make it easier for users of observation reports to link observations from a single observing facility:

- (a) Use the same WIGOS identifier for all reports of the same type from that observing facility. *For example, always use the same identifier for surface synoptic reports;*
- (b) If there is one, use the WMO Programme station identifier that is associated with the type of observation being reported to derive the WIGOS station identifier. *For example, a WIGOS station identifier associated with the World Weather Watch land-station identifier would be used for surface synoptic reports;*
- (c) There is no requirement to introduce new WIGOS station identifiers if the observing facility already has one. *For example, whatever type of observation is reported, if the facility has a WIGOS identifier derived from a World Weather Watch station identifier, then that WIGOS identifier may be used for reporting any type of observation. However, following practice (a) above, different types of reports might use different pre-existing identifiers.*

2.2.3 **Messages containing only reports from stations that have a pre-existing station identifier for the type of report being exchanged**

In many cases, such as for surface observations from World Weather Watch land stations that existed before the introduction of WIGOS station identifiers, no change is needed to report from those stations in BUFR or CREX. The existing identifier should be reported as in the past.

Nevertheless, it is good practice also to report the derived WIGOS station identifier.

2.2.4 **Messages containing reports from stations that do not have a pre-existing station identifier for the type of report being exchanged**

New observing facilities, or those reporting new types of observations, will need to report the full WIGOS station identifier. BUFR and CREX messages that include reports from stations that do not have a pre-existing station identifier appropriate to that type of report have to include the BUFR/CREX sequence 3 01 150 to represent the WIGOS station identifier.

If there is no pre-existing identifier, the value for the station identifier in the standard BUFR/CREX sequence should be set to the value representing "missing".

2.2.5 **Reporting the WIGOS station identifier in a BUFR/CREX message**

When constructing a BUFR or CREX message that refers to WIGOS station identifiers, the sequence 3 01 150 must appear in the message before the sequence describing the information from those stations.

That is, the message contents should be in the order:

< sequence for the WIGOS station identifier (3 01 150)>
< sequence for the data being reported>

2.2.6 **Reporting the WIGOS station identifier when the reporting environment can only handle traditional alphanumeric codes**

Traditional alphanumeric code forms cannot represent WIGOS station identifiers. Furthermore, observations can only be exchanged in traditional alphanumeric code if the observing facility has been allocated a conventional World Weather Watch station identifier. Observation facilities that have not been allocated a World Weather Watch station identifier must exchange their observations using the Table Driven Code Forms.

In some circumstances, however, it may be necessary to report observations internationally from stations that do not have a pre-existing World Weather Watch station identifier and for which the technical environment only supports the traditional alphanumeric codes.

The recommended approach in this case is to agree on a national practice that meets the local technical constraints to identify the observing station in reports (or a bilateral practice where an arrangement is made to translate traditional alphanumeric code to Table Driven Code Format for international exchange). These national reports must be converted to Table Driven Code Format before the international exchange; the conversion must include a translation from the method of identifying the station used in the national report to the WIGOS station identifier for that station. Extreme care must be taken to ensure that the national report is not distributed internationally.

Examples of a possible national practice for a surface synoptic report might be to use five alphabetic characters for the identifier, or a numeric identifier in the range 99000 to 99999 (only two identifiers in that range, 99020 and 99090, were recorded in Weather Reporting (WMO-No. 9), Volume A, in April 2016). A look-up table from that identifier to the WIGOS station identifier would allow the translating centre to insert the WIGOS station identifier.

The situation is more complex for upper-air reports. In this case, the WMO Secretariat should be asked for assistance.

2.3 WIGOS-ID-COUNTRY

This section provides recommended practices for the allocation of issue number and local identifier for Member States and Territories.

2.3.1 Principles for allocating station identifiers

- (a) Issuers of identifiers are responsible for guaranteeing that no two observing facilities share the same station identifier. Note that the structure of WIGOS station identifiers guarantees that issuers cannot create identifiers that have already been allocated by another issuer.
 - (i) Issuers of identifiers may choose to use the issue number to allow them to delegate the task of allocating local identifiers to other organizations responsible for managing individual observing networks. Assigning each organization a different issue number will allow those organizations to allocate local identifiers for their observing facilities.
 - (ii) The issuer of identifiers has to record which issue numbers have been allocated and which organization is responsible for managing local identifiers for each.
- (b) An organization issuing local identifiers (and issue numbers if it has not had one assigned to it) must ensure that no two observing facilities share the same WIGOS station identifier.
 - (i) When issuing the local identifier:
 - a. If the organization is responsible for allocating both issue numbers and local identifiers, it must ensure that no two observing facilities have the same combination of issue number and local identifier.
 - b. If the organization is only responsible for allocating local identifiers then it is sufficient for it to ensure that it does not assign the same local identifier to more than one observing facility.
 - (ii) The organization must maintain a record of the local identifiers (and issue numbers) it has allocated (it may choose to use OSCAR for this).

- a. The organization may choose to use an existing national identifier as the local identifier for the observing facility. Doing so in a systematic way may decrease its administrative load.
 - b. Historically, station identifiers may have been reused when observing facilities closed and new ones opened. If the organization has been allocated a range of issue numbers, it may wish to consider using different issue numbers to distinguish between the different locations, allowing the local identifier to retain the link to the other location.
 - c. Although a single WIGOS station identifier must not be issued to more than one observing facility, it is permitted for a station to have more than one WIGOS station identifier. For example, although all observing facilities with pre-existing World Weather Watch station identifiers have a WIGOS station identifier based on the World Weather Watch identifier, the organization may wish to create a new identifier that is linked to a national numbering scheme.
 - d. The WIGOS station identifier for a closed observing facility must not be reused unless the observing facility reopens.
- (iii) The organization responsible for allocating the WIGOS station identifier should ensure that the operator of the observing facility has committed to providing and maintaining WIGOS metadata for that facility.
- a. In cases where a station has more than one WIGOS station identifier, the organization issuing the local identifier should associate all these station identifiers with the same WIGOS metadata record so that only one WIGOS metadata record needs to be maintained. OSCAR will provide tools to document this linkage.
 - b. If a fixed observing facility is moved, the organization should consider whether it should be issued a new WIGOS station identifier, whether the WIGOS metadata should be updated to state that the observing facility at the previous position has closed and whether a new WIGOS metadata record should be created for the new location. The organization must use meteorological judgement on the impacts of the change in deciding whether to retain the WIGOS station identifier or to issue a new one. A move of a few metres is unlikely to be significant, but a move to the opposite side of a mountain would be treated as a new station.

Note: The structure of the WIGOS station identifier means that the range of WIGOS station identifiers is, for practical purposes, unlimited. This removes the need to reuse WIGOS station identifiers.

- (c) Before issuing a station identifier, search [OSCAR/Surface](#) to make sure that it has not already been allocated.
- (d) Organizations are strongly advised to document their procedures for allocating WIGOS station identifiers in their quality management system.

2.3.2 Specifying the local identifier

The local identifier may be up to 16 characters long. It must not contain or be preceded by blanks, and any blanks added to the end of the identifier by IT systems must be ignored.

The local identifier may contain only alphanumeric characters. These are a set of 62 characters including all the uppercase and lowercase letters from a to z and all the digits from 0 to 9. Symbols and special characters are not allowed in the set of alphanumeric characters to be used for the local identifier.

Leading zeroes in a local identifier are significant and must be treated as part of the character string. (Note that this differs from the treatment of leading zeroes in the issuer of identifier and issue number parts of the WIGOS identifier, which are omitted from the WIGOS station identifier.)

Example 1

- (a) Consider a Member that has observing systems managed by many different organizations, including the National Meteorological Service (NMS), the National Hydrological Service (NHS) and the National Transport Department. Each of these organizations is independent, and each has its existing conventions for labelling observing facilities. For example, the Meteorological Service uses WMO World Weather Watch station identifiers for its synoptic network, its own numbering system for other weather observing facilities, and another numbering system for its climate observing facilities.
- (b) In this situation, the Member (as an issuer of identifiers) might choose to use the following convention for assigning WIGOS station identifiers. In all cases, if an observing facility is closed its local identifier must not be re-attributed (with the same issue number).

Issue number	Interpretation of issue number	Local identifier
1	NMS synoptic observing facility	WMO World Weather Watch station identifier (with leading zeroes if necessary to make it five characters long). Initially, to ensure that plotting software can display local identifiers, the Member chooses to limit their length to five characters and to assign to new WIGOS stations identifiers that lie outside the block of identifiers allocated to the Member by the World Weather Watch.
2	NMS other weather observing facility	Existing national station identifier (with leading zeroes if necessary). The local identifier for a new observing facility is created using the existing procedures for national station identifiers.
3	NMS climate observing facility	Existing climate station identifier (without leading zeroes, as that was the convention for climate observing facility identifiers in the past). New observing facilities are allocated identifiers using the existing practices.
100–200	Used by NHS for allocating identifiers for its observing facilities. The NHS allocates one number to each of its regions. The NHS is organized according to river basins, and it uses its range of issue numbers to subdelegate the allocation of local identifiers to each river basin authority.	The NHS uses its existing river basin observing facility numbering system.

1000–10000	Used by the National Transport Department for allocating its observing facility identifiers. Each road has its own issue number.	Derived from the distance of travel along a road when travelling away from the national capital before reaching the observing facility.
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Example 2

- (a) A Member has implemented a national system for managing its national assets. Each observing facility has to be registered on this system and as a consequence has been allocated an asset number used to track all information about the facility. Some of these assets are mobile platforms (such as moored buoys). Disposable observing platforms (such as radiosondes) are associated with the asset number of their base station.
- (b) The Member wishes to align its WIGOS station identifiers with its national asset management system. It chooses to use the national asset number as the local identifier. The Member is concerned that it may move assets from one location to another. In consequence, the Member uses the issue number to record changes in location. Because it wishes to record past positions as well, it decides initially to use an issue number of 10000 and to increment it for an asset every time that asset is re-deployed. It uses issue numbers less than 10000 to record historical positions for that asset. By doing this, the Member ensures that the asset number will not result in misleading WIGOS metadata histories and the link to the asset number will be maintained.

2.4 WIGOS-ID-WMOPROG

This section explains how to allocate issuers of identifiers for station identifiers associated with WMO Programmes.

2.4.1 Observing Programmes with an international system for assigning station identifiers

Table 2.2 defines the issuer of identifier values in the range 20000–21999 to be used for WIGOS station identifiers. This range is used to ensure that observing facilities that have pre-existing station identifiers can be allocated a WIGOS station identifier in a way that retains an association with the pre-existing identifier. Any new observing facility will be given an identifier within the range allocated to the Member operating the observing facility. The most up-to-date version of Table 2.2 can be found at <http://wis.wmo.int/WIGOSIdProgramme>.

Table 2.2. Issuer of identifier values in the range 20000–21999

<i>Issuer of identifier values</i>	<i>Category of station identifier</i>	<i>Issue number</i>	<i>Local identifier</i>
20000	World Weather Watch land station with sub-index number (SI) = 0	0: station defined in <i>Weather Reporting</i> (WMO-No. 9), Volume A, on 1 July 2016 Any other positive number: to distinguish between different observing facilities that used the same station identifier in the past	Use the block number II, and the station number iii, as a single five-digit number IIIii (with leading zeroes). <i>Example:</i> station 60351 would be represented by 0-20000-0-60351

<i>Issuer of identifier values</i>	<i>Category of station identifier</i>	<i>Issue number</i>	<i>Local identifier</i>
20001	World Weather Watch land station with sub-index number (SI) = 1	0: station defined in <i>Weather Reporting</i> , Volume A, on 1 July 2016 Any other positive number: to distinguish between different observing facilities that used the same station identifier in the past	Use the block number II, and the station number iii, as a single five-digit number Iliii (with leading zeroes). <i>Example:</i> upper-air station 57816 would be represented by 0-20001-0-57816
20002	World Weather Watch marine platform (moored or drifting buoy, platform, etc.)	0: platform for which the identifier was in use on 1 July 2016 Any other positive number: to distinguish between different platforms that used the same identifier at different times	Use the region/platform number combination $A_1b_w n_b n_b n_b$. <i>Examples:</i> The data buoy 59091 would be represented by 0-20002-0-59091 The World Weather Watch list of data buoys has two buoys with identifier 13001. The buoy most recently used at the time WIGOS station identifiers were introduced is allocated 0-20002-0-13001 and the second is issued identifier 0-20002-1-13001.
20003	Ship identifier based on the International Telecommunication Union call sign	0: ship to which the identifier was most recently allocated on 1 July 2016 Any other positive number: to distinguish between different ships that used the same ship identifier at different times	Ship call sign <i>Example:</i> the (now obsolete) weather ship C7R would be represented by 0-20003-0-C7R
20004	Ship identifier – issued nationally	0: ship to which the identifier was most recently allocated on 1 July 2016 Any other positive number: to distinguish between different ships that used the same ship identifier at different times	Ship identifier <i>Example:</i> the fictitious ship XY123AB would be represented by 0-20004-0-XY123AB
20005	AMDAR aircraft identifier	0: aircraft to which the identifier was most recently issued on 1 July 2016 Any other number: to distinguish between different aircraft that used the same aircraft identifier at different times	Aircraft identifier <i>Example:</i> aircraft EU0246 would be represented by 0-20005-0-EU0246

<i>Issuer of identifier values</i>	<i>Category of station identifier</i>	<i>Issue number</i>	<i>Local identifier</i>
20006	ICAO airfield identifiers	0: airfield to which the identifier was most recently allocated on 1 July 2016 Any other positive number: to distinguish between airfields that used the same airfield identifier at different times	ICAO airfield identifier <i>Example:</i> Geneva airport (LSGG) would be represented by 0-20006-0-LSGG
20007	International Maritime Organization (IMO) ship number (hull number)	0: ship to which the IMO number was most recently allocated on 1 July 2016 Any other positive number: to distinguish between ships that used the same IMO identifier at different times	Ship identifier <i>Example:</i> ship 9631369 would be represented by 0-20007-0-9631369
20008	Global Atmosphere Watch (GAW) identifier	0: station to which the GAW identifier was most recently allocated on 1 July 2016	Three-character GAW identifier <i>Example:</i> Jungfrauoch JFJ would be represented by 0-20008-0-JFJ
20009	WMO Satellite Programme	0	Three-digit satellite identifier with leading zeroes (recorded in Common Code table C-5 of the <i>Manual on Codes</i> (WMO-No. 306), Volume I.1) <i>Example:</i> METEOSAT 10 (with identifier 057) would be represented by 0-20009-0-057
20010	WMO Weather Radar	0	Unique key used to cross-reference information about a single radar within the WMO Radar Database (this key was not previously published) <i>Example:</i> Station with record number 121 would be represented by 0-20010-0-121
20011–21999	Reserved for future use	To be determined	To be determined

2.4.2 **Observing programmes/networks that do not have an international system for station identification**

The following observing programmes/networks do not have a pre-existing international system for assigning station identifiers and have not been allocated issuers of identifiers. Members operating the stations supporting these observing programmes should allocate WIGOS identifiers using their national system.

Global Sea-level Observing System: Station identifiers have been issued according to national conventions. In cases where the identifier of another WMO Programme has been used (for example, a land-station identifier), the WIGOS station identifier corresponding to that Programme identifier should be used.

Global network of tsunameters: Station identifiers are issued according to national conventions. In cases where the identifier of a WMO Programme has been used (for example, a land-station identifier), the WIGOS station identifier corresponding to that Programme identifier should be used.

2.5 **WIGOS-ID-PARTNER**

2.5.1 **Allocating issuers of identifiers for station identifiers associated with WMO co-sponsored programmes**

Table 2.3 defines the issuer of identifier values in the range 22000–39999 to be used for WIGOS station identifiers.

Note: No issuer of identifier number in this range has yet been issued.

Table 2.3. Issuer of identifier values in the range 22000–39999

<i>Issuer of identifier values</i>	<i>Category of station identifier</i>	<i>Issue number</i>	<i>Local identifier</i>
22000	Identifiers for marine systems administered through JCOMMOPS Note: JCOMMOPS coordinates some marine observing systems to avoid technical incompatibilities.	Determined by JCOMMOPS	Determined by JCOMMOPS
22001–39999	Reserved for future use	To be determined	To be determined

3. WIGOS METADATA

3.1 INTRODUCTION

The availability of WIGOS metadata is essential for the effective planning and management of WIGOS observing systems. These metadata are also crucial for the Rolling Review of Requirements process and similar activities at national level.

WIGOS metadata are interpretation/description or observational metadata, that is, information that enables data values to be interpreted in context and permits the effective utilization of observations from all WIGOS component observing systems by all users.

The WMO Information System (WIS) is the single coordinated global infrastructure responsible for telecommunications and data management functions. WIS enables: (i) routine collection and dissemination of time-critical and operation-critical data and products; (ii) data discovery, access and retrieval; and (iii) timely delivery of data and products. WIGOS metadata give insight into the conditions and methods used to make the observations that are distributed through the WIS.

WIGOS metadata describe the station/platform where the observation was made, the system(s) or network(s) the station/platform contributes to, the instruments and methods of observations used and the observing schedules, in order to support planning and management of WIGOS observing systems.

WIGOS metadata also describe the observed variable, the conditions under which it was observed, how it was measured or classified and how the data have been processed, in order to provide the users with confidence that the use of the data is appropriate for their application. The Global Climate Observing System Climate Monitoring Principle (c) describes the relevance of metadata as follows:

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. (*The Global Observing System for Climate: Implementation Needs* (GCOS-200), Box 8)

Metadata can be static, for example the exposure of an instrument at a fixed station. Metadata can change with every observation, for example the location of a mobile station, in which case the metadata should be reported with the observations to which they apply.

The WIGOS Metadata Standard specifies the metadata elements that exist and that are to be recorded and made available. More information about the Standard can be found in the *Manual on the WMO Integrated Global Observing System* (WMO-No. 1160) and the *WIGOS Metadata Standard* (WMO-No. 1192). The Standard has been implemented in OSCAR/Surface, which is the WMO official authoritative repository of metadata on surface-based meteorological, climatological, hydrological and other related environmental observations that are required for international exchange. OSCAR/Surface is one of the components of the WIGOS Information Resource.

Observational metadata are to be submitted to and maintained in OSCAR/Surface by WMO Members, and in OSCAR/Space by relevant WMO Members according to the provisions of the *Manual on the WMO Integrated Global Observing System* (WMO-No. 1160). Metadata from a number of co-sponsored observing systems are also maintained in OSCAR. OSCAR/Surface replaces and significantly extends *Weather Reporting* (WMO-No. 9), Volume A. It highlights the much wider scope of all the WIGOS component observing systems.

This chapter provides guidance on recording metadata related to surface-based observations and submitting those to OSCAR/Surface.

3.1.1 Key terminology

Measurand. Quantity intended to be measured (*International Vocabulary of Metrology – Basic and General Concepts and Associated Terms (VIM)*, JCGM 200:2012).

Note: Generally, it is the result of a measurement from an instrument.

Observation. The evaluation of one or more elements of the physical environment (*Technical Regulations (WMO-No. 49)*, Volume I).

Note: It is the act of measuring or classifying the variable. The term is also often used to refer to the data resulting from the observation, even though the term “observational data” is defined as the result of an observation (*Technical Regulations*, Volume I).

Observational data. The result of the evaluation of one or more elements of the physical environment.

Observational metadata. Descriptive data about observational data and/or observing stations/platforms: information that is needed to assess and interpret observations or to support design and management of observing systems and networks (*Technical Regulations (WMO-No. 49)*, Volume I).

Observed variable. Variable intended to be measured (measurand], observed or derived, including the biogeophysical context” (*WIGOS Metadata Standard (WMO-No. 1192)*).

Observing domain. The component of the Earth system which is being observed: atmospheric (over land, sea, ice), oceanic and terrestrial.

Observing facility. An alternative term for “observing station/platform”.

Observing network. More than one observing station/platform, acting together to provide a coordinated set of observations” (*Technical Regulations (WMO-No. 49)*, Volume I).

Observing site Also a term for a place where observations are made. However, it is generally used when taking into account the environmental conditions of the location.

