

Guide to the WMO Integrated Global Observing System

2024 edition

WEATHER CLIMATE WATER



WORLD
METEOROLOGICAL
ORGANIZATION

WMO-No. 1165

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EDITORIAL NOTE

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INTRODUCTION

General

This is the fourth 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) (hereinafter, the “Manual on the WIGOS”). 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. The first edition of the [Guide to the WMO Integrated Global Observing System](#) (WMO-No. 1165) 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.

Purpose and scope

The 2024 edition of the Guide provides material relevant to some of the new WIGOS-related regulations, mainly related to: Resolution 1 (Cg-Ext(2021)) on the WMO Unified Policy for the International Exchange of Earth System Data and Resolution 2 (Cg-Ext(2021)) on the Global Basic Observing Network (GBON) ([World Meteorological Congress: Abridged Final Report of the Extraordinary Session \(2021\)](#) (WMO-No. 1281)); the Regional Basic Observing Network; a new Rolling Review of Requirements process; Regional WIGOS Centres; and the WIGOS station identifiers.

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 – International Codes](#) (WMO-No. 306), Volumes 1.2 and 1.3. 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

The procedures for amending the present Guide can be found in the publication [Rules of Procedure for Technical Commissions](#) (WMO-No. 1240), Annex VII.

List of related publications

The development of the present 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.

Below 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.

- (a) *Technical Regulations* (WMO-No. 49), Volumes I, II and III*
- (b) Manuals:
 - (i) *Manual on Codes – International Codes* (WMO-No. 306), Volumes I.2 and I.3
 - (ii) *Manual on the Global Telecommunication System* (WMO-No. 386)
 - (iii) *International Cloud Atlas: Manual on the Observation of Clouds and Other Meteors* (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 to the WMO Integrated Processing and Prediction System* (WMO-No. 305)
 - (vi) *Guide to the Global Observing System* (WMO-No. 488)*
 - (vii) *Guide to the Implementation of Quality Management Systems for National Meteorological and Hydrological Services and Other Relevant Service Providers* (WMO-No. 1100)
 - (viii) *Guide to the WMO Information System* (WMO-No. 1061)
 - (ix) *Guide to the Implementation of Education and Training Standards in Meteorology and Hydrology* (WMO-No. 1083), Volume I
 - (x) *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

Note: The specifications provided in the referenced GAW implementation plan remain valid beyond the specified period of the plan.

- (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*
-

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 WIGOS* 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, the observing component of the Global Cryosphere Watch and the Space Weather Observing System, 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 Observation, Infrastructure and Information Systems.

The WIGOS framework implementation phase occurred in the period 2012–2019.

Building on the WIGOS framework, the key areas for WIGOS operation and evolution, which support the delivery of the WMO strategic priorities, are listed below and are represented schematically in Figure 1:

- (1) Management of WIGOS operation and evolution;
- (2) Design, planning and optimized evolution of WIGOS by responding to user requirements through the Rolling Review of Requirements process;
- (3) Observing systems operation, maintenance, standardization, interoperability and data compatibility;

- (4) Collaboration with the WMO co-sponsored observing systems and international partner organizations and programmes;
- (5) National WIGOS implementation, including necessary capacity development, partnership agreements and integration of observing systems for all application areas;
- (6) Quality management, and fostering a culture of compliance with the WIGOS technical regulations;
- (7) Implementation of the Global Basic Observing Network and the Regional Basic Observing Networks, as well as the tiered network approach;
- (8) Operation and evolution of the WIGOS tools (WIGOS Data Quality Monitoring System (WDQMS), Observing Systems Capability Analysis and Review (OSCAR), Incident Monitoring System (IMS), etc.);
- (9) Operational implementation of the Regional WIGOS Centres;
- (10) Communications and outreach.

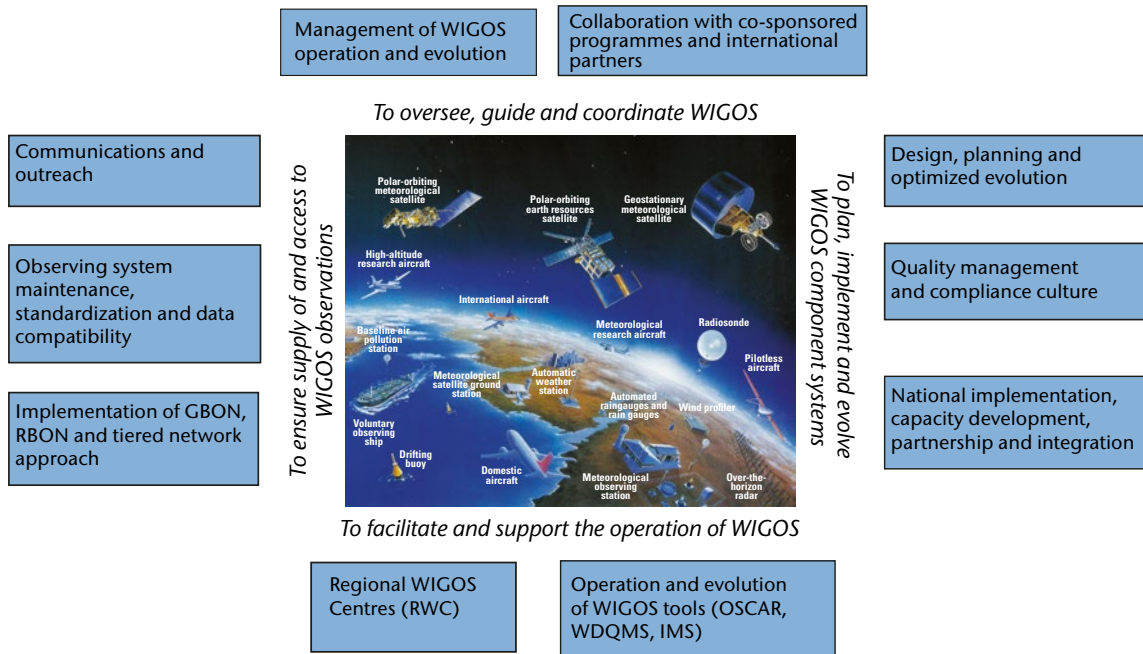


Figure 1. The key priority areas of WIGOS operation and evolution

2. WIGOS STATION IDENTIFIERS

2.1 FUNDAMENTALS

2.1.1 System of WIGOS station identifiers

The system of WIGOS station identifiers¹ is defined in the *Manual on the WIGOS*, Attachment 2.2.

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 Principles of WIGOS identifiers

Each observing station must have at least one WIGOS identifier (WSI). A WSI can only be associated with one observing station. The station WIGOS identifier(s) link(s) the station to its WIGOS metadata.

WIGOS identifiers do not have meaning in themselves, so users must not interpret any patterns they see in these identifiers. Users should use the WMO global compilations of WIGOS metadata as the official sources, such as [OSCAR/Surface](#), to look up the metadata for the station associated with the identifier.

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

WIGOS 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 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 have only WIGOS identifiers.

2.1.4 Assigning WIGOS identifiers to observing stations

Observing stations that had been allocated identifiers by a WMO Programme before the introduction of WIGOS identifiers (that is, before 1 July 2016) should continue to use those identifiers and are not required to have additional ones created for them. For these observing facilities, the WIGOS 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 WIGOS identifier associated with a different programme (in this example, the synoptic report could use the WIGOS identifier derived from the International Civil Aviation Organization (ICAO) location/airfield indicator²).

¹ The expressions “WIGOS identifiers” or “WSI”/“WSIs” are used in this Guide as an abbreviation for “WIGOS station identifiers”. The expression “observing station(s)” is also used as an abbreviation for “observing station(s)/platform(s)”.