Observing station/platform. A place where observations are made; this refers to all types of observing station and platform, whether surface-based or space-based, on land, sea, lake or river, or in the air, fixed or mobile, and making in-situ or remote observations, using one or more sensors, instruments or types of observation (*Technical Regulations (WMO-No. 49)*, Volume I). In many contexts this is abbreviated to “station”.

Observing system. One or more stations/platforms, acting together to provide a coordinated set of observations (*Technical Regulations (WMO-No. 49)*, Volume I).

3.1.2 Managing WIGOS metadata in accordance with the WIGOS Metadata Standard

3.1.2.1 Identification of functions and responsibilities

The following generic national functions and responsibilities need to be fulfilled:

- (a) Network metadata manager: responsible for keeping network observational metadata up to date, correct, quality controlled and complete;
- (b) Observational metadata manager: responsible for encoding and transmitting WIGOS metadata and ensuring that metadata meet the Standard;

- (c) Station/platform metadata maintainer: responsible for recording and maintaining metadata for the station/platform.

The above labels might not be used, but the relevant functions need to be fulfilled.

3.1.2.2 **Using the OSCAR/Surface tool**

The key WMO tool to assist in the above functions is the OSCAR surface-based capabilities database.

The WIGOS Metadata Standard is implemented through the OSCAR/Surface tool, which means that Members must transfer their WIGOS metadata, either in near-real time or less frequently, to OSCAR/Surface for the observations they exchange internationally. All prescribed metadata are to be collected and stored by Members. Moreover, OSCAR/Surface contains a few additional metadata fields not explicitly specified in the Standard, such as population density. Members should include as many of the additional fields as possible in OSCAR/Surface.

Note that OSCAR/Surface provides an interface for the manual submission of metadata. This interface is accessed through the Internet using any Web browser. Machine-to-machine submission of metadata is now also possible.

Further guidance on using OSCAR/Surface is provided in [Chapter 4](#) of this Guide.

3.2 **GENERAL GUIDANCE ON WIGOS METADATA**

The WIGOS Metadata Standard is an observation-focused standard. However, typically observations are grouped in terms of the observing station/platform where one or more sensors or instruments are located.

The following metadata elements of the Standard are mandatory. The initial numbers refer to the elements in the Standard and the numbers in brackets refer to sections of this chapter:

- 1-01 Observed variable – measurand (3.2.2)
- 1-03 Temporal extent (3.2.1, 3.2.2)
- 1-04 Spatial extent (3.2.2 and 3.3.1)
- 2-02 Programme/network affiliation (3.2.1 and 3.2.2)
- 3-03 Station/platform name (3.2.1)
- 3-04 Station/platform type (3.2.1)
- 3-06 Station/platform unique identifier (3.2.1)
- 3-07 Geospatial location (3.2.1, 3.2.1.1, 3.3.1 and 3.3.1.2)
- 3-09 Station operating status (3.2.1)
- 5-01 Source of observation (3.2.2)
- 5-02 Measurement/observing method (3.2.2)
- 6-08 Schedule of observation (3.2.2)
- 7-03 Temporal reporting period (3.2.2)
- 7-14 Schedule of international exchange (3.2.2)
- 9-01 Supervising organization (3.2.1 and 3.2.2)
- 9-02 Data policy/use constraints (3.2.2)
- 10-01 Contact (nominated focal point) (3.2.3)

The following metadata elements of the Standard are mandatory when relevant conditions are met (they are referred to as conditional elements):

- 1-02 Measurement unit (3.2.2)
- 3-01 Region of origin of data (3.2.1 and 3.3.1.1)
- 3-02 Territory of origin of data (3.2.1 and 3.3.1.1)
- 4-02 Surface cover classification scheme (3.2.2)

- 5-05 Vertical distance of sensor (3.2.2 and 3.3.1.1)
- 5-06 Configuration of instrumentation (3.2.2)
- 5-08 Instrument control result (3.2.2)
- 5-12 Geospatial location (3.2.1.1, 3.2.2, 3.2.2.1 and 3.3.1.2)
- 5-15 Exposure of instruments (3.2.2)
- 6-07 Diurnal base time (3.2.2)
- 7-04 Spatial reporting interval (-)
- 7-11 Reference datum (3.2.2 and 3.3.1.1)
- 8-02 Procedure used to estimate uncertainty (3.2.2 and 3.3.1.4)
- 8-04 Quality flagging system (3.2.2 and 3.3.1.4)
- 8-05 Traceability (3.2.2 and 3.3.1.4)

In OSCAR/Surface, metadata are assembled under five headings, one for each subsection below (3.2.1–3.2.5).

Notes:

1. Each time the number in format x-yy appears in this Guide, it refers to the number of the metadata element in the WIGOS Metadata Standard. Where a metadata element is mentioned without this number, it means it is not part of the Standard.
2. Users of OSCAR/Surface may or may not see certain fields when navigating the various stations in the database depending on whether the field was filled out when the station was created/edited.

3.2.1 **Station characteristics**

Under this heading, the basic information about the station/platform with the following mandatory elements can be found: name (3-03 Station/platform name), date established (1-03 Temporal extent), station type (3-04 Station/platform type), WIGOS station identifier (3-06 Station/platform unique identifier), WMO Region (3-01 Region of origin of data), country/territory (3-02 Territory of origin of data), coordinates, that is to say, the latitude, longitude, elevation and geospatial method used (3-07 Geospatial location), 9-01 Supervising organization, and 2-02 Programme/network affiliation (for the station, including the declared status (3-09 Station operating status)).

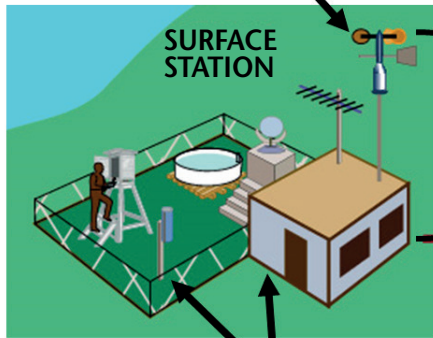
Under this heading, some elements that are not mandatory can be found, such as those describing the relevant environmental characteristics of the station/platform and its surroundings: 4-07 Climate zone, predominant surface cover (4-01 Surface cover), 4-06 Surface roughness, 4-03 Topography or bathymetry, station/platform events/logbook (4-04 Events at observing facility) and site description (4-05 Site information) with possible images (photo gallery) of the station/platform; OSCAR/Surface has used this last field to capture legacy remarks from Weather Reporting (WMO-No. 9), Volume A.

Complementary information that can be inserted under station characteristics that does not correspond to any metadata elements of the Standard includes: station alias, station class(es), Time zone, station URL (a reference/address for a resource on the Internet), Other link (URL), and Population per 10 km²/50 km² (in thousands).

3.2.1.1 **Station coordinates**

The method to specify station coordinates (3-07 Geospatial location) is described in the *Guide to Instruments and Methods of Observation* (WMO-No. 8), Volume I, Chapter 1, 1.3.3.2. The figure in this section shows the various metadata elements related to the station's geospatial location (3-07) versus the instrument's geospatial location (5-12), and their references for the height.

Instrument coordinates: geographic location of instrument sensor; height given above mean sea level.



Vertical distance of sensor above or below reference surface: height in metres above or below reference surface, such as the ground.

Observing facility geographic location: referenced to the primary instrument or administrative point; height above mean sea level.

Note: Marine instruments are generally referenced to mean sea level or lowest astronomical tide for coastal instruments. Vertical distance for marine sensors is negative if the sensor is below the sea or lake surface.

Metadata elements for station location and instrument location, including height references

3.2.2 Observations/measurements

Each observation at a specific station is described succinctly in terms of the following mandatory elements:

- Variable (1-01 Observed variable – measurand);
- Geometry (1-04 Spatial extent);
- Programme/network affiliation (2-02).

For each variable at a specific station, there is a subset of the following mandatory and conditional metadata elements:

- From (date) (1-03 Temporal extent);
- Source of observation (5-01);
- Distance from reference surface (5-05 Vertical distance of sensor);
- Exposure of instruments (5-15);
- Configuration of instrument (5-06 Configuration of instrumentation);
- Supervising organization (9-01).

Under this heading, one or more deployments¹ may be found. The information is structured into two groups of metadata elements: “Instrument characteristics” and “Data generation”.

¹ A data series represents the entirety of observations of the same variable taken at a given station. A deployment is a subset of these observations and represents those that were taken without major interruption and under roughly the same conditions.

Under “Instrument characteristics” the following mandatory elements are required:

- Observing method (5-02 Measurement/observing method);
- Coordinates (5-12 Geospatial location);
- Uncertainty evaluation procedure (8-02 Procedure used to estimate uncertainty);
- Quality assurance logbook (5-08 Instrument control result).

Under “Data generation” the following mandatory elements are required:

- Schedule (6-08 Schedule of observation), which includes month (from–to), day (from–to), and hour (from–to);
- Diurnal base time (6-07);
- Intended for international exchange (Yes/No);
- Schedule of international exchange (7-14), in combination with 6-08;
- Data policy (9-02 Data policy/use constraints);
- Measurement unit (1-02);
- Reporting interval (7-03 Temporal reporting period);
- Reference datum (7-11);
- Data quality flagging system (8-04 Quality flagging system)
- Traceability (8-05).

Other metadata, considered as optional elements of the WIGOS Metadata Standard (see *WIGOS Metadata Standard* (WMO-No. 1192)), can be listed under this heading along with complementary information that should be provided if available.

Often, multiple observations are associated with a single station/platform. Observations at a station/platform are listed in English alphabetical order.

Certain metadata elements covering site characteristics may only be relevant to specific types of observation. For example, 4-02 Surface cover classification scheme is generally mainly applicable to observations such as surface-air temperature, humidity, irradiance and precipitation.

3.2.2.1 ***Instrument coordinates***

A method similar to the one referred to in [section 3.2.1.1](#) should be followed for the coordinates of individual instruments (5-12 Geospatial location). If the instruments are located at a single observing point, the station/platform coordinates may be used as an approximation. Where necessary, the actual geospatial location of the instrument (sensing component) is recorded according to the *Guide to Instruments and Methods of Observation* (WMO-No. 8), Volume I, Chapter 1, 1.3.3.2. Additionally the height or depth of the instrument above or below its reference surface is recorded where appropriate.

3.2.3 **Station contacts**

The details of the station contacts (10-01 Contact (nominated focal point)) are recorded. This may include someone with a relevant function, such as the station or network manager, or the data or metadata holder, or the organization responsible for the data policy.

3.2.4 **Bibliographic references**

Where the data series or deployment, or methods relating to the data series or deployment, have been previously published or referenced, for example nationally or on the Internet, the references are recorded in this section. OSCAR/Surface allows for the upload of documents. There is no direct correspondence between this section and any particular metadata element of the Standard.

3.2.5 **Documents**

This section provides access to documents concerning the station/platform or the observed variables. These may include correspondence, instrument calibration certificates, network descriptions and so on. This section may be related with element 4-05 Site information and can be regarded as a historic archive of complementary documentation on the changes in the station/platform, its instruments and conditions of observation.

3.3 **SPECIFIC GUIDANCE FOR DIFFERENT TYPES OF STATIONS/PLATFORMS**

While the guidance in [section 3.2](#) is intended to be useful for Members managing metadata of any type of station/platform, the following section is intended to provide additional guidance relevant to specific types of stations/platforms.

As mentioned above, the geospatial location of the station/platform should identify the reference location of that station/platform, while the geographic coordinates of the instruments are specified separately for each instrument of the station/platform. A change of coordinates should always reflect a physical relocation of the station/platform and/or instrument. The historical coordinate values of the station/platform location should be retained.

3.3.1 **Stations/platforms on land**

This section describes the metadata aspects of the main types of observations made on land. It is structured according to the geometry (1-04 Spatial extent), i.e. a point, profile or volume, and to the technology (in situ or remote-sensing) used for the observations.

The geospatial location (3-07) of the station/platform may refer to the observation which has existed for the longest period of time, it may be related to the administrative point, or to the primary application area(s) (2-01). The coordinates should be centred over the instrument and the ground elevation should be the natural (undisturbed) surface of the ground.

Stations/platforms on land include observations which are made at a fixed position in relation to the land surface, a mobile observation on land or those which transfer their data to a facility on land. These facilities may be close to land (such as a wharf or on a pylon grounded in the earth). A mobile station may remain in a fixed location during a period of observations or may be mobile during the observation.

3.3.1.1 **Surface in situ observations**

The observations of the variables at a surface in situ observing station, such as wind speed/direction, air temperature, relative humidity, atmospheric pressure, precipitation, present weather, or cloud, made by the instruments/observer located at this station, are described individually. Although such observations are made in situ, they should represent an area surrounding the station, depending on the environmental exposure conditions of the instrument.

Some instruments may measure more than one observed variable at the same time. Each observed variable should be described and the common instrument may be identified through a common serial number. Examples of such instruments include some humidity probes (reporting humidity and temperature), some sonic anemometers (may report wind speed, wind direction, virtual air temperature) and so-called “all-in-one” instruments (for example, reporting temperature, humidity, wind speed, wind direction and pressure).

Surface in situ refers to observations made near the surface of the Earth, over land, for example at automatic weather stations and manual weather stations. The simplest station may make only one observation (for example, rainfall), while others may include observations of several variables, such as air temperature, humidity, wind, soil temperature, rainfall intensity and amount.

The following conditional elements of the WIGOS Metadata Standard are mandatory for fixed stations:

- 3-01 Region of origin of data;
- 3-02 Territory of origin of data;
- 5-05 Vertical distance of the sensor from a (specified) reference level, such as local ground, the deck of a marine platform at the point where the sensor is located, or sea surface;
- 7-11 Reference datum: mandatory for derived observations that depend on a local datum.

3.3.1.2 **Upper-air in situ observations**

Upper-air in situ observations primarily include observations made using instrumentation attached to meteorological balloons (radiosondes), or unmanned aerial vehicles (also called drones). The balloon tracking for the calculation of winds (that is, by radar or radio-theodolite) is also regarded as an upper-air in situ observation. The radiosonde measurement, often referred to as a sounding, delivers a complete profile from the launch point to balloon burst. To ensure timely availability for the data users the sounding is often split into several messages, but the same metadata are included in all parts of the transmitted messages. Observations such as those made by dropsondes, rockets and kites are also included in this category, but specific guidance for these systems will be included in a later release of the metadata standard.

The majority of the metadata for these systems are also incorporated within the WMO-defined BUFR message and are reported along with the data for each sounding. Because the observations are meaningless without these metadata, the station/platform metadata maintainer and the network metadata manager must ensure that the transmitted metadata are valid and accurate for each reported sounding. To prevent any confusion the metadata reported in BUFR messages must be fully consistent with the WIGOS Metadata Standard elements and with the information inserted into OSCAR.

It is common that the launch point of the balloon has different geospatial coordinates than the station/platform and this can have a significant impact for the data users. It is important that both sets of geospatial coordinates are included in the station/platform metadata database,

and that the coordinates incorporated in the BUFR messages are for the balloon launch location. Element 5-12 Geospatial location of the instrument, is related to this, while element 3-07 Geospatial location of the station, refers to the main facility.

Many radiosonde systems no longer include a pressure sensor, and thus the pressure and geopotential height are derived from the Global Navigation Satellite System (GNSS) altitude. The atmospheric pressure can be derived artificially from an estimate of the status of the atmosphere based on WMO-recommended calculus or by using the static predefined International Standard Atmosphere. The metadata defining the source of the pressure and geopotential height measurements are mandatory and must be included in every BUFR message. This relates to element 7-01 Data-processing methods and algorithms, which is an optional element of the Standard.

3.3.1.3 ***Weather radar observations***

Weather radars are active remote-sensing observing systems used to make real-time and high-resolution observations from a large-scale area (up to a radius of 250 km). Weather radar observations have been made particularly for the detection of precipitation, hydrometeor classification and quantitative precipitation estimation. Doppler wind speed and direction can also be reported from some weather radars. Radar station/platform coordinates, height of the location, tower height, frequency, polarization, scanning parameters and other characteristics of weather radar observations are metadata elements contained in the WMO Radar Database (<http://wrd.mgm.gov.tr/Home/Wrd>). Members should continue to collect and supply/update the metadata about their weather radars to the WMO Radar Database (managed by the Turkish State Meteorological Service). The metadata regarding weather radars are transferred from the WMO Radar Database to the OSCAR/Surface by machine-to-machine procedures. Radar metadata cannot be edited manually in OSCAR/Surface.

3.3.1.4 ***Other surface-based remote-sensing observations***

Other surface-based remote-sensing observations include all observations, excluding those from weather radars, made using remote-sensing instrumentation located at a fixed station. These systems are wide ranging in their methods of observation, but primarily result in a measurement profile representative of the atmosphere above the sites. Examples of systems in this category are wind profiling radars, lidars, sodars, radiometers, ground-based GNSS receivers, and high-frequency radars. So, both active and passive remote-sensing technologies are considered here.

The majority of the metadata regarding these systems are incorporated within the WMO-defined BUFR message and thus are only reported along with the data for each sounding. The station/platform metadata maintainer and the network metadata manager must ensure that the transmitted metadata are valid and accurate for each reported sounding.

These systems often use advanced flagging techniques to identify measurements that do not meet the data quality criteria, and it is mandatory to include this information within the metadata that are transmitted with each message. This relates to elements 8-01 to 8-05 of the Standard (Category 8: Data quality).

3.3.2 ***Stations/platforms on the sea surface***

Sea-surface observations are taken from a variety of stations/platforms. These include moored buoys, drifting buoys, ships and off-shore installations. Also terrestrial-based (on shore) high-frequency radars (measuring surface current direction and speed) can be considered as such. Variables most commonly measured are air temperature, atmospheric pressure, humidity, wind direction and speed, sea-surface temperature, wave height, wave period, wave direction, sea-level, current speed and direction, and salinity.

Ship observations typically include air and seawater temperature, atmospheric pressure, humidity, and wind direction and speed. These are commonly measured automatically. Manual ship observations also include wave height, wave period, wave direction, ceiling (cloud cover) and visibility.

Sea-surface observations are also being made from autonomous surface vehicles. These are propelled by wind and/or wave action and measure air temperature, atmospheric pressure, humidity, wind direction, wind speed, sea-surface temperature and sea-surface salinity.

Buoy positions are reported at the time of observation by the organization that operates the platform. Ship positions are also reported at the time of observation; however, many vessels do not report their actual identity due to economic considerations. Autonomous vehicles report their position obtained at the time of observation. The observations are reported under the ownership of the organization that is remotely controlling the vehicle(s).

3.3.3 **Airborne stations/platforms**

Airborne observations, involving measurements of one or more meteorological variables, are made at particular pre-scheduled intervals in space and time, so at a series of locations (in three-dimensional space). In practice these observations are carried out on board of aircraft called aircraft-based observation stations/platforms. These series of observations deliver profiles near aerodromes or are composed of a series of equidistant observations at constant altitude.

In general, data are reported by three categories of aircraft-based observation stations/platforms using different data relay systems. Examples are:

- (a) WMO Aircraft Meteorological Data Relay (AMDAR): aircraft providing meteorological data according to WMO standards and specifications;
- (b) ICAO Automatic Dependent Surveillance – Contract: aircraft providing data under regulations and cooperative arrangements with ICAO;
- (c) Other aircraft-based observation stations/platforms: data derived from observing systems on aircraft not controlled by WMO or ICAO (called third-party data). Data availability is dependent on arrangements between National Meteorological and Hydrological Services and the data provider as to whether data can be ingested into WIS, taking into account requirements stated in the Technical Regulations.

The data from aircraft-based observation stations/platforms require that network metadata managers maintain a database of metadata relating to aircraft models and types, and information on sensors and software for processing the data. There will also be a requirement for airport positional metadata with regards to the initiation and termination of profiles.

Source: Manual on the WMO Integrated Global Observing System (WMO-No. 1160), and the [Guide to Aircraft-based Observations](#) (WMO-No. 1200).

3.3.4 **Stations/platforms underwater**

Underwater observations can be obtained in a number of ways. These include thermistor strings and devices attached to inductive cabling, expendable bathythermographs, acoustic Doppler current profilers, Argo floats, and conductivity, temperature and depth devices. Bottom-mounted water pressure sensors are used to measure variations in the water column, which are indicative of a low-amplitude wave (tsunami) generated by an underwater disturbance (seismic activity). A new technology, profiling gliders, which are unmanned underwater vehicles, is becoming more widespread. The variables observed by these devices include water temperature, water pressure, salinity, current direction and speed, fluorescence and dissolved oxygen. All of these variables are measured at depth – as deep as the sensors or gliders are located.

The underwater observations obtained from moored buoys use the position of the buoy itself and are reported by the organization that operates the buoy. Expendable bathythermograph positions are taken at the point of launch and are reported by the launch vehicle (ship or aircraft). Acoustic Doppler current profilers and conductivity, temperature and depth devices are usually moored at a specific location, which is reported at the time of observation by the organization operating the device. Argo float positions are reported at the time of observation by the organization operating the device. Unmanned underwater vehicle observations are reported using the position of the vehicle when it begins its subsurface excursion and are reported by the organization piloting the vehicle.

3.3.5 **Stations/platforms on ice**

Note: Specific guidance for stations/platforms on ice is under development.

3.3.6 **Stations/platforms on lakes/rivers**

Records of lake/river gauge height or stage and river discharge are fundamental to the management of water resources, the understanding of streamflow variability in time and space and the calibration of hydrological models used in streamflow and flood forecasting. Gauge heights can be measured in various ways, such as direct observation of a staff gauge or by automatic sensing through the use of floats, transducers, gas-bubbler manometers and acoustic methods. River flows are generally computed through conversion of a record of stage to discharge using an empirically derived rating conversion curve or other hydraulic model. General stream-gauging procedures are recommended in the *Manual on Stream Gauging* (WMO-No. 1044), Volumes I and II.

3.3.7 **Satellites**

Satellite observations provide information from all areas of the world. These observations deliver information on surface characteristics, as well as atmospheric conditions depending on the instrument type. Essential information about satellites are orbit and type of orbit (geostationary or polar orbiting), height of the satellite, local observation intervals, types of technology applied (active/passive, optical/microwave, imager/sounder) and instrument characteristics (bands measured, footprint, measurement approach such as scanning versus push broom or similar, swath size if applicable, return period, etc.).

Ensuring accuracy and consistency among space-based observations from operational weather and environmental satellites of the Global Observing System (GOS) is essential for climate monitoring, weather forecasting and environmental applications. To this end, the Global Space-based Inter-Calibration System (GSICS), an international collaborative effort initiated in 2005 by WMO and the Coordination Group for Meteorological Satellites (CGMS), develops common methodologies and implements operational procedures to ensure quality and comparability of satellite measurements taken at different times and locations, using different instruments operated by various satellite agencies. This is achieved through a comprehensive calibration strategy which involves: (a) monitoring instruments' performance; (b) operational inter-calibration of satellite instruments; (c) tying the measurements to absolute references and standards; and (d) recalibration of archived data. The resulting inter-comparisons achieve inter-calibration when the measurements are traceable to absolute references and standards. The Global Space-based Inter-Calibration System contributes to the integration of satellite data within WIGOS.

Meteorological satellites usually transport a variety of instruments, each mounted for specific applications required by a diverse user community. In fact, due to the variety of instruments and the specific observation programme chosen, the related metadata are different from those

obtained with the classic surface-based observations (see the *Guide to Instruments and Methods of Observation* (WMO-No. 8)). As a consequence, metadata for satellite observations with calibration information are collected in a separate database, [OSCAR/Space](#).

4. MAKING WIGOS METADATA AVAILABLE TO WMO USING OSCAR/SURFACE

The OSCAR surface-based capabilities database (OSCAR/Surface) is the key WMO tool for assisting Members in making WIGOS metadata available in accordance with the *Manual on the WMO Integrated Global Observing System* (WMO-No. 1160).

Detailed guidance on how to use OSCAR/Surface is provided in the *OSCAR/Surface User Manual*, which is available at <https://oscar.wmo.int/surface/> and in the [WMO library](#).

The *OSCAR/Surface User Manual* comprises two main sections: section 2. Finding information in OSCAR/Surface contains guidance on how to search the database to find stations and information about available observations – this section is useful for both registered and anonymous users; section 3. Changing information in OSCAR/Surface contains information on how to manage stations in the database – this section is relevant mainly for registered users, such as station contacts and national focal points.

5. OBSERVING NETWORK DESIGN

5.1 INTRODUCTION

The observing network design principles are provided in the *Manual on the WMO Integrated Global Observing System* (WMO-No. 1160), Appendix 2.1. The 12 principles are short and therefore abstract. National Meteorological and Hydrological Services (NMHSs) designing and evolving their observing system networks need more concrete guidance on how to respond to these principles. This chapter thus provides for each principle a set of more specific guidelines or recommendations on their interpretation and implementation.

Some recommendations apply across several principles. For ease of interpretation, these points are repeated wherever applicable.

In some cases in this chapter, rather abstract terms are used. These terms sometimes have their origin in a specific area of meteorological observation, such as in ground-based observation. The terms “network design” and “observing networks”, for example, are regularly used and accepted when describing the process of creating a network of ground-based observing sites in a country, and thus when considering aspects like appropriate distance between stations, other siting conditions or the frequency of observations. The term “network design” can and is already being used in the area of space-based observations. However, this additional application has not yet been adopted generally. Therefore, it is important to recognize that many guidelines and recommendations in this chapter – when referring to, for example “network design” or “observing networks” – are not necessarily restricted to ground-based observations but should be applied to all observing systems.

Abstract or conceptual terms and definitions, for example “integrated station network”, are also sometimes used for the purpose of making certain guidelines and recommendations more generally applicable. Explanations of such abstract terms can be found in the [annex to the present chapter](#).

5.2 GUIDANCE ON THE OBSERVING NETWORK DESIGN PRINCIPLES

Note: For convenience, the observing network design principle is reproduced in parentheses and italic under the name of each principle.

Principle 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.)

Note: A WMO application area is an activity involving the direct use of observations in a chain of activities that allow National Meteorological Services or other organizations to render services contributing to public safety and socioeconomic well-being and development in their respective countries, in a specific domain related to weather, climate and water. The concept of a WMO application area is used in the framework of the WMO Rolling Review of Requirements¹ and describes a homogeneous field of activity for which it is possible to compile a consistent set of observational user requirements agreed by community experts working operationally in this area.

- (a) When designing observing networks, the needs of WMO application areas, as regulated in the *Manual on the WMO Integrated Global Observing System* (WMO-No. 1160), should be taken into account. In particular, see the [WMO Rolling Review of Requirements](#) process,

¹ The WMO Rolling Review of Requirements is described in the *Manual on the WMO Integrated Global Observing System* (WMO-No. 1160), Appendix 2.3.

the WIGOS database of user requirements for observations ([OSCAR/Requirements](#)) and the [Statements of Guidance](#) for all applications areas. As an example, the design of observing networks implemented primarily in support of operational weather forecasting should also take into account the requirements of other applications areas, such as climate monitoring.

- (b) Where practicable, observing networks should be designed and operated in such a way that the needs of multiple applications are addressed. It is acknowledged that different applications have different, and sometimes conflicting, requirements; when an observing network is implemented primarily to serve the needs of one application, compromises may be needed in its ability to serve others. Nevertheless, the requirements of other applications should be actively considered during network design.
- (c) As part of the management of an observing network, a user consultation procedure should be implemented through which the requirements of different application areas can be ascertained, considered and analysed simultaneously. (See also [principle 2](#).)
- (d) In order to respond to the needs of its Programmes, WMO engages in partnerships with other bodies responsible for observations through co-sponsored programmes (see the preamble to the [Implementation Plan for the Evolution of Global Observing Systems \(EGOS-IP\)](#) (WIGOS Technical Report No. 2013-4). These partnerships should be taken into account when designing observing networks.
- (e) Partnerships with other organizations (such as those involved in road transportation or electric power generation), including partner organizations responsible for observations, should be exploited through the integrated and multi-purpose design of observing networks in order to achieve synergies between networks and/or domains and improve cost-effectiveness.

Principle 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.)

Note: User requirements for observations are documented and quantified in the Observing Systems Capability Analysis and Review tool ([OSCAR/Requirements](#)). The user requirements as stated in OSCAR are high-level in the sense that they are not intended to capture all the detailed requirements that must be considered when designing a specific observing system. The requirements in OSCAR/Requirements should therefore be taken into account, but they are not sufficient to provide a full description of the observing system requirements.

- (a) User communities should be involved in the observing network design. To ensure that observing networks respond to the key needs of the user communities, specific decisions about observing network design should include a consultation stage with appropriate application area representatives. A procedure should be implemented to allow a documented collection and synthesis of detailed user requirements.
- (b) When designing their observing networks, Members should take into account the actions listed in the [Implementation Plan for the Evolution of Global Observing Systems \(EGOS-IP\)](#) (WIGOS Technical Report No. 2013-4), as well as the gap analyses from the [Statements of Guidance](#) for all application areas.
- (c) Members should conduct further studies to assess the feasibility of addressing with existing technology the observational user requirements specified in OSCAR, as well as the additional regional requirements that may not be specified in OSCAR and national requirements, taking resources and cost-effectiveness into account. (See also [principle 5](#).)
- (d) Observational data should be processed to a level to be established in consultation with users (for example, raw instrument data, calibrated instrument data or retrieved geophysical variable). This should include an agreement on quality control, formats, etc. The appropriate level of processing will vary according to the user communities' needs

and to the intended applications. Appropriate resources should be allocated to these data-processing requirements. Also, where supported by user requirements, appropriate resources should be allocated to archiving the raw data and metadata, such that data can be reprocessed at a later date.

Principle 3. Meeting national, regional and global requirements

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

- (a) National observing networks are designed and established by Members primarily to respond to their own national needs/requirements, in many cases in agreement with other Members and in accordance with WMO regulatory and guidance material. However, when implementing these national networks, Members should also take into account the requirements for global and regional applications. For example, Members should consider small additional commitments or adjustments (for instance, in terms of data storage, data policy, availability, exchange and documentation) to make data useful to other Members.
- (b) WIGOS regulations should be adopted for observing networks that are implemented primarily to respond to national needs.
- (c) Procedures through which national user requirements are collected and assessed (see [principle 2, paragraph \(a\)](#)) should be designed in such a way that regional and global requirements can be addressed simultaneously.
- (d) For each national network/site, a network/site definition document should be maintained containing information on:
 - (i) Planned observing capabilities of the network/site;
 - (ii) Target performances;
 - (iii) User requirements to which the network/site responds.

Principle 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.)

- (a) In general, the composite observing network should be designed in such a way that it delivers basic observations that are quasi-uniform in space for observed variables and resulting from an analysis of the 3D-resolution requirements provided in [OSCAR](#). Gaps should be assessed in accordance with the *Manual on the WMO Integrated Global Observing System* (WMO-No. 1160). (See also [principle 5](#) for guidance on composite network design.)
- (b) However, for some application areas, the representativeness of observations may be a more important design driver than spatial and temporal homogeneity. In such cases, the density of an observing network should be adjusted according to the variability of the observed phenomena in a given region, for example to address the need for greater density of some observations in mountainous and coastal areas where steep gradients in geophysical variables exist. Also, observing networks should be designed with spatial and temporal spacing such that severe, extreme and high-impact events, often of short duration, are captured, and such that climate-relevant changes (for example, diurnal, seasonal and long-term interannual) can be resolved.
- (c) When considering priorities for additional observations, attention should be given to: data-sparse regions and domains, poorly observed variables, regions sensitive to change

and regions which experience environmental phenomena that place populations at risk. As these are not always located within the territory of the country needing the observations, this creates a need to acquire observations in areas outside the territory of the funding nation or group of nations (for example, the Network of European Meteorological Services funding of the EUMETNET Automated Shipboard Aerological Programme, or the Global Climate Observing System (GCOS) Cooperation Mechanism).

- (d) Observing networks should be designed taking into account measurements and gaps of other systems in the vicinity, such as measurements using the same technology in neighbouring countries or measurements from networks using different technologies, both surface-based and space-based.
- (e) Surface-based observations have to be representative for specific applications. Sites representative² of local features should be generally avoided (for example, on steep slopes, in hollows, in proximity to pronounced features such as buildings, topographical influences or ridges) unless sited for a specific purpose and application.
- (f) Non-NMHS observations can provide valuable measurements for filling in observational gaps. In many areas these may be the only available observations, particularly for elements requiring higher density measurements such as precipitation, and extreme events such as hail or windstorms. NMHSs should investigate collaborations with others within their country in order to complement existing networks, share resources and address gaps. For observations of this type, special attention should be given to possible data-policy issues, and the guidance given under [principle 3, paragraph \(a\)](#), should be followed.
- (g) Where possible, objective tools should be used to assess the impact and benefit of observations, including to demonstrate the impact of observation density. Such tools (for example, Observing System Experiments, Observing System Simulation Experiments or forecast sensitivities to observations) exist in numerical weather prediction and are well-proven. The development of equivalent tools for other application areas is encouraged.

Principle 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.)

- (a) Observing networks should be designed using the most appropriate and cost-effective technologies or combinations of technologies. Guidance documents from the Commission for Instruments and Methods of Observation and other technical commissions on existing technology should be consulted. For example, reference can be made to the [Guide to Climatological Practices](#) (WMO-No. 100), Chapter 2, 2.5; the [Guide to Agricultural Meteorological Practices](#) (WMO-No. 134), Chapter 2, 2.2.4 and 2.4.1.11.3; and the [Guide to the Global Observing System](#) (WMO-No. 488), Part III, 3.1.
- (b) Developments to observing networks should, where possible, build on and lead to the consolidation of existing subnetworks, capitalizing on both existing and new technology and integrating new networks into existing WIGOS capabilities.
- (c) The observing network should evolve in response to changing user requirements. Designs should be sufficiently flexible to allow for incremental expansion, or contraction, without the need for complete network redesign.
- (d) Partnerships with other organizations responsible for observations should be established or maintained in order to build on potential synergies, share costs and provide more cost-effective multi-purpose networks. Other organizations may include WMO partners (see the

² See the *Guide to Instruments and Methods of Observation* (WMO-No. 8), Volume I, Annex 1.D. Siting classifications for surface observing stations on land.

preamble to the *Implementation Plan for the Evolution of Global Observing Systems (EGOS-IP)* (WIGOS Technical Report No. 2013-4)) or national governmental and non-governmental organizations.

- (e) Observing network design should, where possible, be based on the results from scientific studies which assess the impact, importance and value of the observations for the applications to which they contribute. Complementary impact-per-cost studies should also be conducted in order to address the cost-effectiveness of various possible observing systems when designing networks.
- (f) Spaced-based and surface-based observing networks should be designed and operated in such a way that they are complementary, with appropriate activities and cooperation between the communities responsible for these networks, to ensure that observations from each network are used to enhance the impact and effectiveness of the other.
- (g) Observing networks should be designed taking into account measurements available from other networks in the vicinity, including in neighbouring countries, or measurements from networks using different technologies.
- (h) To optimize benefits within a Member's own territory, an effective observing network may require investment outside the Member's territory. This may be realized through, for example, regional collaboration.
- (i) Network design may include the need for visual/manual observations and observations of phenomena not necessarily well detected/identified by automated systems or that are more cost-effective detected manually.

For space-based observing systems

- (j) Space-based observing systems that continue to meet calibration and stability requirements may remain cost-effective for longer than their expected lifetime. Operators should consider continuing to operate such systems at a lower level of maintenance after the designed lifetime.

Principle 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.)

- (a) Only observing technologies with adequately characterized performance should be deployed to ensure that levels of observational quality consistent with user requirements are attained.
- (b) Observing networks should be operated to meet agreed performance targets.
- (c) Observing networks and stations should be assessed regularly using objective criteria to ensure that the desired performance standards are being met.
- (d) As part of routine operations, the quality and homogeneity of data should be regularly assessed through an ongoing programme to monitor performance of the network. This may include both automated and manual checks.
- (e) A comprehensive monitoring of data availability, timeliness and quality should be implemented. For appropriate observation types, this should include monitoring of short-range numerical weather prediction. Monitoring should also be implemented to help detect various types of errors, for example, non-timely or missing data, improperly coded observations and grossly erroneous measurements.

- (f) Monitoring results may be made available in different ways, for example, via web portals, regular reports (review of overall performance statistics) or fault reports (focus on detected errors at specific sites).
- (g) When station relocations or instrument upgrades are made, a sufficient period of overlap between the old and new systems, considering the targeted application areas, should be made whenever practicable. (See also [principle 12.](#))
- (h) The availability of complete metadata is essential to assess the homogeneity of observations. (See also [principle 10.](#))
- (i) For many applications including climate monitoring, it is important that calibration, calibration monitoring and intercalibration be designed as part of the observing network. For applications in (near) real time, it is important that calibration information be made available in (near) real time. It is also important that raw data be archived so that they can be reprocessed at a later date to improve their homogeneity.
- (j) Intercomparisons and validation of observations made using different technologies should be undertaken in order to improve understanding of observational uncertainty or relative performances (bias, standard deviation, gross errors).
- (k) Whilst some non-NMHS observations may be collected using non-standard formats, where possible all observations should be disseminated using standard quality rules, standard formats and according to standard dissemination procedures.
- (l) Observations should be disseminated in such a way that the quality and provenance of the original measurement are retained.
- (m) Members should give a high priority to maintaining the operations of observing stations/sites/systems that have long-term data series, especially for climate applications.
- (n) For climate monitoring applications, surface-based stations should be sited in locations that are least likely to be impacted by changes through time in the natural or man-made environment.

Principle 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 other observations and used to improve their quality and utility.)

Note: In addition to improving the quality and utility of observations, this approach will also lead to improvements in the understanding of the quality of the observations.

- (a) The tiered approach³ should include, as a minimum, a sparse network of reference stations (for example, the GCOS Reference Upper-air Network) from which other stations can be benchmarked. Reference stations should be calibrated to the International System of Units or community-accepted traceable standards with fully quantified uncertainties, have the highest level of robustness (for example, duplicate or triplicate sensors of key variables such as temperature and precipitation), be well sited in locations least affected by urbanization and other non-climatic influences, have regular maintenance and replacement cycling of instruments, have the highest standard of metadata collection including photo documentation, and have continuous monitoring of system performance to resolve instrument and environmental issues as they arise.

³ For a tiered approach, see *GCOS Reference Upper-air Network (GRUAN): Justification, requirements, siting and instrumentation options*, GCOS-112 (WMO/TD No. 1379).

- (b) Stations such as the baseline networks of the Global Climate Observing System (the GCOS Surface Network and GCOS Upper-air Network) can form an intermediate data layer, with quality between that of reference stations and the larger comprehensive network of observing stations.⁴
- (c) In the field of space-based observing, satellite redundancy should be used whenever appropriate to ensure the reliability of data provision from certain orbits. With regards to ground-based observations, even at non-reference stations, instrument redundancy should be used whenever appropriate to ensure the reliability of the observation and measurement accuracy.
- (d) In addition to geostationary and low-Earth orbit Sun-synchronous constellations, space-based observing networks should include high-eccentricity orbits to permanently cover the polar regions, low- or high-inclination low-Earth orbiting satellites for comprehensive sampling of the global atmosphere, and lower-flying platforms, such as short-life nanosatellites, as gap fillers.
- (e) A network of other NMHS or non-NMHS stations can be interspersed with a subset of high-quality stations for more complete coverage.
- (f) Network design should include consideration of skills and training needed for staff, which is expected to be different at different levels in the tiered structure. Expertise of staff at reference stations should be used to provide guidance to other parts of the network.

Principle 8. Designing reliable and stable networks

(Observing networks should be designed to be reliable and stable.)