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

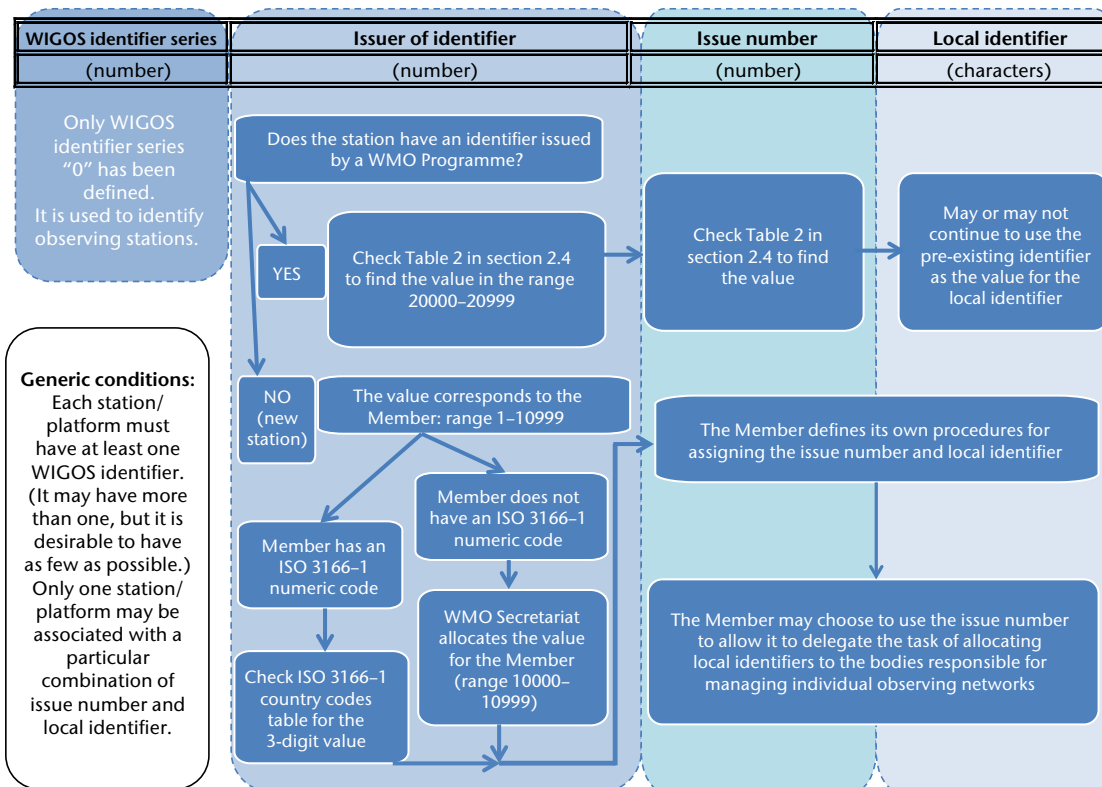


Figure 2. Outline of procedure for Members to allocate a WIGOS station identifier

Although an observing station can have more than one WIGOS 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 identifier should not be issued.

Only a WMO 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 Republic of Korea 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).

The process for Members to allocate a WIGOS identifier is illustrated in Figure 2.

For satellites, WIGOS station identifiers are assigned by the WMO Space Programme, in collaboration with the entity responsible for the satellite (for example, a Member, a space agency or another owner of the satellite).

The WMO or partner programmes that were delegated with the authority to issue WIGOS identifiers (hereafter/hereafter referred to as “WSI issuers”), such as the Comprehensive Nuclear-Test-Ban Treaty Organization (CTBTO), as well as the relevant authority of Global Atmosphere Watch (GAW), Global Cryosphere Watch (GCW), and GCOS Reference Upper-air Network (GRUAN), may use specific issuer of identifier values for issuing WIGOS identifiers for observing stations that contribute to the relevant network on behalf of Members under circumstances specified in the *Manual on the WIGOS*.

Table 1 lists the issuer of identifier values that have been allocated for use for observing stations.

Table 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/Surface | OSCAR allocates the value | Determined by OSCAR/Surface |
| 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 zeros are not shown in WIGOS identifiers). See the ISO website . | Issuer determines its own procedures. Further guidance is available in section 2.3 |
| 10000–10999 | 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 |
| 11000–19999 | Reserved for future use | To be determined | To be determined |
| 20000–20999 | WMO Secretariat, for existing identifiers previously associated with WMO Programmes (before 1 July 2016) – Exception is 20008 which applies to all GAW related stations | Details are provided in section 2.4.1 | Details are provided in section 2.4.1 |
| 21000–21999 | WMO Programmes, with delegated authority for new WIGOS identifiers ³ | Details are provided in section 2.4.2 | Details are provided in section 2.4.2 |
| 22000–22999 | WMO co-sponsored programmes, for new WIGOS identifiers | Details are provided in section 2.4.3 | Details are provided in section 2.4.3 |
| 23000–23999 | WMO Partner Organizations/ Programmes, for new WIGOS identifiers | Details are provided in section 2.4.4 | Details are provided in section 2.4.4 |
| 24000–65534 | 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 identifier in WMO standard code forms.

2.2.1 Reducing ambiguity through systematic use of WIGOS identifiers

An observing facility may have several WIGOS identifiers. Using OSCAR/Surface, 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.

³ That is, after 1 July 2016

2.2.2 **Choosing which WIGOS 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 identifier. For example, a WIGOS 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 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 WIGOS 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 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 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 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 identifier in a BUFR/CREX message**

When constructing a BUFR or CREX message that refers to WIGOS 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 identifier (3 01 150)>
< sequence for the data being reported>

Additional guidelines on how to introduce the WIGOS identifier in BUFR and CREX messages

Where to place:

- (1) When Members report data using BUFR/CREX templates defined in the *Manual on Codes – International Codes* (WMO-No. 306), Volume I.2, Part C, section d, B/C Regulations

or other BUFR/CREX sequences suitable for reporting specific datasets, and include the WSI, the sequence for reporting WSI (3 01 150) should be placed before the BUFR/CREX templates or other BUFR/CREX sequences in BUFR/CREX messages.

How to encode:

- (2) When Members report data from observation sites that have traditional station identifiers, such as a WMO block number (0 01 001)/WMO station number (0 01 002) and buoy platform identifier (0 01 005), these identifiers should also be reported in addition to corresponding WSI (3 01 150), to ensure the continuity of data use. On the other hand, the traditional station identifiers should be reported as “missing” when observation sites do not have the traditional identifiers.

Versions applicable:

- (3) BUFR/CREX messages that include the sequence for reporting WSI (3 01 150) should have master table version number 28 or later, because the sequence 3 01 150 is not defined in the tables with version numbers before 28.

Advanced notification:

- (4) Members should issue advanced notification at least three months before they start distributing new reports that include both traditional station identifiers and WSI (3 01 150), clearly stating the date of change, WSI, corresponding traditional station identifiers (when available), and new and existing bulletin headings. All Members will be notified of these changes through METNO messages defined by the *Manual on the Global Telecommunication System* (WMO-No. 386) and as an entry of the [Operational Newsletter](#).

Distribution not parallel:

- (5) Parallel distribution of BUFR/CREX messages with and without WSI (3 01 150), which consists of the same contents, is discouraged, as the messages coded in conformity with the practice in (2) above satisfies user requirements, and duplicated reporting of the same contents could cause confusion for users.

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

Traditional alphanumeric code forms cannot represent WIGOS 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 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 July 2016). A look-up table from that identifier to the WIGOS identifier would allow the translating centre to insert the WIGOS identifier.