- (a) The design and implementation of observing networks should ensure that standard operating procedures and practices are followed, including appropriate maintenance and calibration procedures.
- (b) Data quality objectives should be defined for each network. Decisions will need to be made regarding the level of quality control to be applied. Fully automatic quality control with no manual assessment may be the most cost-effective but in some cases may result in a lower level of quality.
- (c) The criteria for selecting the station site/satellite orbit should be based on the purpose and tier of the network. Criteria associated with the length of time the station/satellite will be operated, available energy sources, data transmission options, and factors associated with homogeneity and the local environment should be considered.
- (d) Training should be commensurate with the network tier. A basic network consisting of manual observations should focus on sound observing techniques and methods for data recording and dissemination. For automated networks, training should focus to a greater degree on maintenance and operation of instruments and automatic data collection methods. The operation of reference networks will require the greatest level of training and higher standards for calibration, inspection, maintenance and management.
- (e) Observing networks, both ground-based stations and space-based systems, and their telecommunications should be designed to be robust against exposure to severe weather and hydrological, climate and other environmental conditions (such as geomagnetic storms or space debris in case of satellites).

⁴ See the GAIA-CLIM Report/Deliverable D1.3. Gap Analysis for Integrated Atmospheric ECV Climate Monitoring: Report on System of Systems Approach Adopted and Rationale (<http://www.gaia-clim.eu/workpackagedocument/d13-report-system-systems-approach-adopted-and-rationale>).

- (f) A combination of standard and backup power sources (sustainable sources such as solar, water and wind for ground-based stations and other appropriate sources for satellites) should be used whenever possible to better ensure uninterrupted operation of observing platforms in all environmental conditions.
- (g) When possible, data should be made available to global collection centres where data monitoring can be performed and feedback provided in near real time regarding data quality, including the frequency and character of observational errors, reporting percentages, completeness and timeliness.
- (h) Monitoring procedures described under [principle 6](#) should also help in assessing the current and long-term reliability and stability of networks.
- (i) The functioning of the operations of an observing network and its components should be monitored and supported by incident/fault management in order to improve the reliability and stability of a network.
- (j) For climate monitoring, special attention should be given to maintaining stations/satellite orbits with long, historically uninterrupted records and to maintaining their homogeneity in location, instrumentation and observing procedures.
- (k) Parallel long-term data storage (for example, on site) should be designed to augment real-time dissemination, which will help ensure that original observations are preserved (for example, on site) to allow for the higher level of quality and completeness required for climate applications.
- (l) Station sites/satellite orbits should be selected in areas least likely to be impacted by factors such as new construction that will force station relocations.

Principle 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 that meet the needs of regional and global applications.)

- (a) Data availability gaps with respect to the stated user requirements must be addressed. Members should: (i) make efforts to collect and disseminate observations that are made but not currently collected centrally; (ii) exchange existing data internationally in accordance with the *Manual on the WMO Integrated Global Observing System* (WMO-No. 1160); and (iii) improve data timeliness.
- (b) Mechanisms should be established to minimize the loss of existing observational data and to promote the recovery of historical records for climate applications.
- (c) Multiple and overlapping methods of dissemination (for example, through multiple routes) that comply with the Technical Regulations should be used to improve continuity of data delivery to users.
- (d) Cloud concepts and other methods for expanding telecommunication capacities should be considered for managing the rapid growth in data volumes of 2D- and 3D-scanning remote-sensing observing systems (such as satellites and radars).
- (e) To facilitate data availability and access, WMO-defined standard data formats should be used for data exchange.

For climate applications

- (f) All raw data and agreed subsets of processed data should be collected into a documented and permanent data and metadata record following common standards (see, for example, the *Guideline for the Generation of Datasets and Products Meeting GCOS Requirements*, GCOS Report No. 143 (WMO/TD-No. 1530)) and archived in a World Data Centre or other recognized data centre.
- (g) A sustained operational capability is required to produce and maintain the archived data record throughout and after the life of the observing network.
- (h) Resources should be allocated to ensure appropriate reprocessing of observational data to respond to the needs of climate applications.

Principle 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.)

- (a) Metadata practices should adhere to the WIGOS Metadata Standard as specified in the *Manual on the WMO Integrated Global Observing System* (WMO-No. 1160) and the *WIGOS Metadata Standard* (WMO-No. 1192).
- (b) Members should follow standard procedures to collect, check, share and distribute the WIGOS metadata that are required for international exchange, to ensure appropriate homogeneous use of the observational data and knowledge of their quality and traceability; additional WIGOS metadata should be recorded by Members and made available on request.
- (c) Station metadata should be created at the time of network installation and updated regularly to include information such as station location, the surrounding environment, instrumentation type and calibration metrics, observing practices and maintenance. Whenever possible, photographic images of the station and environment should be made and archived annually.
- (d) WIGOS metadata should be updated whenever changes occur, including changes in sheltering and exposure, mean calculations, observation hours, land use, instrument types, quality control, homogenization and data recovery procedures.
- (e) Wherever possible, users should be given advance notice of changes in instruments and data processing.

Principle 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.)

Note: In this context, “sustainable” means that the network can be maintained in the medium to long term. This is desirable for most operational applications and is required for climate monitoring. Requirements for systems to be robust and for their data to be of appropriate quality are discussed under other principles.

- (a) Where appropriate, some research-based systems, namely those that are mature and cost-effective, should evolve to a status of secure, long-term funding, while maintaining or improving the availability and quality of the observations.

- (b) The transition of research observing systems or new observing technologies to long-term operations requires careful coordination between data providers and users (both research and operational users).
- (c) Members should ensure that their funding for the sustained networks remains sufficient in the longer term taking into account the required evolutions and changes (for example, in technology). (See also [principle 12.](#))
- (d) The transition of research-based observing systems or new observing technologies to long-term operations should include the design of robust and maintainable systems that assure appropriate data collection, quality control, archive and access.
- (e) Members should take steps to make preoperational data available to users on a best efforts basis to facilitate early uptake and adoption of the new data, once operational.
- (f) A written agreement for the operational collection and archive of observations should be made with a recognized archive centre.
- (g) When selecting sites/stations/satellite orbits, network planners and administrators should consider locations that can be secured through long-term agreements (for example, leases or ownership for ground-based observing sites).
- (h) Other useful guidance material is available in the *GAIA-CLIM Report/Deliverable D1.3. Gap Analysis for Integrated Atmospheric ECV Climate Monitoring: Report on System of Systems Approach Adopted and Rationale* (see footnote 4 for reference information).

Principle 12. Managing change

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

Note: When considering which changes might be consistent with WMO strategy, reference should be made to the [Implementation Plan for the Evolution of Global Observing Systems \(EGOS-IP\)](#) (WIGOS Technical Report No. 2013-4).

- (a) The impact of new systems or changes to existing systems on user applications should be assessed prior to implementation, taking into account the observational user requirements of all application areas.
- (b) A suitable period of overlap between old and new observing systems⁵ is required (meaning parallel observations) to maintain the homogeneity and consistency of observations in time.
- (c) Test beds and pilot projects are required through which new systems can be tested and evaluated and guidelines for operational transition (including the production and dissemination of the necessary new metadata) developed.
- (d) The objective tools assessing the impact and benefit of observations for certain application areas should be used, where possible, to support change management. (See also [principle 4.](#))

For climate applications

- (e) To avoid gaps in the long-term record, continuity of key measurements should be ensured through appropriate strategies.

⁵ See the *Manual on the WMO Integrated Global Observing System* (WMO-No. 1160), 2.4.6.3; the *Guide to Instruments and Methods of Observation* (WMO-No. 8), Volume III, 1.1.3; the *Guide to Climatological Practices* (WMO-No. 100), 2.6.7; and the *Guide to the Global Observing System* (WMO-No. 488), 3.2.1.4.4.4 and 3.7.4.

- (f) When a period of overlap between old and new systems is not possible, other methods, such as paired observations (co-location of original and new instrumentation), should be used.
 - (g) When introducing a change, efforts should be made to retain as many similarities as possible between the old and new system (for example, similar site exposure for ground-based systems, similar orbital position for space-based systems, similar procedures, instruments and sensors).
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ANNEX. EXPLANATION OF TERMS RELATED TO OBSERVING NETWORK GUIDANCE

Note: Formal definitions of terms are published in the *Technical Regulations* (WMO-No. 49) rather than in Guides.

An **integrated station network** consists of multi-purpose stations and/or stations of different types in the same geographical area in which agreed WMO practices are applied.

A **tiered network** is a network designed in accordance with (or following) an industry standard hierarchical network model. Tiers are used to organize subnetworks into groups within a domain network. A domain network is composed of one or more tiers forming either a hierarchy of tiers or partitioned groups of tiers. A single tier defines a collection of individual subnetworks that all have the same subnetwork definition.

Third parties are persons or organizations who are not a party to a contract or a transaction but are involved. The third party normally has no legal rights in the matter, unless the contract was made for the third party's benefit.

6. GUIDANCE ON NATIONAL WIGOS IMPLEMENTATION

6.1 INTRODUCTION

The purpose of this chapter is to assist WMO Members in developing their National Observation Strategy and National WIGOS Implementation Plan and to enable them to design, plan and develop their national observing system (NOS) as a national WIGOS observing component.

This chapter is aligned with WIGOS-related technical regulations and guidance material developed under the governance of the Inter-Commission Coordination Group on WIGOS (ICG-WIGOS).

6.2 NATIONAL WIGOS IMPLEMENTATION

For WIGOS to deliver on its vision for "an integrated, coordinated and comprehensive observing system to satisfy, in a cost-effective and sustained manner, the evolving observing requirements of Members in delivering their weather, climate, water and related environmental services", commitments and actions are required at the global, regional and national levels.

National Meteorological and Hydrological Services (NMHSs) of Members are expected to become the key integrators at the national level, both by strengthening their own observing systems in accordance with the regulations and guidance provided by the WIGOS framework, and by building national partnerships and providing national leadership based on their experience in the acquisition, processing and dissemination of observational data for environmental monitoring and prediction purposes.

The leadership of NMHSs in integrated observing systems and the engagement of national partners are central to the success of WIGOS implementation. WIGOS provides NMHSs with an opportunity to strengthen their role in all aspects of their national mandates, including national coordination and exchange of observations across all relevant domains (weather, climate, hydrology, space weather, ocean, atmospheric composition, cryosphere, environment, etc.) and to reinforce their status as the national meteorological and hydrological service provider of choice.

Proactive engagement with all relevant stakeholders, users and partners, is a great opportunity to build stronger relationships. Both formal and informal, regular and ad hoc, productive two-way communication with stakeholders is needed.

National Meteorological and Hydrological Services are operating in a rapidly changing environment in terms of technological advances and the growing demand for more and more diverse services from increasingly sophisticated and capable users. Technological advancements and related trends such as big data and crowd sourcing, the emergence of commercial observing networks, data and service providers, and the affordability of digital technology, all are game changers that require rapid adaptation and change in behaviour in both the NMHSs and the private sector.

The private sector may contribute by accelerating the uptake of technological innovations, and might be able to assist NMHSs in providing more efficient, attractive and accessible personalized services. National Meteorological and Hydrological Services will benefit from working with private sector partners to introduce those innovative methods into their own operations. There are many opportunities for optimization and efficiency through integration of networks, computing power and service delivery.

By the Eighteenth World Meteorological Congress (2019), all Members should be “WIGOS ready”. According to the plan for the WIGOS preoperational phase¹ this implies:

- (a) **OSCAR/Surface**: WIGOS metadata completed for all observing stations across all WIGOS components for which observations are exchanged internationally;
- (b) WIGOS metadata: compliance achieved;²
- (c) WIGOS Station Identifiers implemented;³
- (d) WIGOS Data Quality Monitoring System (WDQMS): information on the national process for dealing with data quality issues received from the WDQMS in place;
- (e) Embracing all NMHS-operated observing systems and willing partners;
- (f) National WIGOS governance, coordination and implementation mechanisms established;
- (g) Nomination of national WIGOS focal points and OSCAR focal points completed.

Further expected outcomes, at a minimum, can be as follows:

- (a) Enhanced national integrated observing system delivering better and better documented observational input to support the needs of national services in a more cost-effective way;
- (b) Increased integration and open sharing of observations from WMO and non-WMO sources across national and regional boundaries;
- (c) Progressively greater availability and quality of WIGOS observational data and metadata;
- (d) Increased visibility and stronger role of NMHSs at the national level;
- (e) Enhanced cooperation with partners at the national and regional levels;
- (f) Enhanced culture of compliance with the Technical Regulations (WMO-No. 49), Volume I, Part I – The WMO Integrated Global Observing System, and the *Manual on the WMO Integrated Global Observing System* (WMO-No. 1160);
- (g) Improved human and technical capacity of Members for planning, implementation and operation of WIGOS.

To achieve the above, the following key activities are envisaged at the national level:

- (a) Analysis of current and future national strategic requirements, needs and priorities, and biggest gaps in observations, systems, processes, capabilities, etc.;
- (b) Analysis of the national implications of the WIGOS concept of integration, partnerships and data sharing, and of WIGOS relevant technical regulations and culture of compliance;
- (c) Development of a National WIGOS Implementation Plan;
- (d) Critical analysis of capabilities and gaps (systems, processes, people, networks, governance, issues of compliance);
- (e) Specification of expected deliverables, outcomes, milestones and key performance indicators for national WIGOS implementation;

¹ *Executive Council, Sixty-eighth Session: Abridged Final Report with Resolutions and Decisions* (WMO-No. 1168), Resolution 2.

² See the *Manual on the WMO Integrated Global Observing System* (WMO-No. 1160), 2.5.

³ See the *Manual on the WMO Integrated Global Observing System* (WMO-No. 1160), 2.4.1.

- (f) Establishment of governance and key relationships.

6.2.1 **Development of a National Observing Strategy: understanding national needs and priorities**

Development of a National Observing Strategy will enable the NMHS to better meet user needs and demands, and will help ensure that the NMHS has the best basis for planning its investment in systems, science and people. It will also allow the NMHS to make informed decisions, based on user requirements, for future planning purposes. The four key principles of the Strategy are: (1) demand- and user-driven products and services; (2) a phased approach to implementation; (3) effective partnerships; and (4) building on core strengths.

The Strategy will recognize the NMHS as a strategic national asset that contributes to the security of transport, food, water, energy and health (Key Pillars of the GFCS) in addition to being vital to sustainable development, climate change mitigation and adaptation, and disaster risk reduction. To that end, the National Observing Strategy should be well aligned with the overarching vision, mission and strategic plan of the NMHS. It should also set the scene for the partnerships that will be sought in implementing WIGOS.⁴

The National Observing Strategy provides the overall strategic framework for implementing WIGOS and should take into account the needs and goals of users and the broader environmental observing community, including the marine, atmospheric, hydrological and cryospheric observing communities. These may be considered partners in the implementation of WIGOS.

Examples of National Observing Strategies can be found at:

- (a) www.wmo.int/pages/prog/www/wigos/documents/Principal_Docs/OSS_eBook.pdf;
- (b) <http://bibliotheek.knmi.nl/knmipubmetnummer/knmipub233.pdf>.

6.2.2 **Development of a National WIGOS Implementation Plan**

The National WIGOS Implementation Plan (N-WIP) builds on the National Observing Strategy and specifies expected deliverables and outcomes, priorities, activities, milestones, timeline, resources, responsibilities and key performance indicators needed for:

- (a) Establishment of national (and subregional/cross-border when appropriate) WIGOS governance and coordination and management mechanisms for planning, implementation and coordination of the national observing systems in place;
- (b) Development of key national partnerships/relationships;
- (c) Design, planning and evolution of the national composite observing system, including identification and mitigation of critical gaps (implementation of the national Rolling Review of Requirements (RRR));⁵
- (d) Gap analysis of WIGOS-related systems, processes, people, governance, issues of compliance;
- (e) Sustained and standardized operation of national observing networks/systems in compliance with the *Technical Regulations* (WMO-No. 49), Volume I, Part I – The WMO Integrated Global Observing System, and the *Manual on the WMO Integrated Global Observing System* (WMO-No. 1160);

⁴ See also *WMO Integrated Strategic Planning Handbook* (WMO-No. 1180).

⁵ See *Manual on the WMO Integrated Global Observing System* (WMO-No. 1160), 2.2.2, and Chapter 5 of this Guide.

- (f) Operational implementation of WIGOS Metadata Standard through populating the OSCAR/Surface database and keeping its content up to date;
- (g) Operational implementation of WIGOS Station Identifiers;
- (h) Monitoring the availability and quality of observations through the national WDQMS, and taking corrective action as necessary (incident management);
- (i) Systematic and rigorous performance monitoring and evaluation of WIGOS capabilities;
- (j) Increased integration and open sharing of observations from NMHSs and non-NMHSs sources;
- (k) Development and implementation of a data and information framework;⁶
- (l) Implementation of modern data lifecycle management and practices;
- (m) Availability and protection of suitable radiofrequency bands required for meteorological and related environmental operations and research;
- (n) Development of an effective resource mobilization strategy;
- (o) Development of a risk management plan;
- (p) Development of a workforce plan or a capacity development plan of the staff managing and operating national observing networks/systems.

The N-WIP is intended to put the national WIGOS framework in place, not to fix all problems and issues. It is a tool to start planning observation improvements. It should be realistic and achievable.

6.2.3 Planning

Planning is the first step in the so-called **Plan-Do-Check-Act (PDCA) Cycle**, whose chief aim is to ensure continued improvement of a given service or product, in the case of WIGOS observations flowing to the WMO community. In WIGOS implementation, it is important to maintain an integrated view of user requirements and corresponding capabilities based on the RRR process.

To fully embrace the WIGOS concept at the national level requires an integrated approach to the design, planning and operation of the full suite of national observing systems. This means, in effect, operation of a national composite observing system (that is, a system of systems) that is optimized to address diverse user needs as efficiently and effectively as possible and with just enough redundancy and overlap to provide resilience and continuity.

The implementation of a national RRR process will help Members understand and assess user requirements, define the characteristics of the observations required and design the system solutions that will deliver them; it is a tool for the coordinated evolution of NOS enabling Members to tackle those requirements in an integrated way.

A comprehensive strategic and operational planning process will then allow the development of staged approaches to the design, development and implementation of new and improved systems, processes and networks, supported by well-structured business cases and budget proposals. Budget shortfalls may of course limit or delay the achievability of the overall plans, but the information gained through the RRR process will still inform decisions on priority use of existing resources.

⁶ See example at http://www.bom.gov.au/inside/BoMDataFramework_Final.pdf.

Planning includes close collaboration and coordination with all users to assess their requirements; a review of the existing components of NOS; an assessment of their adequacy in meeting current and future requirements; identifying future opportunities; prioritizing; and finally deciding on a strategy matched with resources.

Close collaboration and cooperation among the NMHS and other relevant national agencies; the establishment and implementation of appropriate mechanisms; and partnerships and data policy principles, while respecting ownership, are needed to meet WIGOS requirements at national level. This specifically refers to enhanced cooperation among meteorological, hydrological and marine/oceanographic institutions/services where they are separated at the national level, as well as to national implementation mechanisms for related international observing programmes such as the Global Climate Observing System (GCOS), Global Ocean Observing System (GOOS) and Global Earth Observation System of Systems (GEOSS).

In addition to meeting requirements at the national level, the NMHS needs to address international commitments as part of the design, development and implementation of NOS. Driving forces likely to impact on the design, operation and required deliverables of NOS in the future include:

- (a) Need for a holistic approach to planning and evolution of NOS and enhanced integration of its components;
- (b) Growing demand for meteorological services overall, in contrast to decreasing public funding to support the necessary infrastructure;
- (c) Greater emphasis on climate monitoring and services in addition to continued demands for weather-related services;
- (d) Increased requirements for quality management, standardization and interoperability, efficiency and cost effectiveness;
- (e) Available or emerging technological opportunities.

The National WIGOS Implementation Plan should reflect the Member's national situation, in terms of the mandate of its NMHS, the requirements of the user community and the need to reach out to partners to develop an integrated observing system that meets national service needs. It should link the NMHS with its national partners for increased integration and open sharing of observations, including those from non-WMO sources.