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

2.3 **RECOMMENDED PRACTICES FOR THE ALLOCATION OF ISSUE NUMBER AND LOCAL IDENTIFIER**

Members are recommended to develop their national schema for assigning WSIs with agreed procedures for allocating the issue number and local identifier, taking into account their national organizational structure and requirements. A WSI national schema may define specific ranges (for the issue number) for delegating national authority for issuing WSIs to identified organizations for the observing facilities they operate. It may also define procedures for the allocation of local identifiers. Members may decide whether the implementation and maintenance of the national schema for allocating WSIs is centrally managed by a single organization or is distributed across various national organizations receiving delegated ranges for assigning WSIs, via the issue number.

2.3.1 **Allocating WIGOS identifiers**

- (a) Issuers of identifiers are responsible for guaranteeing that no two observing stations share the same WIGOS identifier. Note that the structure of WIGOS 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 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 identifier must not be issued to more than one observing facility, it is permitted for a station to have more than one WIGOS identifier. For example, although all observing facilities with pre-existing World Weather Watch station identifiers have a WIGOS 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 identifier for a closed observing facility must not be reused unless the observing facility reopens.
- (iii) The organization responsible for allocating the WIGOS 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 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 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 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 identifier means that the range of WIGOS identifiers is, for practical purposes, unlimited. This removes the need to reuse WIGOS identifiers.

- (c) Before issuing a WIGOS identifier, it is important to search [OSCAR/Surface](#) to make sure that it has not already been allocated, and to register that WSI in OSCAR/Surface first, before exchanging any reports with such WSI.
- (d) Members and organizations issuing WIGOS identifiers are strongly advised to document their procedures for allocating WIGOS identifiers in their quality management systems.

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 zeros 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 zeros in the issuer of identifier and issue number parts of the WIGOS identifier, which are omitted from the WIGOS 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 identifiers. In all cases, if an observing facility is closed its local identifier must not be re-attributed (with the same issue number).

| <i>Issue number</i> | <i>Interpretation of issue number</i> | <i>Local identifier</i> |
|---------------------|--|---|
| 1 | NMS synoptic observing facility | WMO World Weather Watch station identifier (with leading zeros 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 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 zeros 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 zeros, 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. |

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 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 ALLOCATING ISSUERS OF IDENTIFIERS FOR OBSERVING STATIONS

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

2.4.1 WMO Secretariat for existing identifiers previously associated with WMO Programmes (before 1 July 2016)

Table 2 defines the issuer of identifier values in the range 20000–20999 to be used for WMO Programmes to issue WIGOS identifiers. This range is used to ensure that observing facilities that have pre-existing station identifiers can be allocated a WIGOS 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 (station/platform). Otherwise, WSI issuers, with delegated authority, will allocate a WIGOS identifier to any new observing facility that contributes to the relevant network, on behalf of Members, following provisions documented in the *Manual on the WIGOS*. Sections 2.4.1-2.4.4 of this Guide define the ranges of values for WSI issuers for stations associated with WMO co-sponsored programmes and WMO partner programmes.

Table 2. Issuer of identifier values in the range 20000–20999

| <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> , 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 Iiii (with leading zeros). Example: station 60351 would be represented by 0–20000–0–60351 |
| 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 Iiii (with leading zeros). Example: upper-air station 57816 would be represented by 0–20001–0–57816 |

| <i>Issuer of identifier values</i> | <i>Category of station identifier</i> | <i>Issue number</i> | <i>Local identifier</i> |
|------------------------------------|---|---|--|
| 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 A1bwnbnbnb. Example: 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 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 Example: 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 Example: 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 Example: aircraft EU0246 would be represented by 0-20005-0-EU0246 |
| 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 Example: Geneva airport (LSGG) would be represented by 0-20006-0-LSGG |

| <i>Issuer of identifier values</i> | <i>Category of station identifier</i> | <i>Issue number</i> | <i>Local identifier</i> |
|------------------------------------|---|--|---|
| 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 Example: 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 Example: Jungfrauoch JFJ would be represented by 0-20008-0-JFJ |
| 20009 | WMO Space Programme | 0 | Three-digit satellite identifier with leading zeros (recorded in Common Code Table C-5 of the <i>Manual on Codes – International Codes</i> (WMO-No. 306), Volume I.2) Example: 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) Example: Station with record number 121 would be represented by 0-20010-0-121 |
| 20011–20999 | Reserved for future use | To be determined | To be determined |

2.4.2 **WMO programmes with delegated authority for new WIGOS identifiers (after 1 July 2016)**

Table 3 defines the issuer of identifier values in the range 21000–21999 to be used for WIGOS identifiers.

Table 3. Issuer of identifier values in the range 21000–21999

| <i>Issuer of identifier values</i> | <i>Category of station identifier</i> | <i>Issue number</i> | <i>Local identifier</i> |
|------------------------------------|---------------------------------------|---------------------|-------------------------|
| 21000 | Identifiers for GCW – See 9.1 | | |

| <i>Issuer of identifier values</i> | <i>Category of station identifier</i> | <i>Issue number</i> | <i>Local identifier</i> |
|---|--|---------------------|---|
| 20008 | GAW – See 9.3 (as an exception, the issuer of identifier for GAW stations is not within the range 21000–21999) | | |
| 21009 | Identifiers for WMO Space Programme (See 9.7) | 0 | Three-digit satellite identifier with leading zeros (recorded in Common Code Table C–5 of the <i>Manual on Codes – International Codes</i> (WMO-No. 306), Volume 1.2) |
| 21010 | WRD – See 9.4 | | |
| 21011 | WMO Aircraft-based Observations Metadata Repository (ABO-MR) – See Guide to Aircraft-based Observations (WMO-No. 1200), Appendix D | To be determined | Issued by the ABO-MR in accordance with Guide to Aircraft-based Observations (WMO-No. 1200) |
| 21016 | WHOS – See 9.5 | | |
| Remaining values in the range 21000–21999 | Reserved for future use | To be determined | To be determined |

2.4.3 **WMO co-sponsored programmes for new WIGOS identifiers**

Table 4 defines the issuer of identifier values in the range 22000–22999 to be used for WIGOS identifiers.

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

Table 4. Issuer of identifier values in the range 22000–22999

| <i>Issuer of identifier values</i> | <i>Category of station identifier</i> | <i>Issue number</i> | <i>Local identifier</i> |
|------------------------------------|---|------------------------|-------------------------|
| 22000 | GOOS – Identifiers for marine systems administered through OceanOPS – See 9.2 Note: OceanOPS coordinates some marine observing systems to avoid technical incompatibilities. | Determined by OceanOPS | Determined by OceanOPS |
| 22001 | GRUAN | | |
| 22002–22999 | Reserved for future use | To be determined | To be determined |

2.4.4 **WMO partner organizations/programmes for new WIGOS identifiers**

Table 5 defines the issuer of identifier values in the range 23000–23999 to be used for WIGOS identifiers.

Table 5. Issuer of identifier values in the range 23000–23999

| <i>Issuer of identifier values</i> | <i>Category of station identifier</i> | <i>Issue number</i> | <i>Local identifier</i> |
|------------------------------------|---------------------------------------|---------------------|-------------------------|
| 23000 | CTBTO | | |
| 23001 | Copernicus-C3S | | |
| 23002–23999 | Reserved for future use | To be determined | To be determined |

2.4.5 **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 WIGOS 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: WIGOS 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 identifier corresponding to that Programme identifier should be used.

Global network of tsunameters: WIGOS 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 identifier corresponding to that Programme identifier should be used.

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 (5) describes the relevance of metadata as follows:

In order to ensure the utility of the observations, the details and history of local conditions, site location, instruments, operating procedures, data-processing algorithms, data errors and biases, and other factors pertinent to interpreting data (that is, metadata) and their changes over time should be documented and treated with the same care as the data themselves.

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* (WMO-No. 1192) 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 WIGOS 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 WIGOS*. 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* (WMO-No. 49), 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 (WMO-No. 1192)

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 OSCAR/Surface, which is the WMO official repository of WIGOS metadata for surface-based observing stations and platforms.

For surface-based observations, the *WIGOS Metadata Standard* (WMO-No. 1192) 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.

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 e-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.

3.2 **GENERAL GUIDANCE ON WIGOS METADATA**

The *WIGOS Metadata Standard* (WMO-No. 1192) 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:

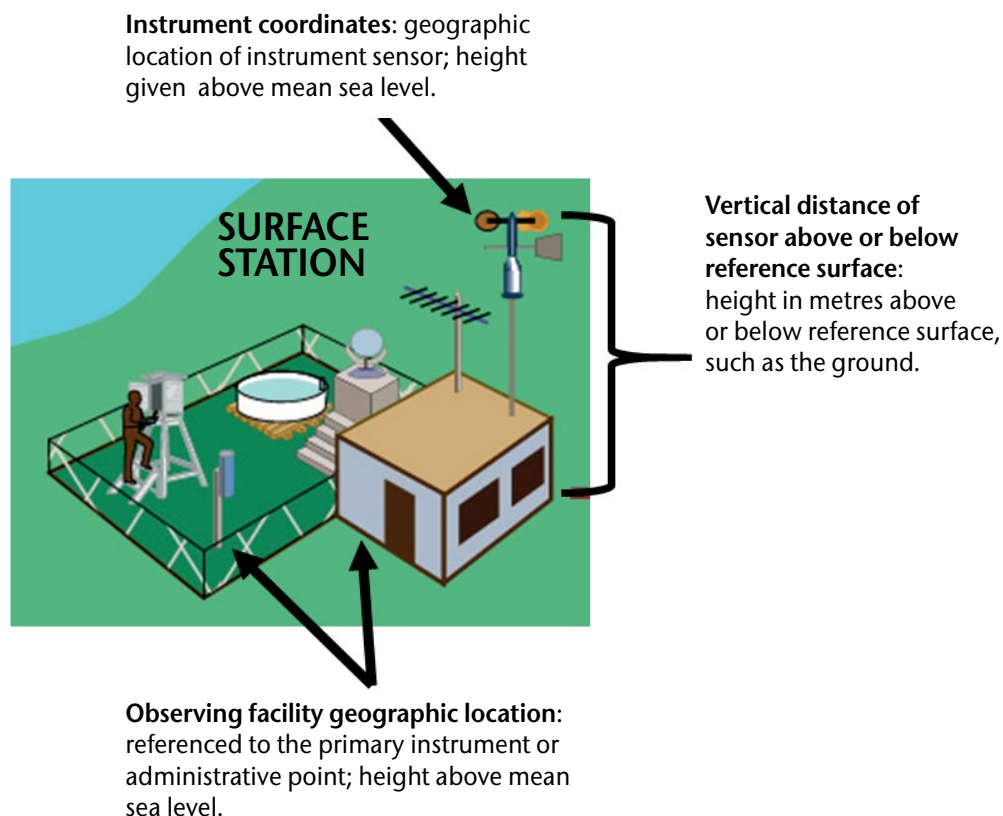
1. Each time the number in format x-yy appears in this Guide, it refers to the number of the metadata element in the *WIGOS Metadata Standard* (WMO-No. 1192). Where a metadata element is mentioned without this number, it means it is not part of the Standard.
2. Users of OSCAR/Surface may or may not see 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 ge positioning 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).



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.

Figure 3. Metadata elements for station location and instrument location, including height references

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. Figure 3 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.

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”.

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.

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.

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 **Guidance material related to grouping observing facilities to station clusters**

3.2.3.1 **Definitions**

According to the metadata categories and elements outlined in the *WIGOS Metadata Standard* (WMO-No. 1192), three levels of grouping measurements are supported:

- Single instrument/sensor/device: provides independent measurements for one or more variables as part of an observing facility;
- Observing facility² (station or platform): provides measurements/observations from one or more instruments and devices at the same location reporting under the same WIGOS station identifier (WSI);
- Station set or cluster³ is an optional element of the *WIGOS Metadata Standard* (WMO-No. 1192) "station/platform cluster" (ID 3-10), that allows the grouping of two or more observing facilities, each with its own WSI, for a defined purpose.

The concept of a station cluster as a grouping of observing facilities was introduced to the *WIGOS Metadata Standard* (WMO-No. 1192) to address requirements of Members to represent relationships between observing facilities registered under different WSIs. It allows, for example, Members to reflect ownership of infrastructure and/or data, programme affiliation, governance, purpose, historical traceability and connections between observing facilities related to representativeness, exposure conditions, or environmental or geographical characteristics (for example, related to the terrain, mountainous conditions).

OSCAR/Surface is the tool that provides the functionality to establish station clusters. It implements the definition of the *WIGOS Metadata Standard* (WMO-No. 1192) as indicated above. In OSCAR/Surface a station cluster is identified by a cluster name and a short description, which allows for details of the rationale for establishing the station cluster to be provided.

3.2.3.2 **Members' responsibilities**

A station cluster should only be introduced when two or more observing facilities are to be grouped for a clearly defined purpose, to avoid the unnecessary proliferation of such groupings. The decision to group observing facilities into a cluster rests with the Member operating those observing facilities.

If a grouping into a station cluster is required by a single institution or programme, the institution or programme may define such a grouping. Where a cluster is required to group observing facilities with multi-application purposes or operated by different organizations, the Permanent Representative of a WMO Member, via the delegated authority of an OSCAR/Surface

² The present chapter refers mainly to observing facilities. It should be noted that other comparable terms such as "station" might be used throughout the *Manual on the WMO Integrated Global Observing System* (WMO-No. 1160).

³ For consistency the term "station cluster" is used throughout the present Guide.

national focal point (NFP) in consultation with the WIGOS NFP, may decide on grouping these observing facilities into a station cluster in consultation with the proponent of the grouping and the owner of the observing facility.

3.2.3.3 **Procedural guidance**

Considering that observing networks and facilities should be designed to meet or address requirements for observations across several purposes and many application areas in the sense of the Rolling Review of Requirements process, multi-purpose observing should be encouraged.

It is up to each Member to decide whether an observing facility belongs to either none, one or several station clusters. To assist Members with the decision on whether to group instruments or observations to form an observing facility with one WSI or a station cluster at surface level, procedural guidance is as follows:

- (a) All instruments providing observations expected to be internationally exchanged as part of the same report/message, under the same WSI, should be grouped under one observing facility (station), not under a cluster.
- (b) The decision to group instruments or observations under one WSI rests with the Member, in compliance with the provisions of the *Manual on the WIGOS*.
- (c) The process for deciding whether a set of observing facilities at surface level with various WSI should be grouped together as a station cluster, or not, is as follows:
 - (i) Create a cluster for the various observing facilities if they have strong commonalities or are strongly related, that is, if at least one of the following conditions is met:
 - All observing facilities observe the same geographic or physiographic feature (for example, a glacier, airport, catchment, research area);
 - Benefits can be identified from grouping them as a cluster and a rationale can be described, for example, grouping them as a cluster might be relevant for data usage or other reasons, although not related to geographic features at all;
 - There is some historical continuity across the observing facilities;
 - The observing facilities are managed together or their data is used together, for example, because they are operated by the same entity or affiliated to the same programme, such as a CryoNet cluster or a group of buoys.
 - (ii) If none of the conditions above are met, no station cluster should be defined.