There is no one-size-fits-all approach. WMO Members and their NMHSs differ in size and available resources, whether financial, technical or scientific, therefore, their N-WIPs will naturally differ both in content and style. While Members can learn from the plans and experiences of others, through case studies and workshops, they will be provided with additional WMO guidance materials to help them understand the various steps in the planning process.

In developing their national WIGOS implementation plans, Members should be guided by the Key Activity Areas (KAAs) of the WIGOS framework Implementation Plan (WIP) that are the building blocks of the WIGOS framework, as well as by the [Regional WIGOS Implementation Plan](#) of the respective regional association.

The WIGOS National Self-assessment Checklist was developed to help Members better understand the WIGOS Framework to be implemented in their countries; to help Members assess their readiness for implementation and the challenges ahead of them, but especially to recognize that WIGOS is a natural change process. The Self-assessment Checklist is also useful in assessing Member's priorities, plans, gaps and capabilities, and will provide the basis for developing an achievable national WIGOS plan.

Members are encouraged to draw on the WIGOS National Self-assessment Checklist; some examples are available at: <https://www.wmo.int/pages/prog/www/wigos/checklist.html>.

A wide range of other materials already exists to guide Members in relation to WIGOS, including the Implementation Plan for the Evolution of Global Observing Systems (EGOS-IP) and relevant plans for the Global Framework for Climate Services (GFCS), the Global Atmosphere Watch (GAW), the WMO Hydrological Observing System (WHOS), the Global Cryosphere Watch (GCW), and the Global Climate Observing System.⁷ Altogether, those materials help identify national priorities and gaps in observations, systems, processes and capabilities, and provide the basis for developing a national WIGOS plan. Alignment of WIGOS plans with national planning for GFCS, Disaster Risk Reduction (DRR), the WMO Information System (WIS) and other WMO priorities has considerable advantages:

- (a) Ensuring that the specific observation requirements for national planning are factored in as effectively as possible;
- (b) Capturing efficiencies and synergies and avoiding duplication of efforts and potential conflict;
- (c) Optimization and alignment of capacity development and project opportunities;
- (d) Demonstration to stakeholders and donors of the professionalism and coherent approach of the NMHS.

6.2.4 **Data management**

Careful management of data and their associated metadata is a vital aspect of any observing network/system, with real-time monitoring centres as well as with delayed-mode analysis centres. A key component of such data/metadata management is non-stop monitoring of the data stream with feedback and corrective action when needed. This implies timely quality monitoring of the observations by the monitoring centres and early notification (i.e. incident management) to observing system operators and managers of both random and systematic errors, so that timely corrective action can be taken. Such an operational system is needed to track, identify and notify network managers and operators of observational irregularities, especially time-dependent biases, as close to real-time as possible.

6.2.5 **Resources**

In a time of increasing demand for meteorological information and services and decreasing resources, it is of crucial importance to invest the available resources where they create the greatest benefit. The gap analysis of the RRR process will help identify such points.

The success of WIGOS implementation will depend critically upon ensuring adequate resources for both technical programme management and specific network needs. Data/metadata acquisition, processing and management systems that facilitate access, processing, monitoring, use and interpretation of the data with the help of associated metadata are of crucial importance.

It is also important to recognize that WIGOS activities are primarily the responsibility of the individual WMO Members and that the cost should be covered by national resources. WIGOS implementation requires planning, priority setting and committed effort over a considerable number of years. Members' experience has shown that substantial changes in the national observing system depend on considerable adjustments to resource commitments. Such adjustments are not easy without planning and priority setting with a long lead time.

⁷ The corresponding links will be included in due course.

6.3 **CONCLUSION**

Establishing a comprehensive “system of systems” that meets the observational needs of multiple users and applications areas requires effort, and each Member will need to assess the size of that challenge and weigh up the costs and benefits. Through the engagement of non-NMHS organizations in a national “system of systems”, the NMHS may consolidate and strengthen its role as the national meteorological authority, especially in areas where it may not already be firmly established, for example in climate monitoring and delivery of climate services. Integration does not mean that “one size fits all”. Where opportunities exist to serve multiple needs with a single solution, real efficiencies can be achieved, but as a rule, integration is more about finding an optimum balance between needs and solutions.

As the integration process moves forward, gaps and shortcomings, incompatibilities, deficiencies in national observing system capabilities and duplication of efforts will be identified and addressed. This is the most cost-effective and efficient way to make better use of existing infrastructure and improve the timeliness, quality and utilization of observational information for enhanced services and decision-making.

ANNEX. PLANNING AND MANAGEMENT TOOLS

1. THE PLAN-DO-CHECK-ACT CYCLE

The Plan-Do-Check-Act (PDCA) cycle is an efficient tool for continual improvement. The methodology applies to both high-level strategic processes and to simple operational activities. It consists of:

- (a) **Plan:** planning the improvement on the basis of the [gap analysis](#) (what needs to be done, where, when and how to do it; who should do it);
- (b) **Do:** implementing the plan;
- (c) **Check:** monitoring and measuring the results against the plan, requirements, policies and objectives;
- (d) **Act:** taking actions and measures to improve the process/performance.

Plan-Do-Check-Act is a continuous cycle that can be applied within any individual process or across a group of processes within the organization. Further information can be found at:

<https://asq.org/quality-resources/pdca-cycle>

<http://9001quality.com/plan-do-check-act-pcda-iso-9001/>

<http://9001quality.com/continual-improvement-process-iso-9001/>.

2. GAP ANALYSIS

The gap analysis is a technique for determining the steps to be taken in moving from a current state to a desired future state. It is also called “need-gap analysis” or “needs analysis”.

A gap analysis generally consists of five steps: (1) reviewing a current (as is) system; (2) determining the requirements of the proposed (future) system and (3) comparing the two in order (4) to determine the implications and (5) requirements in getting from one state (as is) to the other (future state). Key gaps identified in the observing capabilities will result in proposals for activities to fill these gaps, reflecting priorities and taking account of the resources available (see also: [Guidelines on the Role, Operation and Management of National Meteorological and Hydrological Services](#) (WMO-No. 1195)).

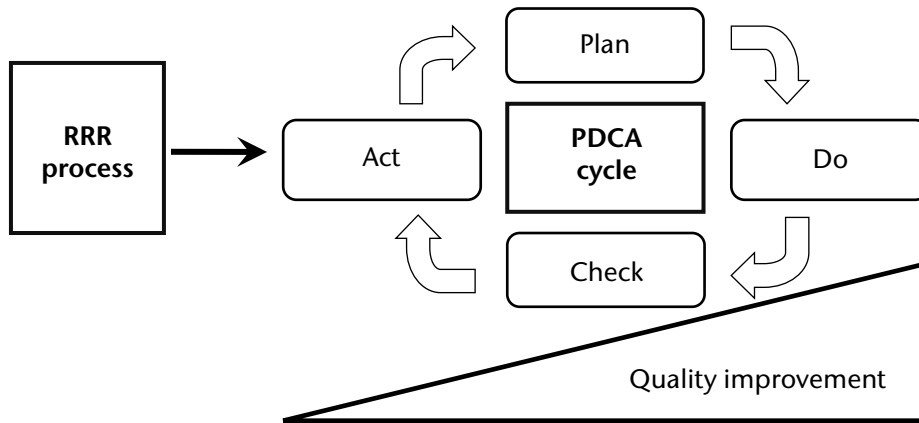
3. THE ROLLING REVIEW OF REQUIREMENTS

The Rolling Review of Requirements (RRR) described in the *Manual on the WMO Integrated Global Observing System* (WMO-No. 1160), section 2.2.4., is used to compare user observing requirements with the capabilities of present and planned observing systems to satisfy them. The process consists of four stages:

1. A continuous review of user requirements for observations;
2. A continuous review of the observing capabilities of existing observing systems and of available or emerging technological opportunities;
3. A Critical Review of the extent to which the capabilities (2) meet the requirements (1);
4. A Statement of Guidance based on (3).

The RRR process will continuously issue new Statements of Guidance to be implemented in the management of national observing systems. It is a process directly linked to the Act step of the PDCA cycle.

The relationship between the RRR process and PDCA cycle is shown in the figure below.



The Rolling Review of Requirements and the Plan-Do-Check-Act cycle

7. GUIDANCE ON WIGOS DATA PARTNERSHIPS – PART I

7.1 INTRODUCTION

WIGOS provides a framework for WMO to define and manage weather, water, climate and other observations required for WMO Programmes and to support the broader interests of WMO Members. With an Earth system perspective, WIGOS is designed to manage observations from a diversity of surface- and space-based observing systems across physical domains. These observations are acquired by a variety of players with the aim of providing an integrated, composite set of observations accessible to many users and are suitable for many service and science applications. An integrated and comprehensive set of observations across the atmospheric, terrestrial and oceanic domains is necessary to support the range of important national and global issues such as climate change, sustainable development, and human and ecosystem health.

The implementation of WIGOS is initially focussed on the integration of existing WMO Observing Systems,¹ which are predominantly, though not exclusively, operated by National Meteorological and Hydrological Services (NMHSs) and their established partners. However, WIGOS also encourages and enables the integration of observations from new partners such as other governmental and non-governmental organizations, research institutes, volunteer networks, the private sector and individual citizens. It is known that useful observations of Earth system variables are being collected by these stakeholders, but their incorporation into WMO observing systems has been constrained by the lack of an integrating framework and by a variety of technical barriers. WIGOS now offers the framework and tools to enable these observations to be integrated, thus contributing more effectively to national and global interests.

The implementation of WIGOS also presents an opportunity for Members to better coordinate and strengthen their national observing capabilities in support of their national priorities. WIGOS provides tools for the analysis of observation needs and gaps, and encourages NMHSs and other observing system operators to coordinate their efforts to address them. On behalf of Members, NMHSs promote and facilitate the adoption of WIGOS in their countries, and other observing system operators are invited to explore this opportunity with them.

7.2 PURPOSE AND SCOPE

This chapter is Part 1 of *Guidance on WIGOS Data Partnerships* with additional material to follow. It provides guidance on integrating observations from non-NMHS sources into WIGOS and addresses the mutual benefits of data sharing and the challenges associated with such integration. It also highlights the roles and expectations of NMHSs in encouraging and facilitating the integration process.

This Part focuses on surface-based meteorological observations, although the principles and general guidance are broadly applicable to other types of observation. This initial focus was chosen because surface meteorological stations are considered to be the most numerous and widely available sources of additional observations and can, therefore, enhance overall national (and in turn global) observation sets. In parallel, several WMO communities (such as the Global Atmosphere Watch (GAW), the Global Cryosphere Watch (GCW), the Global Climate Observing

¹ These include: the Global Observing System (GOS), the observing components of the Global Atmosphere Watch (GAW) and the Global Cryosphere Watch (GCW), the World Hydrological Observing System (WHOS), and WMO contributions to co-sponsored systems (Global Climate Observing System (GCOS), Global Ocean Observing System (GOOS), Global Terrestrial Observing System (GTOS)), the Global Framework for Climate Services (GFCS) and the Global Earth Observation System of Systems (GEOSS).

System (GCOS) and the Joint WMO/IOC Technical Commission for Oceanography and Marine Meteorology (JCOMM)) are leading the integration of related observations into WIGOS, including the incorporation of observations from partner organizations.

7.3 INTENDED AUDIENCE

While primarily intended to support NMHSs in their national implementation of WIGOS, this chapter is relevant to both NMHS and non-NMHS audiences.

Sections 7.5 and 7.6 are intended primarily for Permanent Representatives with WMO, NMHS Directors, and senior managers serving as the national promoters and implementers of WIGOS. These sections contain the principles and general guidance for establishing and maintaining partnerships with operators of observing systems. Those principles are also of relevance to non-NMHS organizations considering a data partnership with their NMHS.

Section 7.7 is intended primarily for NMHS Observing System Managers in their role as technical leads and facilitators of national WIGOS implementation. This section provides technical guidance on how to integrate observational data from other sources in compliance with the *Manual on the WMO Integrated Global Observing System* (WMO-No. 1160). This section is also of relevance to technical managers from non-NMHS organizations enabling them to understand the technical implications of sharing their observational data with an NMHS.

7.4 EXPLANATION OF TERMS

Within WIGOS, “observations” and “observational data” refer to the result of the evaluation of one or more elements of the physical environment. These terms include observational metadata – descriptive information about observations that is needed (a) to assess and interpret the observations or (b) to support the design and management of observing systems and networks. Observations and metadata may come in paper or electronic format, but now the terms predominantly refer to electronic data handled by information and communication technology (ICT).

In this publication, “non-NMHS observational data” refers to observations and metadata that are collected by organizations outside an NMHS. “Non-NMHS operators”, “non-NMHS providers” and “partners” refer to the organizations or individuals outside NMHSs that operate observing systems or networks. The nature of the relationship between an NMHS and a non-NMHS operator can vary widely, from a partnership for mutual benefit to a commercial contract, however, the generic term “partnership” is used in this publication to cover the full range of such relationships.

7.5 PRINCIPLES

7.5.1 Data sharing for mutual benefit

Integrating observations from diverse sources into WIGOS supplements NMHS observations and ultimately leads to better NMHS services and broader benefits for Members. Yet there must also be incentives for non-NMHS operators to share their observations with an NMHS and potentially with the international WMO community. A key principle of successful and sustained observation partnerships is the recognition of mutual benefit based on common organizational interests and strengthened collaboration.

7.5.1.1 ***National Meteorological and Hydrological Services***

National Meteorological and Hydrological Services are typically supported by their national governments in establishing and operating an observing system to carry out their core mandate. Depending on the national situation, the NMHS is often responsible for weather and climate observations, and may also be responsible for hydrologic, ocean, and other observations. The increased demand for hydrometeorological services and products at ever finer spatial scales has led to a growing demand for spatially denser and more integrated observations across these domains. At the same time many NMHSs are facing increasing logistical and economic challenges in supporting their current observing systems, and they may be unable on their own to deploy observing networks that meet those new requirements. In this context, it is logical for NMHSs to look to other operators as sources of observational data. More broadly, Member governments are continually seeking more cost-effective approaches to meeting their needs, including opportunities such as WIGOS to maximize the value of existing national observing capabilities.

The overarching goal in integrating more observational data within WIGOS is to keep pace with user expectations and to improve the quality and value of Members' services, products, and science. Beyond national interests, there is also the broader goal of improving the quality of global services and science through the international exchange of observational data across WMO. In this context, the incentives for NMHSs to enter into observational data partnerships include:

- (a) Filling observation gaps:
 - (i) Increasing the density and timeliness of observations especially in high-impact locations or observation-sparse regions, or for parameters not observed by the NMHS;
 - (ii) Improving access to real-time observations of current conditions for situational awareness and nowcasting;
- (b) Cost-efficiency:
 - (i) Gaining access to observations at no or low cost;
 - (ii) Gaining access to observing sites with power and communications infrastructure;
 - (iii) Gaining access to non-NMHS secure and monitored observing sites (for example, to prevent vandalism);
 - (iv) Reducing infrastructure and operating costs through contracting out of station operations;
- (c) Strengthening national observing capabilities:
 - (i) Establishing a more complete and robust national observing system to support a wide diversity of NMHSs and other national applications;
 - (ii) Improving observation quality assessment and quality control by using redundant and/or diverse sources of observations;
 - (iii) Raising the overall quality and reliability of national observations through outreach to non-NMHS operators, training, promotion of standards and, potentially, national policies or regulations;
- (d) Strengthening NMHS leadership and visibility:
 - (i) Exercising and demonstrating national leadership through broad engagement and coordination, including with the general public;

- (ii) Strengthening the commitment of NMHSs and the effectiveness of their mission;
- (iii) Reducing complaints or criticism, through active engagement with other organizations and the general public.

7.5.1.2 **Non-NMHS operators**

Non-NMHS operators have invested in observing systems to meet the specific needs of their organizations or for other reasons. Many also recognize that observations may benefit the broader community. Non-NMHS operators may include other governmental organizations, research institutions, the commercial sector, academia, voluntary organizations and private citizens. The needs of these operators vary widely depending on the type of organization and its needs. Consequently, the incentives to share observational data with NMHSs or internationally with WMO Members are also very diverse.

The incentives for non-NMHS operators to enter into observational data partnerships include:

(a) Operational requirements:

Observational data that are shared with NMHSs and WMO improve the weather, water and climate products and services that support their operational needs or interests;

(b) Access to other observations:

Observational data are provided to NMHSs in order to leverage access to a larger pool of observations from other national sources, or to access the global observational data exchanged among WMO Members;

(c) Business opportunity:

The commercial sector wishes to sell or license observational data to NMHSs for profit or for cost recovery;

(d) Association with a public-good programme:

The visible contribution of observational data to a recognized national or international public-good programme lends significant credibility to many observing programmes and is frequently leveraged to justify funding;

(e) Quality assurance and observational data management:

Observational data are provided in exchange for authoritative quality assessment by the NMHS, and/or for long-term preservation in climate archives;

(f) Technical support:

Observational data are provided in exchange for authoritative guidance and assistance from the NMHS in technical matters such as equipment, station configurations, standards, calibration and maintenance;

(g) Volunteerism:

Observational data are provided by organizations or citizens as a contribution to the public good or for scientific record;

(h) Operational support:

Organizations seek to transfer station operations to NMHSs in cases where they may have resources to buy equipment, but have no technical capability to operate it.

Many observational data partnerships are voluntary and rely on the mutual interest and goodwill of the participants to make the partnership work. Nevertheless, well-documented agreements to define and manage the partnership are common and are highly recommended. These arrangements can vary greatly in content, formality and enforceability, ranging from best-effort Memoranda of Understanding to more formal Letters of Agreement or legally binding contracts. Section 7.6.4 – Establishing and sustaining observation partnerships – provides more details.

7.5.2 **WIGOS observational data quality**

Quality is one of the most frequently expressed concerns about observations from non-NMHS sources. Knowledge of the quality of observations is an important factor in the credibility and authority of NMHS and WMO products and services, so the use of other observational data without sound knowledge of the collection and processing procedures is considered by many as a risk to the overall quality of NMHS and WMO programmes.

WMO has historically used a “controlled and documented quality” approach to observational data quality. Quality is managed through well-defined, end-to-end technical standards and recommended practices to which NMHSs and other operators are expected to adhere. Thus quality is controlled through a rigorous process. Many non-NMHS operators are unaware, unable or unwilling to adhere to WMO quality requirements as they are often considered too stringent or expensive for their internal needs. As a result, the real quality of much non-NMHS observational data is largely unknown.

On the other hand, there are many non-NMHS organizations that operate well-controlled systems to high standards and provide high-quality, well-documented observational data, for example for aviation, road weather, wind energy, climate and hydrological applications. Some organizations also operate under the ISO/IEC 17025:2005 standard (*General requirements for the competence of testing and calibration laboratories*) to satisfy their business requirements. Another example of an observational data quality standard is *Quality Assessment Using METEO-Cert – The MeteoSwiss Classification Procedure for Automatic Weather Stations* (Instrument and Observing Methods Report No. 126) which is applied to non-NMHS operators’ stations at the time of inspection.

To address the issue of observational data quality, WIGOS has adopted an approach based on the principle of documented known quality. This approach seeks to maximize the descriptive metadata associated with an observation in order to allow the user to understand how the observational data was produced and to assess its appropriateness for the intended application. The user, for example, will be able to assess whether an observation meets aviation standards or is suitable for long-term climate monitoring.

This approach is adaptable to a range of observing systems and practices, and accommodates the real-world variability of observational data from different observing system operators. This is especially helpful in supporting operators where compliance with equipment and operating standards is uneven or lacking. The approach also supports the informed use of the same observations for multiple applications. The principal tool for supporting the “known quality” approach is the [WIGOS Metadata Standard](#) (WMO-No. 1192) (see also 7.7.2 below).

7.5.3 **Roles and responsibilities**

The successful integration and use of observations from multiple sources require collaboration and coordinated activities across several entities within WIGOS. These include NMHSs, regional associations, Regional WIGOS Centres (RWCs) and the non-NMHS partners that contribute data to WIGOS.

7.5.3.1 ***National Meteorological and Hydrological Services***

As national authorities for weather, water and climate information, NMHSs have a national leadership role in the continued improvement of national observing capabilities that build on WIGOS principles, practices and procedures.