Notes:

1. Clustering should not replace nor duplicate the affiliation of observing facilities with programmes/networks (ID 2-02 Programme/network affiliation, as outlined in the *WIGOS Metadata Standard* (WMO-No. 1192)). Cluster and affiliation are different concepts.
2. Creating station clusters is about indicating linkages between observing facilities. The introduction of station clusters will not remove, replace or degrade any existing information in OSCAR/Surface.
3. WSIs are defined at station level (see Figure 5 for an example of a station cluster using different WSIs, in Lindenberg) and are essential for international data exchange. WSIs must not be introduced for stations clusters. Therefore, to exchange messages and reports internationally, the WSIs that were assigned to the particular observing facility to which the messages and reports are referring will be used.
4. There is no specific recommendation as to the maximum distance between observing facilities within a station cluster or grouping because the driver for the grouping should be the rationale (see Figure 6 for the example of the GAW/GOS Zugspitze-Hohenpeissenberg cluster). Similarly, geographical proximity is not necessarily a rationale for grouping stations.

5. If an observing facility "A" provides data to be used for computing-derived data and/or for reporting observations from another nearby observing facility "B" (for example, precipitation or snow depth observations both being used for the GOS and Global Cryosphere Watch), then both observing facilities "A" and "B" should be grouped together as a station cluster.
6. The *WIGOS Metadata Standard* (WMO-No. 1192) explicitly supports the specification of geospatial location and changes thereof at the level of both the observing facility and individual instrument(s). Therefore, in case an observing facility is replaced by a new one, for example, at a different location, it is recommended that the old (closed) observing facility and the new observing facility (with a new WSI) be linked as a station cluster if the exposure, conditions and representativeness remain the same, even though the location of the instrument changes. This would ensure historical continuity of data series.
7. The concept of grouping observing facilities into station clusters is not limited to land-based stations and can be expanded, for example, to ocean, sea ice or potentially even space weather observing facilities.

3.2.3.4 **Station cluster metadata**

A station cluster can be configured in OSCAR/Surface by an authorized NFP or metadata editor, by selecting "Station Cluster" under the "Search" tab. The following metadata must be provided when establishing a station cluster:

- Cluster name – this should be unique and representative;
- Cluster description – free text of up to 1 024 characters. The description should provide a rationale for establishing the station cluster, for example, by including additional links to web pages relevant to the purpose of the cluster;
- Names of stations included in the cluster – these are selected from among those already registered in OSCAR/Surface, based on the stated rationale.

Once established, the name and the composition of a cluster is indicated on the OSCAR/Surface page of each station belonging to this cluster, and the list of clustered stations will be available.

Changes to existing station clusters, for example, the addition of stations, are possible only by the authorized NFP or metadata editor.

It is expected that future versions of OSCAR/Surface will be searchable by name and description.

3.2.3.5 **Examples from OSCAR/Surface**

In OSCAR/Surface the term "station" is used to describe metadata of an observing facility. To avoid confusion, this term is used in the present section.

Example 1: CryoNet clusters

CryoNet clusters are already introduced in OSCAR/Surface following the definition described in the *Manual on the WIGOS* (Chapter 8). See Figure 4 for an example of Davos Integrated CryoNet cluster.

Davos Integrated CryoNet Cluster

The Davos Cluster stretches from Klosters (1100 m) to the Verstanciahorn (3298 m asl) and covers ~ 300 sqKm, with various micro-climates. Measurements include permafrost temperature, active layer depth, albedo, snow surface temperature, measured over several decades and to continue, long-term measurements of temperature, precipitation and snow (end of the 19th century) in Davos, and the longest series of daily snow measurements at high elevation (Weissfluhjoch Versuchsfeld, 2536 m asl). It encompasses the Silvretta glacier (~ 3000 m asl) with the second-longest mass-balance series worldwide (Huss et al., 2015), a reference glacier of WGMS. Dirschma valley, known for studies on snow hydrology, snow-vegetation interactions (Stilberg) and on accumulation and ablation patterns, lies within the cluster. A weather radar (MeteoSwiss) on Weissfluh (2832 m asl) and a planned Swiss Alpine Remote Sensing station (1513 m asl) will allow for new research, monitoring, and cal/val activities; map: <http://bit.ly/1qEgXRJ>

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Members

| Station | Country | WMO Region | WIGOS ID |
|------------------------------|-------------|------------|----------------|
| Davos observer station (SLF) | Switzerland | Europe | 0-756-1-601286 |
| Kreuzweg | Switzerland | Europe | 0-756-1-605310 |
| Flüela permafrost | Switzerland | Europe | 0-756-1-387493 |
| Davos Stilli (SLF) | Switzerland | Europe | 0-756-1-927792 |
| Davos ASRB (SLF) | Switzerland | Europe | 0-756-1-799649 |

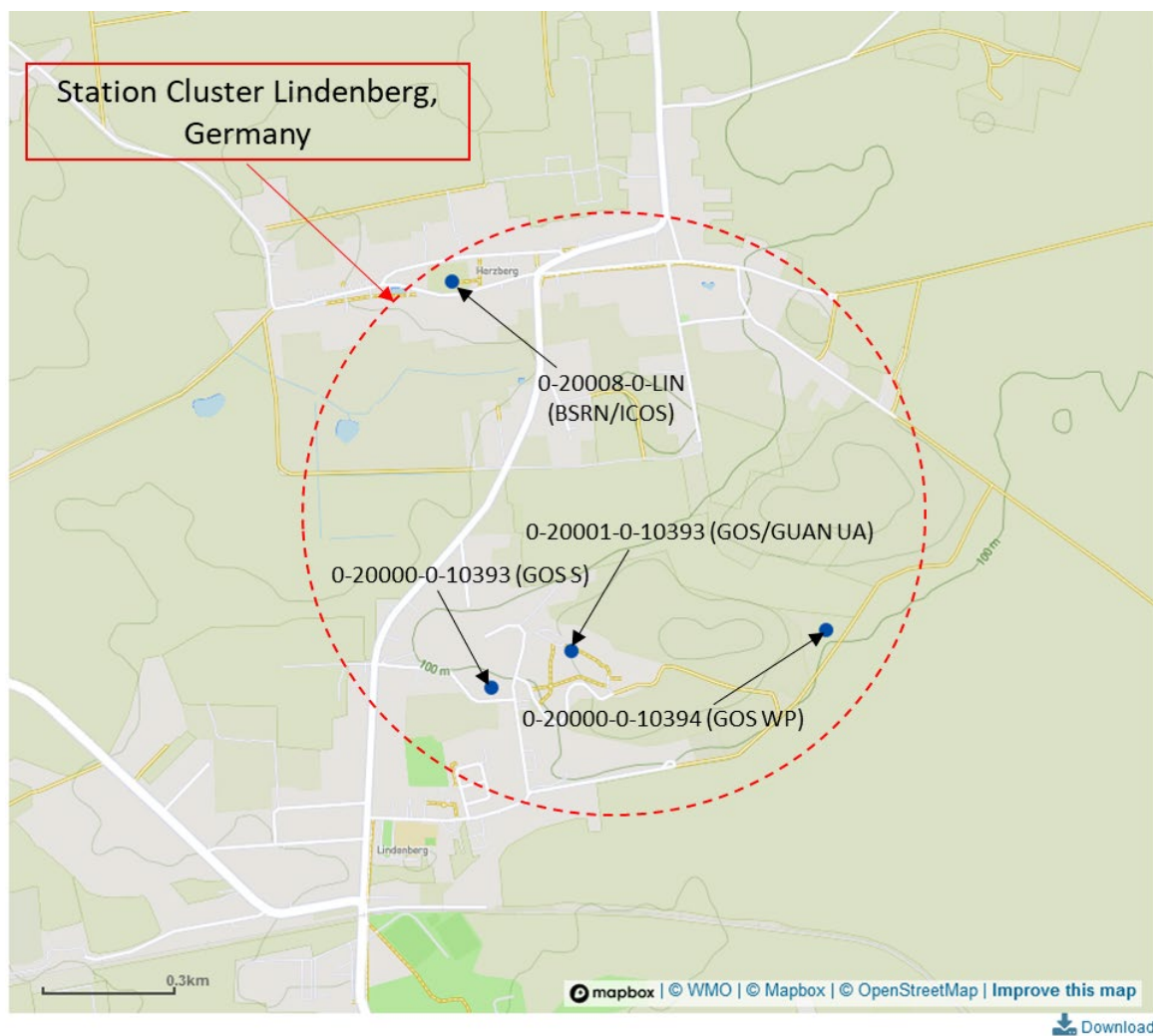
Figure 4. Example of a CryoNet station cluster