The principal role of NMHSs with respect to non-NMHS observations includes:

- (a) Leading the implementation of WIGOS at the national level through the development of a National Observing Strategy and a National WIGOS Implementation Plan;
- (b) Managing the assignment of WIGOS Station Identifiers for national stations;
- (c) Engaging and encouraging national non-NMHS operators to contribute their observations to a consolidated pool of observational data for the benefit of all at the national, regional or global level;
- (d) Articulating and exploring with non-NMHS operators the benefits of contributing and sharing their observational data with NMHSs and WMO programmes;
- (e) Developing and maintaining agreements with non-NMHS operators using suitable mechanisms (such as Memorandums of Understanding or contracts) which articulate the benefits of the partnership and specify the roles and responsibilities of the participants;
- (f) Encouraging and supporting the use of WIGOS standards (such as the WIGOS Metadata Standard) and tools (such as OSCAR/Surface) to the greatest possible extent for national observations;
- (g) Assessing the relevance, quality and sustainability of non-NMHS observations to support national and global programmes;
- (h) For observations of high global value, helping non-NMHS operators to be compliant with the WIGOS Metadata Standard to enable metadata compatibility;
- (i) Supporting outreach and training related to WIGOS, for instance, on WIGOS standards, recommended practices and procedures and mechanisms for observational data exchange;
- (j) Supporting effective observational data management and/or observational data sharing;
- (k) Encouraging and supporting the implementation of adequate cyber security mechanisms.

7.5.3.2 ***Regional associations and Regional WIGOS Centres***

Regional associations and Regional WIGOS Centres are uniquely positioned to support WIGOS implementation beyond national borders.

The principal role of regional associations with respect to non-NMHS observations includes:

- (a) Managing the Regional Basic Synoptic Network (RBSN) and the Regional Basic Climatological Network (RBCN) and their transition to a Regional Basic Observing Network (RBON);
- (b) Identifying issues and opportunities of regional importance where cross-border coordination of non-NMHS observations would be beneficial (for example, across international watersheds; see La Plata Basin WIGOS-Southern South America (WIGOS-SAS case study));

- (c) Establishing regional/subregional coordination mechanisms to support cross-border WIGOS activities, including the coordination of observational data from non-NMHS sources, and, potentially, coordinating the response to observational data issues and incidents identified by the WIGOS Data Quality Monitoring System (WDQMS).

In addition, Regional WIGOS Centres will play a critical role in advancing the implementation of WIGOS within their region (or subregion) and will provide regional coordination and technical support to Members.

7.5.3.3 **Non-NMHS partners**

The contribution of observations by non-NMHS organizations is generally voluntary, but partners are expected to support an effective WIGOS. National Meteorological and Hydrological Services are encouraged to support non-NMHS partners in performing their role.

The principal role of non-NMHS partners includes:

- (a) Identifying and sharing observations of relevance to meet national needs and support national priorities, and potentially sharing observations internationally;
- (b) Providing WIGOS metadata to ensure the appropriate use of the observations;
- (c) Maintaining WIGOS metadata up to date via OSCAR/Surface, in collaboration with NMHSs;
- (d) Developing and maintaining an agreement with NMHSs (or other collaborating organizations) which articulates the benefits of the partnership and specifies the roles and responsibilities of the participants;
- (e) Implementing to the greatest extent possible NMHS, national and WMO standards and recommendations regarding the collection of observations and data management.

7.6 **GENERAL GUIDANCE**

7.6.1 **Non-NMHS observational data of relevance to WIGOS and national observing systems**

The overall aim of gaining access to observational data from non-NMHS sources is to increase the number of relevant observations to support Members' and WMO programmes. But what kind of observational data should be sought and what factors should be considered in assessing non-NMHS observational data opportunities?

7.6.1.1 **WIGOS requirements**

The observational requirements to support WMO Programmes are established through the [Rolling Review of Requirements](#) (RRR), and critical gaps in the observing system are identified in Statements of Guidance. For Members, the key reference for WIGOS observational requirements and systems is the Observing Systems Capability Analysis and Review tool (OSCAR).

The [OSCAR/Requirements](#) database is the official repository of [requirements](#) for the observation of geophysical [variables](#) in support of all activities of WMO and its various co-sponsored programmes. The database provides a listing of the observational requirements for all WMO application areas as listed in the *Manual on the WMO Integrated Global Observing System* (WMO-1160). The database also provides a description of geophysical variables, as well as minimum and desirable figures for the uncertainty of the measurement, resolution, frequency and timeliness.

The [OSCAR/Surface module](#) is the official repository of WIGOS metadata for all surface-based observing stations and platforms registered with WMO. The module provides a description of the observing sites (through WIGOS metadata) and an interactive map to display the geographic location of those sites. It is mandatory that stations be registered in OSCAR/Surface for observations to be exchanged internationally.

These tools may also be used to support assessments of the adequacy of existing observing systems to meet the needs of specific application areas, and to identify parameter and geographic gaps. Future releases of OSCAR are planned to include some level of automated analysis tool to provide further assistance with such assessments.

7.6.1.2 **National observational requirements**

WMO Members frequently have observational requirements beyond those specified in OSCAR in order to support national programmes and priorities. Observations are typically required to provide more geographically-detailed information or to support applications of high national impact such as those concerning agriculture, transport and flood forecasting. The requirements are driven by the needs of the specific application, the local environment and climatology, and by the national relevance of the application.

National or local observational requirements may or may not be formalized, but local relevance is often an incentive for non-NMHS organizations to establish their own observing capabilities – for instance, for agriculture or water management agencies. As a result, existing non-NMHS observing systems are often already well aligned with national or local interests and likely to be of high relevance to the NMHS as well. Such observations may also help address gaps in WMO requirements, and the opportunity for international exchange of these data should be sought. Citizen-operated or other stand-alone observing sites may also supplement the observations from more formal institutional partners.

7.6.2 **Data use and sharing**

As signatories to the WMO Convention, Members of the Organization have committed to “facilitate worldwide cooperation in the establishment of networks of stations for the making of meteorological observations as well as hydrological and other geophysical observations related to meteorology” (From [Basic Documents No.1](#), Convention of the World Meteorological Organization, Article 2 (a)).

Also, through their adoption of [Resolution 40 \(Cg-XII\)](#) they have committed to “broadening and enhancing the free and unrestricted international exchange of meteorological and related data and products”, and through [Resolution 25 \(Cg-XIII\)](#) to “broadening and enhancing, whenever possible, the free and unrestricted international exchange of hydrological data and products, in consonance with the requirements for WMO’s scientific and technical programmes”. [Resolution 60 \(Cg-17\)](#) further extends these principles to the exchange of climate observational data to support the Global Framework for Climate Services (GFCS).

Alongside these long-standing commitments, WMO Members also approved the *Manual on the WMO Integrated Global Observing System* (WMO-No. 1160), which in its Annex 2.1 lists the observing network design principles. Principle 9 explicitly states that observational data should be made available to other WMO Members: “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 that meet the needs of regional and global applications.”

It is clear, therefore, that the case for increasing the amount of observational data that is shared is very strong, and is indeed the underpinning infrastructure on which the services of NMHSs are built. It is also clear, however, that there remain significant barriers to the free exchange of observational data. A foundational principle of WIGOS is to expand the global observing systems

beyond those historically operated by NMHSs and to include networks operated by other entities, public as well as private. These additional networks may operate under a wide range of data policies:

- Some governments have committed to releasing taxpayer-funded data under an open licence, either through the auspices of an Open Data Charter or through an equivalent instrument. This simplifies the use and exchange of data, including observational data, from these sources because there are few restrictions on use or reuse.
- Private operators are increasingly offering their observations (typically surface-based observations, GPS-Radio Occultation and aircraft data) to NMHSs for use in the generation of products and services. The license terms are typically more restrictive than those in the above category and they may not allow onward sharing and exchange. Members are encouraged to seek licence terms that support at least Members' obligations regarding the exchange of observational data and, wherever possible, permit the open or broadest exchange.
- There has been a significant increase in the amount of observational data generated by private citizens in recent years. Data policies are often imposed by the operators of the data portal to which the individual chooses to submit their observations (for example, the UK Met Office [WeatherObservationsWebsite](#) (WOW), also used by the Australian Bureau of Meteorology). The sharing of these observational data amongst NMHSs can be challenging, however the observations are often free to view and download via the web.

As NMHSs consider how best to implement WIGOS in their national context, a comprehensive assessment should be conducted to understand what observational data could be available to support national interests and priorities. This could then shape a national implementation plan to use existing partnerships, create new partnerships where necessary, and ensure that the benefit of these observations can be realized.

7.6.3 **Legal considerations (liability)**

Many non-NMHS operators that contribute observations to NMHSs or WMO Programmes do so for the public good on a voluntary and best-effort basis. In general, these contributing organizations expect that they will not incur any legal risks as a consequence of any incorrect or missing observations. This is considered a reasonable expectation and should be a principle supported by NMHSs. For instance, the operator of a Voluntary Observing Ship should not risk a legal claim for third-party liability in the event that inaccurate or missing observations were a contributor in some way to a marine incident. If voluntary contributors of observational data were required to assume legal risks from their observations, this would limit their willingness to contribute and consequently reduce the benefits to all.

The WIGOS metadata will help users to assess the limitations and appropriate uses of observational data, while NMHS quality control procedures and the WIGOS Data Quality Monitoring System will seek to identify issues with the quality and the availability of observations. But the risk of faulty decision-making and legal action as result of flawed observational data provided by an external operator is still possible.

Most Members, their NMHSs and other governmental organizations are protected from such liabilities by national regulations. This immunity, however, cannot normally be transferred to non-governmental organizations, so NMHSs should seek to find mechanisms within their national laws to reduce the risk of liability for non-governmental partners, in order to obviate this potential barrier. For data that may be acquired and subsequently distributed by the NMHS through a partnership agreement, it may be possible, through the agreement, to transfer those risks to the government or to otherwise limit the risks for external partners.

There is a second dimension to liability to be considered in observational data partnerships. Participants may wish protection in the event that an action by one participant causes damage to the other, for instance, physical damage to equipment. Between agencies of the same

government these risks are often assumed by the participants, or mechanisms for recourse are clearly defined in advance in a partnership agreement. For partnerships with non-governmental operators, clear definitions and limitations of liability should be included in the agreement, although NMHSs may wish to consider liability only in the event of misconduct or wilful negligence (versus accidental damage) in order to minimize barriers to cooperation. For example, MeteoSwiss has successfully incorporated issues of liability in the Terms and Conditions of its agreements with its non-NMHS partners.²

7.6.4 **Establishing and sustaining observation partnerships**

Section 7.5 identifies mutual benefit as a core principle and summarizes the incentives for NMHSs and other operators to enter into a partnership. While observational data provided by partners are often thought to be free or low-cost, NMHSs will nevertheless have to consider the value, internal costs and sustainability of such arrangements. Similarly, commercial observations will raise questions of value for money, restricted-use licensing and sustainability.

The Australian Bureau of Meteorology (BoM) has developed a [framework](#) for the incorporation of non-NMHS observations into their operations. The framework includes a practical step-by-step process to assess, approve and manage these observational data. A summary of this process is presented in the annex to this chapter.

The process is relevant for NMHSs seeking observations from non-NMHS sources, as well as for NMHSs that are approached by non-NMHS operators offering their observations.

7.6.5 **Commercial arrangements**

An alternative mechanism to acquire observations from non-NMHS sources is through supply arrangements with the commercial sector. These are formal contractual agreements, in contrast to the cooperative arrangements with voluntary partners. Commercial arrangements may be developed with companies whose primary business is selling meteorological observations and services, or with companies that collect meteorological observations to support their own business activities (for example, transportation, agriculture, dam operations) and then offer to sell them as a supplemental source of revenue. The commercial sector can have strong technical capabilities and can often be more agile than governmental organizations in offering modern observing technologies, so it may be an attractive option for establishing or enhancing observing capabilities. A commercial arrangement may be for observational data only (i.e. a “data buy”) or may include more comprehensive services such as the supply of observing equipment, installation and maintenance, quality assurance and observational data management.

Should NMHSs choose to use a commercial arrangement, the following should be considered.

7.6.5.1 ***Purpose of the network***

Commercial networks may be developed independently or collaboratively. Independent networks are set up for a specific business purpose by the commercial operator that is not connected to the NMHS. For example, a beverage bottling company may develop a network to monitor the availability, quantity and quality of the water they sell. They may be willing to share their observational data with the NMHS, but may not consider any additional technical requirements such as the WIGOS Metadata Standard. They may also impose restrictions on use and redistribution of the data. The NMHS generally incur little or no implementation or operational risk, but the risk of data availability can be high if the business requirement of the operator is not sustained, or if release of the observations negatively impacts a commercial advantage.

² <http://www.meteoswiss.admin.ch/home/measurement-and-forecasting-systems/land-based-stations/automatisches-messnetz/partnernetze.html>

Collaborative networks are set up to meet the specific technical and operational needs of the NMHS, while leveraging the infrastructure and technical capabilities of a commercial partner to obtain observations in a more cost-effective fashion or with less implementation or operational risk for the NMHS. These collaborative networks can, therefore, more easily meet WIGOS requirements. For example, a private company may already have sites, telecommunications infrastructure and the technical capacity to develop and operate an observing network to NMHS specifications. Collaboratively developing this network enables a “data buy” arrangement for the NMHS. The risk of implementation and operation is transferred to the private partner, while data quality can be monitored to meet NMHS specifications. Longer-term agreements increase the sustainability of such partnerships for both parties.

7.6.5.2 **Long-term value**

When assessing the value of a commercial arrangement, the long-term costs to the NMHS must be considered. These include the cost of establishing the capability within the NMHS itself, the duration of the contract, any supplemental costs (for example, telecommunications, land lease) and ownership and maintenance of the equipment at the end of the contract. The decision to proceed with a commercial supply arrangement should be supported by a sound business case which examines all costs, risks and comparative assessments of alternatives, if available. It is recommended that performance requirements (such as availability of observations, timeliness and quality) be specified in the statement of requirements. In a commercial contract, enforceable penalties for non-performance may also be considered.

Guidance on the definition of requirements is under development as a collaborative effort between the Association of the Hydro-Meteorological Equipment Industry (HMEI) and WMO.³

7.6.5.3 **Ownership and use**

A key consideration is ownership of the observational data and metadata, and any constraints on their use and sharing. Often, the ownership and intellectual property rights of commercial observational data remain with the company, and a licence is provided to use the observations for specific purposes. For instance, the observations may be used internally by an NMHS to produce forecasts and climate analyses, but the observational data itself may not be sharable with others, including other NMHSs. The value of sharing observations in the national and international context is universally recognized, and Members are encouraged to carefully consider the terms of commercial arrangements and whether they support WMO Resolutions and data sharing principles.

The duration of the licence is also an important consideration when the commercial observations are to be archived for the climate record. Data supply arrangements should specify the right to store and use the data in perpetuity, not just for real-time use or for the duration of the supply arrangement. Similarly, if the supply arrangement includes proprietary data management or data access tools, provisions to access the data beyond the validity of the contract should be considered. Data formats and processing systems should be built on open standards/open source to enable ongoing access to observational data and tools. It is recommended that closed, proprietary formats and tools be avoided.

7.6.5.4 **Sustainability**

Because commercial contractual arrangements are normally of limited duration (for example, 5–10 years), consideration should be given to the long-term sustainability of the observations, both to support current NMHS operations and to maintain an uninterrupted climate record. Furthermore, the commercial providers themselves may cease operation during the period of the contract, or may be unable or unwilling to renew the contract at the end of the term.

³ see <https://www.wmo.int/pages/prog/www/IMOP/IMOP-home.html>

To mitigate these risks, the following should be considered in the supply agreement:

- (a) Mechanisms for the transfer of equipment to the NMHS at the end of the contract or at the end of company operation;
- (b) Long-term financial planning to sustain an observing capability beyond the current contract, including periodic refresh of the technology;
- (c) Upkeep of technical capability within the NMHS to ensure operation, maintenance and life cycle management of equipment, where required;
- (d) The commercial operator's business environment in order to assess the risk that the operator may suddenly modify the technical implementation, increase prices or cease operations altogether.

7.6.5.5 **Accountability**

Public accountability for the quality and authority of observational data will normally rest with an NMHS, even if it chooses to outsource the supply of data through a commercial arrangement. Careful consideration should be given at the beginning of the commercial arrangement to the equipment specification, quality assurance measures and oversight of the services to protect this public accountability.

7.7 **TECHNICAL GUIDANCE**

After agreement is reached between an NMHS and a non-NMHS partner, several technical matters need to be addressed to enable the exchange and management of the observational data. These include the assignment of WIGOS station identifiers, the collection and maintenance of WIGOS metadata, the technical mechanisms for the exchange of observational data, data management and archiving and issues of cyber security.

The WIGOS-related regulatory and guidance material does not address technical matters of data processing and data management. However, technical matters of specific relevance to WIGOS observational data partnerships are presented here for completeness.

7.7.1 **WIGOS station identifiers**

Guidance on the format and use of WIGOS station identifiers is provided in Chapter 2 of this Guide. In general, Members issue identifiers to national stations, including those operated by entities outside the NMHS. The NMHS has a coordination function in the management of station identifiers in order to avoid confusion or duplication.

WIGOS station identifiers are mandatory for stations to be registered in [OSCAR/Surface](#) (i.e. for the data to be exchanged internationally).

The structure of WIGOS station identifiers essentially provides for a limitless number of codes and is well suited to supporting both NMHS and non-NMHS stations. Because there are no constraints on the number of available codes, the new standard provides the opportunity to use a single, consistent station identifier scheme across all observing systems in a country regardless of operator. This could unify and simplify the tracking of national observing capabilities and could reduce the complexity of the supporting data management and processing systems. National Meteorological and Hydrological Services should consider a nationally-coordinated approach when WIGOS station identifiers are assigned, including to non-NMHS operators.

The process for issuing station identifiers to non-NMHS stations is the same as for NMHS stations. Non-NMHS stations that were previously registered in *Weather Reporting* (WMO-No. 9), Volume A, are migrated automatically to OSCAR/Surface. Non-NMHS stations that were not previously registered must be registered with a new WIGOS Station Identifier.

7.7.2 WIGOS metadata

The purpose of WIGOS metadata is to provide the details and history of local conditions, instruments, operating procedures, data processing algorithms and other factors pertinent to the interpretation of observations, as well as to the management of the station and observing programmes. As noted earlier, WIGOS metadata are essential to support the WIGOS principle of “known quality”. Figure 7.1 summarizes WIGOS metadata principles and content, and what is expected of Members.

For observations to be exchanged internationally, metadata need to adhere to the *WIGOS Metadata Standard* (WMO-No. 1192) and be registered in OSCAR/Surface. This requirement applies equally to observations from NMHS and non-NMHS stations.

The *WIGOS Metadata Standard* (WMO-No. 1192) is comprehensive, as it is designed to meet a broad range of WMO operational and scientific requirements, and the scope of the information required to fully comply with the standard is substantial. The effort required in collecting and maintaining this information is significant and requires careful planning and resourcing. This may cause reluctance in some non-NMHS operators.

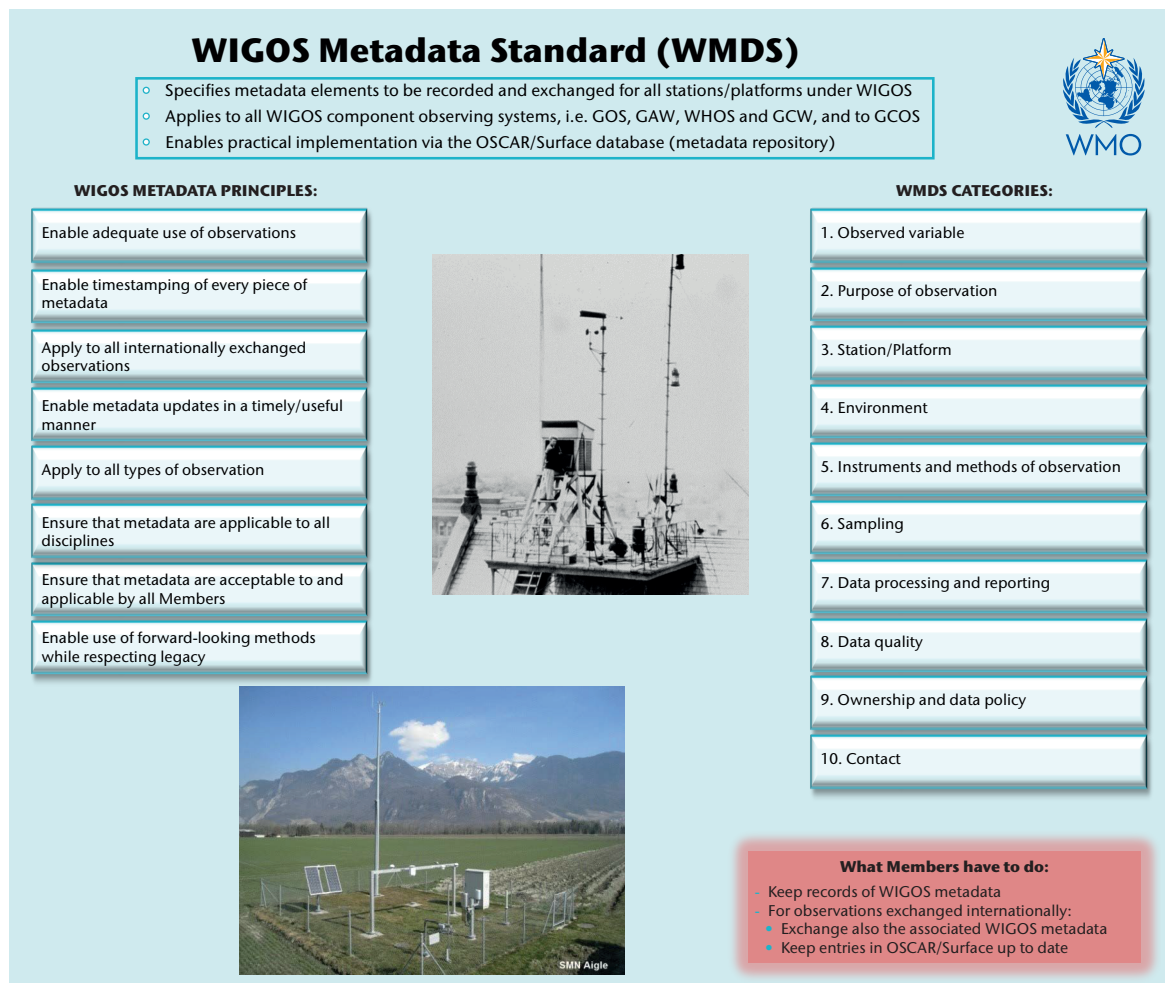


Figure 7.1. Overview of the WIGOS Metadata Standard

To facilitate compliance, the *WIGOS Metadata Standard* has included a certain degree of flexibility:

- (a) Optional elements which “should” (vs “shall”) be reported;
- (b) Some mandatory elements may be reported as “inapplicable” or “unknown” with an explanation as to why the information is not available.

These options can be used to maximize the international exchange of observations, although progress towards complete metadata is always encouraged. National Meteorological and Hydrological Services can play a key role in assisting observation providers in complying with the standard. Among the actions NMHSs should consider with partners are:

- (a) Raising awareness of the WIGOS quality principles, the WIGOS Metadata Standard, and their benefits;
- (b) Providing expertise and assistance to partners in the collection of WIGOS metadata, including periodic review and update;
- (c) Metadata entry and maintenance in OSCAR/Surface on behalf of the partner;
- (d) Nominating the partner as a station contact in OSCAR/Surface for a defined set of stations.

The international exchange of observations may not be possible for reasons of quality, reliability or data ownership, or there may not be a strong international demand. For instance, observations from a national energy company might be made available for internal use by the NMHS to support national forecast products, but they might not be authorized for redistribution outside the NMHS. Even if it is not desirable or feasible to exchange observations internationally, NMHSs and observing partners are still encouraged to follow the WIGOS Metadata Standard as a consistent tool for a coordinated national observing system and to develop its use among non-NMHS operators to the extent possible.

When the international exchange of observational data is not planned, NMHSs can assist their partners in the national exchange of observations with an initial sub-set of WIGOS Metadata Standard elements, which over time may grow to become fully compliant and eligible for international exchange. This approach will increase overall compliance and awareness of the standard, facilitating the international exchange over time.

In assessing what initial sub-set of WIGOS Metadata Standard elements may be appropriate for national applications, it is useful to consider the different uses of observations and the varying levels of quality required of each application: observational data for a safety-critical use (such as aviation) or climate monitoring, for example, require a much higher level of quality.

7.7.3 **OSCAR/Surface – WIGOS metadata entry and maintenance**

A key responsibility of WIGOS observing system operators is to supply and maintain accurate WIGOS metadata in the OSCAR/Surface database. Typically, NMHSs are the authorized users of OSCAR/Surface (through their National Focal Points) and will undertake this responsibility for NMHS stations. Data entry and maintenance may be through the OSCAR/Surface web interface or through a machine-to-machine interface for NMHSs with existing metadata management systems.

In the case of non-NMHS observing sites, it is expected that the NMHS will take responsibility for maintenance of metadata in OSCAR/Surface on behalf of partners. The National OSCAR/Surface Focal Points will have the training and expertise to manage OSCAR/Surface metadata and are best positioned to ensure the accuracy and coherence of these metadata for national observing capabilities. At present, there are no defined standards for the accuracy of WIGOS metadata (a possible future development), so National OSCAR/Surface Focal Points are encouraged to work with partners to strive for the highest achievable accuracy to support the intended use of the observations. For instance, long-term climate monitoring requires greater accuracy and

completeness of metadata than Numerical Weather Prediction. The regular review and update of non-NMHS station metadata in OSCAR/Surface should be an integral part of agreements with partners.

7.7.4 **Mechanisms for the exchange of observational data**

Once station identifiers and metadata have been established, the actual transfer of observational data can occur. To support the principle of mutual benefit, the technical mechanisms for the exchange of observational data should be bi-directional, so that:

- NMHSs receive observations from partners;
- NMHSs provide access to observations. Ideally the observations made available by the NMHSs result from the consolidation of observations from many suppliers, which have been quality assessed, are presented in a consistent format, and are offered through interfaces based on standards.

In this context, the WMO Hydrological Observing System (WHOS) is intended to provide an additional capability as a federated resource for National Hydrological Services. This System is built around two fundamental components: service providers and service consumers. Although service consumers can directly connect with service providers to request and receive observational data and products, a third component, a service broker, is introduced to facilitate discovery and access across different service providers by offering mediation services. The WMO Hydrological Observing System provides advanced data access and analysis capability through web services that use standardized data formats and service types, together with common formats and services, with the aim of improving interoperability between clients and server interfaces.

The exchange of data involves two elements: (a) the exchange format, and (b) the data access mechanism.

7.7.4.1 **Exchange format**

The WMO Information System (WIS) defines standards for the discovery and operational exchange of data among WMO Members (for example, the WIS Discovery Metadata standard, Table-driven Code Forms). However, these standards are quite complex, unique to WMO, and are not widely used by non-NMHS organizations. Instead, there are many formal and de facto standards for data exchange with partner organizations that are commonly used because of their ease of use, practicality, and wide acceptance across numerous communities. Such standards range from the manually-initiated exchange of simple Comma-separated Values (CSV) files to fully automated, dynamic queries through geospatial web services.

Given the diversity of partners and technology environments, there is no firm guidance on specific standards or tools, and the choice of exchange format may depend on the telecommunications protocol being used. Ideally an exchange format should be:

- Open: based on open, non-proprietary, industry-wide standards;
- Portable: able to operate on any platform or operating system;
- Stable: with a large user base/community which will encourage long-term stability and availability;
- Self-describing: the format and content are fully described in the exchanged file.

Common formats used for the exchange of hydrometeorological data today include, but are not limited to:

- Web form – manual input of data on a website or smart phone app;
- CSV – Comma-separated Values;
- XML – for example, Open Geospatial Consortium (OGC) Observations and Measurements, WaterML2, or other derivatives of the OGC Geography Markup Language (GML);
- JSON – JavaScript Object Notation;
- NetCDF – Network Common Data Form;
- HDF – Hierarchical Data Format.

The use of open, non-proprietary exchange formats facilitates vendor-neutral and multi-application access whether off-the-shelf tools or custom solutions are used. For example, the open-source [Geospatial Data Abstraction Library](#) (GDAL) provides read/write/translation capability for hundreds of formats for both raster (model output, satellite imagery) and vector (alerts, observations) data. The Geospatial Data Abstraction Library also provides support for numerous data access and visualization tools, both open-source and commercial.

The use of open exchange formats with wide vendor and community support is encouraged as it reduces the barriers to hydrometeorological data and to new information communities.

7.7.4.2 **Data access mechanisms**

Regardless of the exchange format, the transfer of data requires an upload and/or download mechanism. The ubiquity of the Internet has provided a telecommunications backbone that lowers the barriers to data transfer, but there is still a range of access mechanisms of varying sophistication and complexity. The desirable characteristics of data exchange formats (open, portable, stable, etc.) are equally applicable to data access mechanisms.

Common data access mechanisms for meteorological data exchange include, but are not limited to:

- (a) Human interface:
 - (i) Data entry on a web form (desktop or phone app);
 - (ii) File transfer by email attachment (manual transfer);
 - (iii) File transfer via neutral data-sharing service (for example, iCloud, Dropbox);
- (b) Machine-to-machine interface:
 - (i) File transfer by email attachment (automated send);
 - (ii) Automated download (data “pull” from Secure File Transfer Protocol (SFTP) or Web Accessible Folder (WAF) sites);
 - (iii) Automated subscription service (event-driven “push” of data from the provider);
 - (iv) Geospatial web services (dynamic, timely access through client/server environment and tools) based on international standards (OGC, ISO).⁴

Like the choice of exchange formats, the choice of access mechanisms depends on the technical environments of the NMHS and its partner, and whether the access will be machine-to-machine or through human interaction. The choice should also be made bearing in mind the

⁴ www.wmo.int/pages/prog/www/WIS/documents/MOAWMO_OGC.pdf

operational reliability and timeliness of the transfer, for instance, to meet global Numerical Weather Prediction (NWP) cut-off times of <2–3 hours. In general, automated transfer by email attachment is not recommended because of frequent issues with reliability (for example, emails not being sent, not received, blocked or misplaced by email filters). Furthermore, the use of secure transmission protocols (for example, SFTP and Secure Shell (SSH)) is recommended to reduce security vulnerability (see section 7.7.8 on cyber security). These decisions need to be jointly made by the NMHS and its external supplier in order to enable and sustain a secure operational data transfer.

7.7.5 **WIGOS Data Quality Monitoring System**

The *Manual on the WMO Integrated Global Observing System* (WMO-No. 1160), section 2.4, specifies that Members shall ensure the quality control of WIGOS observations. This includes the application of real-time quality control prior to the exchange of observations via WIS, and non-real-time quality control prior to archiving. These requirements apply equally to observations from both NMHS and non-NMHS sources that are to be exchanged internationally, and they are also highly recommended for observations that are to be used only for national purposes.

Many NMHSs already have quality control procedures in place to support these requirements for their own observations, and it is recommended that the same procedures be applied to non-NMHS observations for consistency and to minimize the effort to maintain separate procedures and tools. Guidelines on quality control procedures for observations from automatic weather stations are provided in the *Guide to the Global Observing System* (WMO-No. 488), Appendix VI.2. Quality control considerations and procedures for climate observations are described in the *Guide to Climatological Practices* (WMO-No. 100), sections 2.6 and 3.4. *Quality Assessment Using METEO-Cert – The MeteoSwiss Classification Procedure for Automatic Weather Stations* (Instrument and Observing Methods Report No. 126) also provides useful guidance.

In addition to procedures applied by NMHSs, the WIGOS Data Quality Monitoring System (WDQMS) will assist Members in the evaluation of the quality of observations. The Quality Monitoring Function operated by global NWP or other Global Data Management Centres identify issues with data against predefined criteria. Regional WIGOS Centres can then use the WDQMS Evaluation Function and Incident Management Function to analyse these data issues and determine whether any of them should be regarded as an incident. The RWC can then engage with the NMHS or other authorized body to ensure that the incident is rectified in the most effective manner. Once an RWC is operational, the reports produced by the WDQMS on the performance of all observations will be issued to all relevant parties.

The WDQMS makes no distinction between NMHS and non-NMHS observations. Regional WIGOS Centres may have different procedures for NMHS- and non-NMHS- related incidents, and the incident management mechanisms may vary from one partner organization to another. It is strongly recommended that procedures for the management of data issues and incidents be included in an observational data agreement.

7.7.6 **Technical management of constrained-use observations**

As noted earlier, there may be constraints on the use and sharing of non-NMHS observations. The specifics of any constraints should be clearly defined in the agreement with the provider. It is very important that these conditions be respected in order to maintain the reputation of the NMHS as a trusted partner, and to ensure the willingness of external providers to contribute observations. Furthermore, a breach of the terms of an agreement may have legal consequences. Functionality within an NMHS data management system is therefore required to manage observations with constraints.

The WIGOS Metadata Standard specifies two parameters under Category 9: ownership and data policy, which can be used to detect observational data that require special consideration in processing (*WIGOS Metadata Standard* (WMO-No. 1192), Chapter 7).

Parameter 9-01 – Supervising organization: a mandatory parameter providing the name of the organization that owns the observation.

Parameter 9-02 – Data policy: a mandatory parameter that provides details relating to the use and limitations of the observation, imposed by the supervising organization. This parameter currently defines three observation policy conditions:

- WMO Essential – Resolution 40/25 observations with no constraints on use
[WMO_DataLicenceCode = 0]
- WMO Additional – Resolution 40/25 observations with constraints on use that need to be researched through other documentation
[WMO_DataLicenceCode = 1]
- WMO Other – Other observations with constraints not set by WMO policy
[WMO_DataLicenceCode = 2]

These parameters enable constrained observations to be detected in the NMHS processing systems, but these systems must also be able to interpret and use this information in accordance with the data policy of the provider. The three WMO_DataLicenceCodes may be insufficient to adequately cover all the observation policy variations across several partner organizations, so additional codes or internal tools may be required to add precision to the processing flow. For example, MeteoSwiss has implemented a hierarchical five-level framework that assigns an internal USE_LIMITATION_CODE to manage various levels of constraints (see Figure 7.2). The hierarchical approach has facilitated the technical implementation: a limited, but adequate, set of use cases is defined and constraints are applied progressively with the use of a single USE_LIMITATION_ID code.

Restrictions on use of partners' data

USE_LIMITATION_ID	Description	Internal use	Distribution to other governmental organizations	Distribution to education/research institutions	Distribution to anybody
10	MeteoSwiss is the data owner; unrestricted use	Yes	Yes	Yes	Yes
20	Partners' data that can be used without restriction (indication of source necessary)	Yes	Yes	Yes	Yes
30	Partners' data that can be distributed to other governmental organizations and used for education/research	Yes	Yes	Yes	No
40	Partners' data that can be used internally and distributed to other governmental organizations	Yes	Yes	No	No
50	Internal use only	Yes	No	No	No

Figure 7.2. The technical framework for the management of constrained data established by MeteoSwiss

7.7.7 Archiving

Observations from non-NMHS sources are often used to support near-real-time applications and services, but they may also offer opportunities to enhance the climate record.⁵ The [Guide to Climatological Practices](#) (WMO-No. 100) outlines the basic principles and practices relevant for climate services, and includes guidance on climate observations, stations and networks (Chapter 2) and on climate data management (Chapter 3). Regarding non-NMHS observations, special attention should be paid to matters of data quality, longevity of the observation record and long-term preservation and access, as well as to matters of inter-comparability of observations. The WIGOS Metadata Standard is designed to capture information relevant to data quality and long-term inter-comparability, so attention to populating and maintaining the metadata records for both NMHS and non-NMHS climate observations is paramount.

The technical management of observational data for archiving purposes also requires special consideration. Observational data to support near-real-time applications are typically managed within an operational database, and specific arrangements are normally required to transfer these data (including metadata) to a separate climate data management system (CDMS) or to an International Data Centre. In archiving non-NMHS observations, it is important to be able to distinguish the different sources of data (through metadata fields or through separate databases) as there may be significant differences in the quality of data and metadata that could impact climate analyses and services. The subject of archiving externally-sourced data will be covered in detail in the Manual on Climate Data Management planned for publication in 2019.

The above applies to data available in digital formats, but it is important to bear in mind that much historical data may exist only in hard copy (paper). Guidance on securing and archiving hard copy records and images is provided in [Guidelines on Best Practice for Climate Data Rescue](#) (WMO-No. 1182).

7.7.8 Cyber security

Cyber security is an area of concern due to growing threats to the integrity, reliability and privacy of information systems and data. The World Wide Web and, more recently, social networks have improved cooperation among WMO Members and have also facilitated the exchange of information with many new providers of observational data. Alongside these positive changes, however, an increasing number of cyber-security threats are present everywhere the Internet. Because of its widespread use, the Internet has unfortunately become a medium of choice for disseminating unwanted information and for launching electronic attacks against organizations and their information assets. It is, therefore, necessary for NMHSs to recognize these risks and to protect their information systems in order to maintain operational data processing and to securely exchange information.

As all WMO Members are interconnected, it is essential that each Member take appropriate measures to secure the exchange of its information and ensure that it will not be the cause of further security problems within WIS.

Security standards, recommendations and best practices have already been adopted by a large number of WMO Members for securing the exchange of information within WIS. The [Guide to Information Technology Security](#) (WMO-No. 1115) outlines the basic concepts and principles of information security, and provides a broad overview of the main information technology security components, processes and best practices. The principles described in the Guide can be used to exchange data with non-NMHS providers in order to ensure the consistency of security practices within the WMO community.

At the national level, cyber security requirements and implementation are increasingly being defined by organizational or national authorities and, in general, NMHSs are expected to comply with such requirements. The security requirements of non-NMHS organizations can vary widely

⁵ The climate record should be broadly interpreted in the context of this document as any form of meteorological, oceanographic, hydrological, cryospheric or other observation with a time-series component.

and may sometimes be in conflict with those of NMHSs. Access to observational data across firewalls is a common challenge as organizations typically restrict external users' access to their systems. A frequently-used solution is to establish data repositories outside firewalls and to require the use of secure transmission protocols (for example, HTTPS, SFTP, SSH).

ANNEX. A MODEL FOR NON-NMHS OBSERVATIONAL DATA INGESTION

The annex describes a generic model for the ingestion of observational data from non-NMHS organizations into NMHS data systems.¹ The model is schematically represented in Figure 7.3.