A CryoNet cluster is defined in the *Manual on the WIGOS* as being comprised of two or more coordinated stations, of which at least one must be a CryoNet station or a CryoNet contributing station together with a station providing representative meteorological observations, and which together, meet the requirements for a CryoNet station.

Example 2: Grouping observing facilities in close vicinity

This example demonstrates possible reasons why a number of observing facilities in close vicinity might be grouped in a station cluster, as is the case in Lindenberg:

- Two or more observing facilities registered under different WSIs host various associated equipment at the same or nearby location but serve different purposes.
- Equipment managed/operated by multiple organizations or for different programmes, registered under different WSIs are installed at the same location. For example, Germany operates a GOS surface station with WSI 0-20000-0-10393, a GCOS Upper-air Network (GUAN) station with WSI 0-20001-0-10393, a Global Observing System (GOS) wind profiler (0-20000-0-10394) as well as a Baseline Surface Radiation Network (BSRN) and Integrated Carbon Observing System (ICOS) station (WSI 0-20008-0-LIN) in close vicinity. These four observing facilities were therefore able to be grouped as a station cluster, named “Lindenberg” (see Figure 5).



| WMO Region | Country | Station | Coordinates | WIGOS ID | Actions |
|------------|---------|----------------------|---------------------------------------|-----------------|---------|
| Europe | Germany | LINDENBERG (10393-0) | 52.2084°N 14.1179°E Elevation: 98 | 0-20000-0-10393 | |
| Europe | Germany | LINDENBERG (10393-1) | 52.2092°N 14.1206°E Elevation: 112 | 0-20001-0-10393 | |
| Europe | Germany | LINDENBERG (WP) | 52.2096°N 14.1289°E Elevation: 101 | 0-20000-0-10394 | |
| Europe | Germany | Lindenbergl | 52.2166°N 14.1166°E Elevation: 112 | 0-20008-0-LIN | |

Note: Further stations in this area which do not belong to this station cluster might be shown on the OSCAR/Surface map.

Figure 5. Example of a grouping of observing facilities, in Lindenbergl, Germany

Example 3: Grouping observing facilities to meet a defined purpose

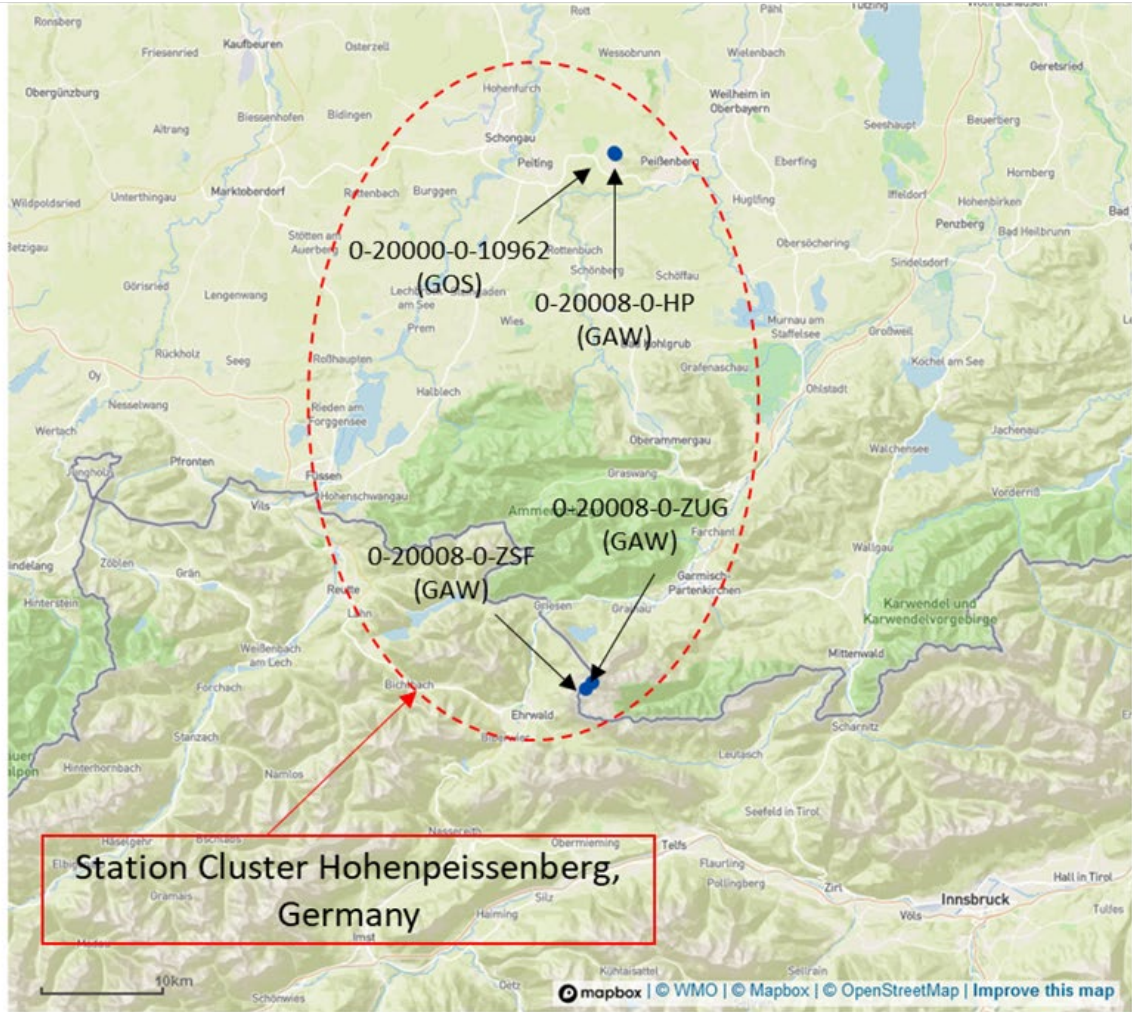
Several observing facilities, identified by their own WSIs and which are not in close vicinity, could also be grouped to a station cluster to meet a defined purpose. These observing facilities may operate different sets of instruments for different programmes and/or be owned by different institutions (9-01 Supervising organization, *WIGOS Metadata Standard* (WMO-No. 1192)). For example, the three Global Atmosphere Watch (GAW) stations Zugspitze-Schneefernerhaus, Zugspitze-Gipfel and Hohenpeissenberg were able to be grouped together, as they are all contributing to the same purpose, and such grouping was also able to include the GOS surface

land station Hohenpeissenberg (see Figure 6). The decision will always lay on the NFP, or someone with delegated authority in OSCAR/Surface, who should provide such a rationale under the cluster description.