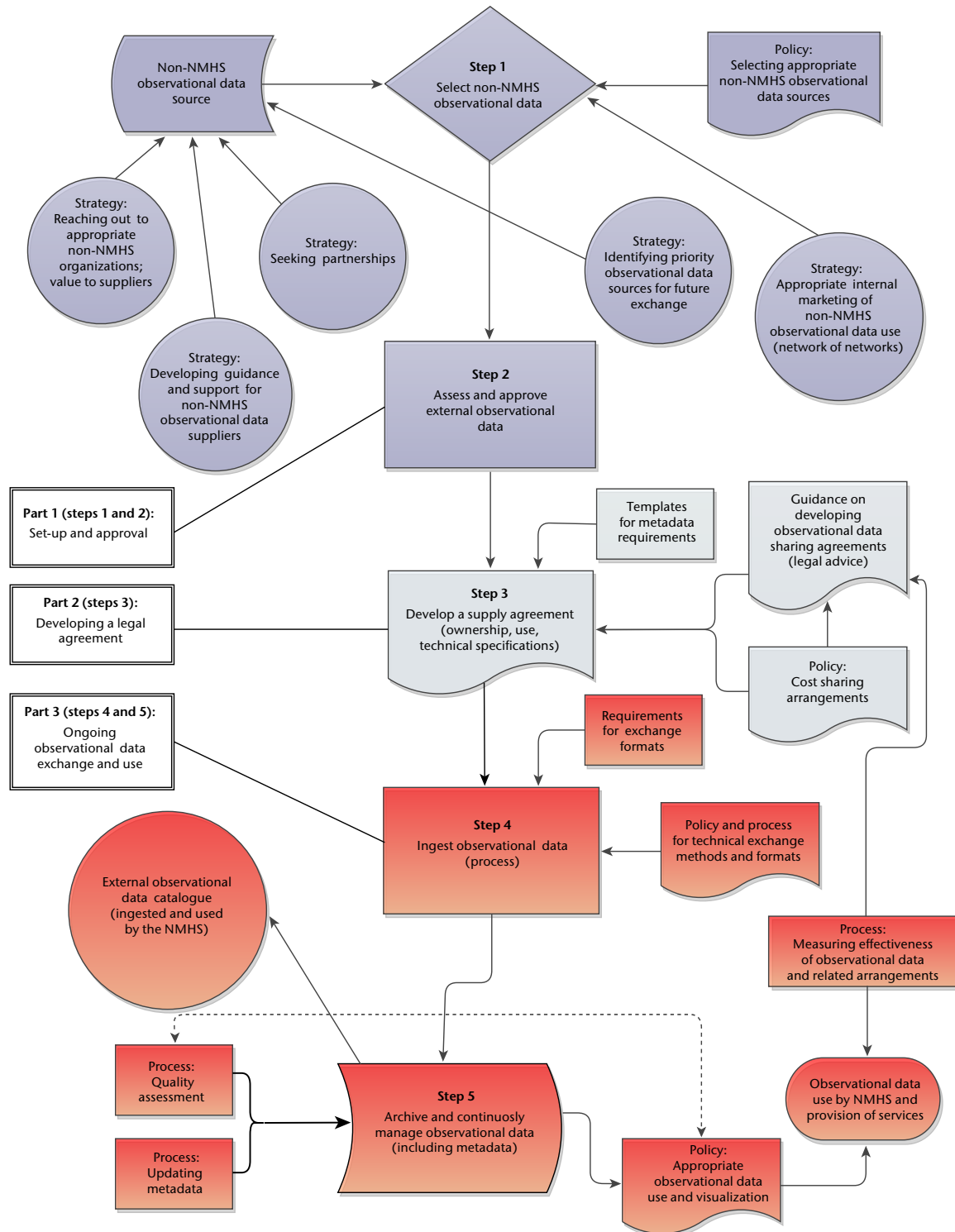


Figure 7.3. Non-NMHS observational data exchange model

¹ This model has been developed, implemented and applied by the Bureau of Meteorology (Australia).

PART ONE

Step 1: Decide the appropriateness of observational data for ingestion using a policy for selecting non-NMHS observational data based on five fundamental questions:

- (a) **Value** – What are the benefits and value for NMHS and non-NMHS suppliers of observational data?

The NMHS may assess value in three different areas: contribution to the network, quality of the data and relationship with the data supplier. For example:

- (i) How the observational data are going to be used and to provide value (impact on NMHS models, products and services);
- (ii) The extent of the NMHS reliance on the observations (can the observations be sourced elsewhere?);
- (iii) Required observational data quality;
- (iv) Influence of the prior relationship with the non-NMHS party;

Detailed questions about value may include:

- (i) Why do we want the information?
- (ii) What do we need to know to judge the value of the information?
- (iii) How do we know that the information is adding value (what is the key performance indicator)?
- (iv) Are the observational data filling a spatial or temporal gap in the current network or are they providing redundancy?
- (v) What is the quality of the observational data? (Will they satisfy the requirements of particular users? If not, is there sense in the collection, archiving and quality control of the observational data?)
- (vi) Is there a risk in having too much observational data?
- (vii) Can lower data quality be accepted in observation-sparse areas or where observational data are critical to a product?

The value proposition may also be considered by the supplier of observational data. For example, data suppliers recognize the key benefits of providing their observational data to an NMHS:

- (i) It promotes access of their data to a much wider audience;
- (ii) It enhances their own reputation by working in association with the NMHS;
- (iii) Much value is potentially added to the data through assimilation into NMHS products and services, particularly forecasting tools and models.

The final stage of the value assessment is to assign the observational data to a tier. This will help with decisions concerning many data requirements, the nature of an agreement and intellectual property rights.

A number of tools are needed at this stage of the decision-making process, including:

- (i) A policy for the value assessment;

- (ii) User requirements that articulate the frequency, reliability and spatial distribution of the data needed;
 - (iii) A network design that reflects the user's spatial requirements for a particular type of observational data;
 - (iv) Quality standards and criteria for the observational data for each tier;
- (b) **Metadata** – Does the NMHS know enough about the observational data to make effective use of them?

The supply and maintenance of metadata is crucial to the ongoing assessment of observation quality by the NMHS. Consideration should be given to how often metadata need to be updated by the supplier.

Metadata should be obtained for each tier, and the risk associated with lack of metadata should be assessed. Appropriate storage, access and reporting of metadata and a mechanism for external agencies to submit and update metadata records should be in place.

- (c) **Restrictions** – Can the NMHS use the observational data as it pleases? For example, are there any terms of use? Are there any restrictions to intellectual property?

Some providers of observational data may place restrictions on redistribution or may demand that data be only for NMHS internal use. These observational data can support NMHS national products, but ideally NMHSs should encourage arrangements that are consistent with open data principles and that permit broad sharing and reuse. Key issues include:

- (a) Standard Open Data Licence or other open source agreement;
 - (b) Understanding of the NMHS readiness to accept risk;
 - (c) A priority rating on the value of the observational data.
- (d) **Implementation** – Can the NMHS access and manage the observational data and metadata?

Once the value and usefulness of the observational data has been determined, the next question is their accessibility and the capacity of the NMHS to assimilate the observational data into its system and use them.

For example:

- (i) Can the data be displayed?
- (ii) Are there any restrictions?
- (iii) Can the data be delivered securely?
- (iv) Can the data be archived and can quality control of the data be implemented?

Key information required may include:

- (i) The format, volume and content of the observational data;
- (ii) Transmission security;
- (iii) Estimates of communications costs;

- (iv) Estimates of integration costs.
- (e) **Agreement** – Do the NMHS and its partner have the ability to manage the relationship in the long term?

An agreement provides a consistent framework for:

- (i) Managing and monitoring the relationship;
- (ii) An ongoing assurance of the required observational data quality (through maintenance of metadata);
- (iii) The longevity of the data supply arrangement.

It is important that both parties understand their mutual commitments and impact. Most importantly, the agreement should include points of review and renewal to ensure regular contact between the organisation and the supplier and a healthy working relationship.

Step 2: Assess and approve non-NMHS observational data for ingestion ensuring that:

- (a) The requestor (for example, an NMHS data user) assesses the appropriateness of the non-NMHS observational data using the above guidance;
- (b) The NMHS evaluates the request for approval. This may involve a cost-benefit analysis and a risk assessment.

The assessment may consider the following aspects:

- (i) Reliability of the source of observational data (particularly for operational use);
- (ii) Terms of use;
- (iii) Metadata availability;
- (iv) Compliance or compatibility with NMHS systems;
- (v) Regimes for site inspections, validation and maintenance;
- (vi) Data life-cycle;
- (vii) Cost of using observational data and of maintaining an ongoing relationship;
- (viii) Observational data access and archiving;
- (ix) Willingness to enter into formal agreements.

PART TWO

Step 3: Develop an observational data supply agreement allowing the NMHS to mitigate identified risks and to ensure the continued supply of data as negotiated.

PART THREE

Step 4: Commence the technical ingestion and processing of non-NMHS observational data using standard and approved methods for formatting and transporting data (in line with NMHS policies and processes).

Step 5: Manage the arrangement for the supply of observational data, including ongoing monitoring of observational data quality, alerts, metadata updates, archiving (and retention) of observational data and applications by the NMHS (informed by the use of classification schemes such as network tiering or flags).

8. ESTABLISHING A REGIONAL WIGOS CENTRE IN PILOT MODE

8.1 INTRODUCTION

This chapter provides guidance on the establishment of a Regional WIGOS Centre (RWC) in pilot mode. The overall purpose of RWCs is to provide Members and Regions with support and assistance in national and regional WIGOS implementation and operational activities.

8.2 RATIONALE

The Seventeenth World Meteorological Congress decided that WIGOS, supported by WIS, was one of the WMO strategic priorities for 2016–2019. Subsequently, concept development and initial establishment of RWCs was identified as one of five priority areas for the WIGOS preoperational phase (2016–2019).

The Executive Council at its sixty-eighth session recognized the critical role that RWCs would play in advancing the implementation of WIGOS at the regional level by providing regional coordination, technical guidance, assistance and advice to Members and regional associations in accordance with the *Technical Regulations* (WMO-No. 49), Volume I, and the *Manual on the WMO Integrated Global Observing System* (WMO-No. 1160), which is Annex VIII to the *Technical Regulations*.

Regional WIGOS Centres will be working closely with data providers to facilitate primarily: (a) regional WIGOS metadata management (OSCAR/Surface); and (b) regional WIGOS performance monitoring and incident management (WIGOS Data Quality Monitoring System (WDQMS)). Chapters 4 and 9 of this Guide provide more details on OSCAR/Surface and WDQMS, respectively.

WMO Regions differ in terms of WIGOS readiness, economic strength, cultural and linguistic characteristics, and these differences need to be taken into account in establishing and operating their respective RWCs.

The Executive Council at its sixty-eighth session endorsed the concept note on establishment of WMO Regional WIGOS Centres (hereafter referred to as “RWC Concept”), included as Annex 1 to this chapter, as general guidance for regional associations. The RWC Concept outlines the basic principles for establishment of RWCs and provides a clear specification of mandatory and optional functions.

8.3. PROJECT DESCRIPTION

8.3.1 Objectives

Expected results of setting up an RWC in pilot phase include an assessment of the feasibility of subsequently establishing a fully operational RWC and, based on the final project evaluation, a set of recommendations on key aspects of such a centre, including institutional set-up, concept of operations and strategy for long-term sustainability.

8.3.2 Terms of reference

The Terms of Reference (which should include the main WIGOS functionalities offered by the Centre) must be defined; at a minimum, they must include the mandatory functions as specified in the RWC Concept (see Annex 1 to this chapter); however, depending on available

resources and the willingness of the Member with primary responsibility for the RWC, one or more optional functions may be considered, for example, assistance with regional and national observing network management, calibration support, education and training.

8.3.3 **Infrastructure**

8.3.3.1 **Basic infrastructure**

In order to ensure a rapid start-up for the Centre, it would be desirable for the host country to make available to the Centre, either permanently or on a temporary basis, adequate, secure, fully-equipped and easily accessible premises. These premises must be supplied with water and electricity and must be equipped with a reliable telecommunications system.

8.3.3.2 **Technical infrastructure**

The Centre must have adequate information technology facilities and infrastructure (work stations, high-speed Internet access, data processing and storage capabilities) needed for RWC mandatory functions.

8.4 **RESOURCING**

There is no funding for RWC operations in the regular WMO budget. The responsibility for funding the establishment and operations of an RWC thus rests with the Member(s) involved. Suitable resources for establishment and sustained operations of the Centre must be identified. The amount and nature of resources required will depend on the intended functionalities of the Centre.

In order to ensure the long-term sustainability of the RWC, the Pilot phase should include the development of a long-term funding strategy based on effective resource mobilization where appropriate.

8.4.1 **Human resources**

The necessary human resources (managers and scientific, technical and administrative personnel) should be specified in terms of competencies and number of staff (expressed in full-time equivalents) allocated to RWC development and operations. The staff may be permanent NMHS employees or may be hired on a temporary basis. Where appropriate, some of the responsibilities of the RWC may be fulfilled through secondment of staff from other WMO Members in the Region.

8.4.2 **Financial resources**

The responsibility for funding RWC operations rests with the Member(s) involved, and it is expected that efficiencies made by the RWC in designing, procuring and operating the observing systems will offset most of these costs. Nonetheless, it might be difficult for less well-resourced Members to identify the required resources at the national level. In such cases, the RWC partner(s) will have to develop effective resource mobilization strategies with a view to deriving maximum benefit from the various multilateral funding mechanisms and regional development institutions. The WMO Secretariat is prepared to support all stages of such resource mobilization efforts.

8.5 IMPLEMENTATION STAGES

To be designated as an RWC, after the launch period (start-up phase), there must be a successful pilot phase, after which the Centre may enter an operational phase.

8.5.1 Start-up phase

The candidate RWC will write to the president of the WMO regional association to which it belongs, through the Permanent Representative of the country where the Centre is located and, with his/her endorsement, express its intention to be designated as an RWC in pilot mode. The application template for a candidate RWC is reproduced in Annex 2 to this chapter.

The president of the regional association, in close collaboration with the management group and relevant expert group of the association, the Intercommission Coordination Group on WIGOS (ICG-WIGOS), and the WIGOS Project Office in the WMO Secretariat, will consider the proposal. The candidate(s) shall follow the recommendations and guidance for further elaboration of the proposal.

During this phase, which may last several months, the framework for pilot phase operations is created, the infrastructure and human resources are made available, the functionalities assigned to the Centre are specified and clarified, partners are mobilized and consortia of technical, scientific and financial partners, if needed, are set up.

8.5.2 Pilot phase

The objectives of this phase are: (a) to help a group of Members within the domain of the RWC to benefit from WIGOS; and (b) to lay solid foundations for a transition to a subsequent operational phase, depending on final assessment. The functionality and services provided during this phase are evaluated on a regular basis by the RWC Project Manager, with methods readjusted as necessary.

At the beginning of the pilot phase, the RWC Project Manager will ensure that the required preparatory work is conducted, and implementation arrangements are put in place in accordance with the Project document.

At the end of the pilot phase, the RWC Project Manager will prepare and submit a Project Final Report to the president of the regional association, the relevant regional WIGOS working body and the management group of the association. The final report will contain an evaluation of the Project performance and sustainability of results, and will document the experience. For this purpose, the RWC Project Manager will:

- (a) Assess the Centre performance in terms of achievements, as compared to the targets, as well as their sustainability; the assistance and benefits received by Members of the Region (or subregion) should be documented;
- (b) Assess the Project financial management, including allocation of funds (final status as compared to the initial budget);
- (c) Draw lessons from the overall project management experience, including stakeholder engagement, and monitoring and reporting system, for subsequent implementation project;
- (d) Describe the measures put in place to ensure continuity of the Centre in operational mode, as appropriate.

Upon successful completion of the pilot phase, and on the basis of the positive assessment of the regional WIGOS working body and the management group of the regional association, the

president of the association will contact the Secretary-General of WMO with a request for formal designation of the candidate as an RWC accompanied by documentation that confirm the ability of the centre to meet the designation criteria.

8.6. **RISK ASSESSMENT AND MANAGEMENT**

The main risks, their impact on RWC operations and WIGOS as a whole, and possible mitigation measures should be considered. The level of risk should be assessed (low, medium, high) for each type of risk. Typical risks are:

- (a) Political/institutional, such as low political commitment to the Project, waning interest from stakeholders, or change in government;
- (b) Financial, such as inadequacy of the financial management system, or lack of project resources;
- (c) Human resources-related, such as lack of skills and/or expertise; mismatch between existing and required experience and specialized skills.

The risk management plan will be developed for each implementation activity or sub-project, including risk mitigation.

8.7 **GOVERNANCE, MANAGEMENT AND EXECUTION**

The Project management (i.e. RWC Project Manager, Project Executive) should work closely with the president of the regional association, the management group and the relevant WIGOS working body of the association, the WMO Secretariat (Observing and Information Systems (OBS) Department) and other WMO related entities.

8.8 **MONITORING AND EVALUATION**

The RWC Project Manager is responsible for routine management, coordination, monitoring and evaluation of the Project, and for reporting to the Executive Management of the organization under which the RWC is framed.

He/she is also responsible for updating procedures and practices if and when needed. The monitoring and evaluation process should demonstrate the progress achieved as well as identify risks, problems and difficulties encountered, and the need for adjustment of the Project accordingly.

ANNEX 1. CONCEPT NOTE ON ESTABLISHMENT OF REGIONAL WMO INTEGRATED GLOBAL OBSERVING SYSTEM CENTRES

(This concept note is an annex to Decision 30 (EC-68), see [Executive Council, Sixty-eighth Session: Abridged Final Report with Resolutions and Decisions](#) (WMO-No. 1168))

ANNEX 2. APPLICATION TEMPLATE FOR A CANDIDATE REGIONAL WIGOS CENTRE

An agency or organization that wishes to be considered for WMO designation as a Regional WIGOS Centre (RWC) will make this known to the president of the respective WMO regional association in writing through, and with the endorsement of, the Permanent Representative of the country in which the candidate RWC is situated.

The written communication should comprise a letter of intent that clearly states the candidate's willingness and ability to provide RWC functionalities and an annex containing the following information (this applies also to individual members of a virtual RWC which will collectively fulfil the RWC functions):

1. Name of the country, WMO regional association, name of the organization and full address;
2. Affiliation (sponsors, stakeholders, partnering agencies, etc.) at the global, regional and national levels;
3. Mandate of the Centre relevant to WIGOS activities (mandatory and optional functions);
4. Liaison with relevant existing WMO centres, particularly regional centres;
5. Website of the Centre describing WIGOS-related activities;
6. Current operational activities relevant to the candidate's application (following the mandatory and optional RWC functions);
7. Staff deployment/human resources relevant to RWC activities (managerial, scientific, technical and administrative categories);
8. Description of current facilities, the necessary basics, physical infrastructure and communication systems relevant to RWC mandatory and optional functions;
9. Funding strategy to ensure the long-term sustainability of the RWC;
10. Geographical/economic/linguistic region for which the RWC functionalities are offered;
11. Type of RWC (a single multifunctional RWC or a virtual/distributed RWC (RWC network) provided by a group of Members);
12. Proposed RWC Project Manager (name, position, contacts and curriculum vitae);
13. Stakeholders engaged in the current and planned RWC operations;
14. Relevant National Focal Point(s);
15. Project proposal:
 - Prepared by (name, position);
 - Approved by (name, position);
 - Project Executive (name, position);
 - RWC Terms of Reference;
 - Implementation period;

- Project budget;
- Funding sources;
- List of activities, deliverables, outcomes, milestones, resources required and associated risks;
- Additional documentation demonstrating the experience and the capacity of the candidate organization to fulfil the described functions;

16. Additional information as appropriate.

References:

1. *Seventeenth World Meteorological Congress: Abridged Final Report with Resolutions* (WMO-No. 1157)
 2. *Executive Council, Sixty-eighth Session: Abridged Final Report with Resolutions and Decisions* (WMO-No. 1168)
 3. *Project Management Guidelines and Handbook*, Parts I and II.
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9. WIGOS DATA QUALITY MONITORING SYSTEM FOR SURFACE-BASED OBSERVATIONS

Regulations related to the WIGOS Data Quality Monitoring System are provided in the 2019 edition of the *Manual on the WMO Integrated Global Observing System* (WMO-No. 1160).

The annex to this chapter, [*Technical Guidelines for Regional WIGOS Centres on the WIGOS Data Quality Monitoring System*](#), has been issued as a separate publication (WMO-No. 1224). Its purpose is to assist Regional WIGOS Centres (RWCs) in successfully running the WDQMS, which is one of the mandatory functions of RWCs.

The Guidelines contain a generic description of the three main functions of the WDQMS: monitoring, evaluation (including reporting) and incident management.

Details are provided on the recommended quality monitoring practices for the surface-based stations of the GOS, which are needed for an RWC to cover the various categories of monitoring (availability, timeliness and accuracy); some recommended performance targets are also included. The Guidelines describe the daily tasks needed to run the monitoring and evaluation functions as well as the necessary resources and the operational detailed procedures for the incident management function.

Furthermore, the Guidelines provide the specifications for the quality monitoring Web tools and for the automated quality monitoring reports to be produced daily.

For more information, please contact:

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