Hohenpeissenberg (Germany)

Last updated: 2021-08-09 by Lindauer Matthias

Part of Zugspitze-Hohenpeissenberg (Zugspitze-Schneefernerhaus, Zugspitze-Gipfel, ZUGSPITZE, HOHENPEISSENBERG) in WMO Region VI - Europe



| WMO Region | Country | Station | Coordinates | WIGOS ID | Actions |
|------------|---------|--|---|-----------------|---------|
| Europe | Germany | HOHENPEISSENBERG | 47.8008°N 11.0108°E Elevation: 977.2 | 0-20000-0-10962 | |
| Europe | Germany | Hohenpeissenberg | 47.8014°N 11.0096°E Elevation: 985 | 0-20008-0-HPB | |
| Europe | Germany | Zugspitze-Gipfel | 47.4210°N 10.9858°E Elevation: 2962 | 0-20008-0-ZUG | |
| Europe | Germany | Zugspitze-Schneefernerhaus | 47.4165°N 10.9796°E Elevation: 2671 | 0-20008-0-ZSF | |

Note: Further stations in this area which do not belong to this station cluster might be shown on the OSCAR/Surface map.

Figure 6. Example of a GAW/GOS station cluster, in Zugspitze-Hohenpeissenberg, Germany

3.2.3.6 **Searching for station clusters in OSCAR/Surface**

Details on how to add and search for station clusters in OSCAR/Surface and how to find other stations that are part of a cluster can be found in the [OSCAR/Surface User Manual](#).

3.2.4 **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 national or network focal point, the metadata editor, programme approver, instrument expert, or the organization responsible for the data policy. Any user who is not assigned a specific user role/function is considered a regular user of OSCAR/Surface and has minimum access rights to the OSCAR/Surface database. Specific access rights of the different types of users are documented in Table 2 of the *OSCAR/Surface User Manual*.

3.2.5 **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.

3.2.6 **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, snow depth, glacier area, permafrost thickness, or sea-ice concentration, 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, and snow depth.

The following conditional elements of the *WIGOS Metadata Standard* (WMO-No. 1192) 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* (WMO-No. 1192) 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 or a measurement representative of the cryosphere on the ground. Examples of the atmospheric observing systems in this category are wind profiling radars, lidars, sodars, radiometers, ground-based GNSS receivers, and high-frequency radars. Examples of the cryospheric observing systems are sonic and optical snow measuring instruments, snow pillow, snow scale, and passive gamma radiation instruments. So, both active and passive remote-sensing technologies are considered here.

The majority of the metadata regarding these atmospheric observing 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 atmospheric observing 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, salinity, sea-ice thickness, sea-ice concentration, sea-ice type, sea-ice velocity, sea-ice temperature profiles, snow depth on ice, and snow-ice interface temperature.

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), visibility, sea-ice type, sea-ice thickness, sea-ice freeboard, sea-ice concentration, and iceberg position.

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* (WMO-No. 49), Volume I.

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.

More details are provided in the *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**

Stations/platforms on ice include those established on glaciers and ice caps, ice sheets, ice shelves, pack ice, and moving with ice, as well as those on fast ice. These are often major stations/platforms monitoring the above-mentioned cryosphere components.

Common observed glacier variables are surface accumulation, surface ablation, surface mass balance, glacier area, glacier velocity, calving flux, and glacial runoff, and the first three are also commonly observed ice sheet variables. Basal ablation and ice velocity are commonly observed variables for ice shelves. Stations/platforms for measuring sea ice may either be deployed on fast ice or pack ice and their lifetime depends on the sea-ice survival, with instrumentation on fast ice often recovered before ice breakout and re-deployed during the next ice season. Common observations for sea ice include ice thickness, ice freeboard and snow depth on ice. Some stations/platforms also measure temperature profiles of sea ice and snow on ice, the temperature at the ice-water interface and at the surface-air interface.

At the time of performing cryospheric measurements, meteorological variables such as air temperature, atmospheric pressure, humidity, wind speed and wind direction may be measured by an Automatic Weather Station (AWS) nearby or by appropriate sensors integrated within the ice instrumentation. Other measurements may include radiation, sensible heat, latent heat, water vapour, and CO₂ fluxes.

Where observing platforms move considerably, their position data are recommended to be integrated in the regular data relay. For near-stationary instrumentation, users are recommended to update the coordinates of stations and observations on a yearly basis, or as frequently as deemed necessary. More detailed moving track can be uploaded as a specific document in the “Documents” section via the [OSCAR/Surface Graphical User Interface](#).

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

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](#). Hydrological monitoring also includes reservoir inflows, outflows and heights as relevant variables for water resources management.

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 intercomparisons 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. OBSERVING NETWORK DESIGN

4.1 INTRODUCTION

The observing network design principles are provided in the *Manual on the WIGOS*, Appendix 2.1. The 13 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 Annex 4.1.

4.2 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 that allows National Meteorological and Hydrological Services or other organizations to render services related to weather, climate, water and other environmental events,¹ contributing to public safety, socioeconomic well-being and development in their

¹ In the context of the *WMO Strategic Plan 2020–2023* (WMO-No. 1225), the term “weather” refers to short-term variations in the state of the atmosphere and their phenomena or effects, including wind, cloud, rain, snow, fog, cold spells, heatwaves, drought, sand and dust storms and atmospheric composition, as well as tropical and extratropical cyclones, storms, gales, the state of the sea (for example, wind-generated waves), sea ice, coastal storm surges, and so forth. “Climate” refers to longer-term aspects of the atmosphere-ocean-land surface systems. “Water” includes freshwater above and below the land surfaces of the Earth, and its occurrence, circulation and distribution, both in time and space. Related “environmental” issues refer to surrounding conditions affecting human beings and living resources, for example, the quality of air, soil and water, as well as “space weather” – the physical and phenomenological state of the natural space environment, including the Sun and the interplanetary and planetary environments.

respective countries. The concept of a WMO application area is used in the framework of the WMO Rolling Review of Requirements² and describes a homogeneous activity for which it is possible to compile a consistent set of observational user requirements agreed by community experts working in this area.

- (a) When designing observing networks, the needs of WMO application areas, as regulated in the Manual on the WIGOS, should be taken into account. In particular, see the [WMO Rolling Review of Requirements](#) process, the WIGOS database of user requirements for observations ([OSCAR/Requirements](#)) and the Statements of Guidance, which together represent all application areas, as well as the [High-Level Guidance on the Evolution of Global Observing Systems During the Period 2023–2027 in Response to the Vision for WIGOS in 2040](#) (WMO-No. 1334). 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 relevant comments in the preamble to the [High-level Guidance on the Evolution of Global Observing Systems During the Period 2023–2027 in Response to the Vision for WIGOS in 2040](#) (WMO-No. 1334)). 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 in the applicable domains (vertical layer/s and horizontal coverage), the space-time resolution, uncertainty, timeliness and stability needed, and taking into account relative priorities.)

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.

² The WMO Rolling Review of Requirements is described in the [Manual on the WMO Integrated Global Observing System](#) (WMO-No. 1160), Appendix 2.3.

- (b) When designing their observing networks, Members should take into account the actions listed in *the High-level Guidance on the Evolution of Global Observing Systems During the Period 2023–2027 in Response to the Vision for WIGOS in 2040* (WMO-No. 1334), 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, including differences in requirements, as well as the additional detailed 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 WIGOS*. (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 representative³ 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 on existing technology should be consulted. For example, reference can be made to the *Guide to Instruments and Methods of Observation* (WMO-No. 8), the [Guide to Climatological Practices](#) (WMO-No. 100),

³ 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.

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 relevant comments in the *High-level Guidance on the Evolution of Global Observing Systems During the Period 2023–2027 in Response to the Vision for WIGOS in 2040* (WMO-No. 1334)) 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) Space-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) While 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 approach⁴ 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.
- (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.⁵
- (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.

⁴ For a tiered approach, see *GCOS Reference Upper-air Network (GRUAN): Justification, requirements, siting and instrumentation options*, GCOS-112 (WMO/TD No. 1379).

⁵ 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>).

- (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).
- (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 WIGOS*; 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 *Manual on the Global Telecommunication System* (WMO-No. 386) 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 metadata standard as specified in the *Manual on the WIGOS* 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 *High-level Guidance on the Evolution of Global Observing Systems During the Period 2023–2027 in Response to the Vision for WIGOS in 2040*.

- (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 systems⁶ 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.

⁶ 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.

- (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.
- (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).

Principle 13. Advancing environmental sustainability

(The environmental impacts of observing networks should be considered in their design and operation. Advancements in the environmental sustainability of networks should be promoted where viable solutions are available that meet user requirements.)

Notes:

- (1) In the present context, “environmental sustainability” means the practice of conserving, maintaining and protecting global ecosystems when planning observing systems across all domains, without adding unnecessary strain on ecosystems. Principle 13 “Advancing environmental sustainability”, Principle 8 “Designing reliable and stable networks” and Principle 11 “Achieving sustainable networks”, must be balanced in the context of the value of the observation, as determined by appropriate impact planning/assessments.
- (2) In the context of the present Principle, “observing system” means both the observing system in itself as well as the infrastructure and works required for deployment, operation and decommissioning, (such as the construction of specific roads, buildings, power generators, data and power lines, and ground work).
- (a) Environmental impacts should be considered for the entire life cycle of an observing system, from design, procurement, manufacturing and transport to operations, maintenance, calibration, decommissioning and disposal.
- (b) When planning an observing network, efforts should be made to ensure optimized operations that will reduce duplication and their associated negative environmental impacts (for example, consideration should be given to the required land space, maintenance, site visits and power consumption).
- (c) Opportunities to implement a tiered network approach should be considered at the network design stage to minimize negative environmental impacts while ensuring the fit-for-purpose data quality of an observing system.
- (d) Implementation of innovative methods of observation and technologies for increasing environmental sustainability should be explored. Solutions could include selection of equipment and infrastructure that is robust and reusable, and use of environmentally friendly materials and of renewable energy sources.
- (e) At every opportunity along the life cycle of an observing system, consideration should be given to minimizing the negative environmental impacts of physical and hazardous waste. This includes reducing waste in general, as well as ensuring proper disposal.

- (f) Procurement activities should include clauses in tender documents specifying the requirements for environmental sustainability.

ANNEX 4.1. EXPLANATION OF TERMS RELATED TO OBSERVING NETWORK GUIDANCE

Note: Formal definitions of terms are published in the *Technical Regulations* (WMO-No. 49), [Volumes I, II and III](#), and their annexes, the Manuals, 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.

5. GUIDANCE ON NATIONAL WIGOS IMPLEMENTATION

5.1 INTRODUCTION

The purpose of this chapter is to assist WMO Members in developing their National Observation Strategy and National WIGOS Implementation Plan, to enable them to implement the WMO Unified Policy for the International Exchange of Earth System Data and to design, plan and develop their national observing system (NOS) as a national WIGOS observing component and as a national contribution to the Global Basic Observing Network (GBON).

This chapter is aligned with WIGOS-related technical regulations and guidance material developed under the governance of the Commission for Observation, Infrastructure and Information Systems and the former Inter-commission Coordination Group on WIGOS (ICG-WIGOS).

5.2 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 observational 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.

During the WIGOS Initial Operational Phase (2020–2023),¹ national-level WIGOS implementation, including necessary capacity development, partnership agreements and integration of observing systems for all application areas, was one of the highest priorities for WIGOS.

In this period, an important underlying issue was the need to implement sound practices, policies and capabilities within individual meteorological, climatological, hydrological and other relevant environmental institutions and partner organizations in relation to the life cycle management of data. This is important for ensuring that Members are able to manage their observations and data efficiently and effectively, to maximize the value and impact of the data in support of their services, and to integrate observations and data from diverse platforms and from external sources (such as the academic community, the private sector and third parties) to support the implementation of the WMO Unified Policy for the International Exchange of Earth System Data and the establishment of the Global Basic Observing Network.²

During the WIGOS Initial Operational Phase, National Meteorological and Hydrological Services (NMHSs), working with their national partners, were expected to take on greater responsibility for the national implementation of WIGOS and to use the framework provided by WIGOS to exert leadership in the acquisition and management of meteorological, climatological, hydrological, oceanographic and other relevant environmental observations at the national level.

NMHSs should strive to act as the key players at the national level, both by strengthening their own observing systems in accordance with the *Technical Regulations* (WMO-No. 49), Volume I, 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. Data customers are demanding more data and information be delivered precisely when and how they need it. As a key national service provider, NMHSs have to respond effectively to this rapidly evolving data landscape.

¹ See *Executive Council: Abridged Final Report of the Seventy-third Session* (WMO-No. 1277), Resolution 9.

² *World Meteorological Congress: Abridged Final Report of the Extraordinary Session* (WMO-No. 1281), Resolution 1 and Resolution 2, respectively.

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.

NMHSs 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.

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) Enhanced capabilities to identify and address gaps in global, regional, subregional and national observing systems in the context of user needs, issues, etc.;
- (c) Increased integration and free and unrestricted sharing of observations from various sources (NMHSs and other governmental and non-governmental organizations, research institutes, volunteer networks, the private sector, etc.) across national and regional boundaries to support improved service delivery by Members;
- (d) Progressively greater availability and quality of WIGOS observational data and metadata;
- (e) Increased visibility and strengthened role of NMHSs, as a partner, enabler and integrator of observations, at the national level;
- (f) Enhanced cooperation and collaboration with partners at the national and regional levels;
- (g) Enhanced culture of compliance with the Technical Regulations (WMO-No. 49), Volume I, Part I, and the *Manual on the WIGOS*;
- (h) Improved human and technical capacity of Members for planning, implementation and operation of WIGOS.

NMHSs, as enablers and integrators of observations at their national level, will reach out to their national partners, such as other governmental and non-governmental organizations, research institutes, volunteer networks and the private sector, to develop and maintain agreements 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. Chapter 6 provides details.

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, legal and institutional frameworks, etc.;
- (b) Analysis of the national implications of the WMO Unified Policy for the International Exchange of Earth System Data with respect to core data, the WIGOS-relevant provisions of the *Technical Regulations* (WMO-No. 49), Volume I, Part I, and the *Manual on the WIGOS*, with a strong emphasis on the Global Basic Observing Network regulations, and a culture of compliance;
- (c) Promotion of alignment of national policies and regulations concerning Earth system data sharing and exchange, nationally and internationally, with the WMO Unified Policy for the International Exchange of Earth System Data;
- (d) If not already in place, establishment of national governance and key partnerships to enhance the exchange of Earth system data among national and regional stakeholders in order to improve integration of data across disciplines and domains;
- (e) Strengthening effective coordination and collaboration with relevant partners and stakeholders on matters related to data policy and practice;
- (f) Critical analysis of capabilities and gaps (systems, processes, people, networks, governance, issues of compliance);
- (g) Specification of expected deliverables, outcomes, milestones and key performance indicators for national WIGOS implementation;
- (h) Development of a National WIGOS Implementation Plan.

5.2.1 **Development of a National Observing Strategy: Understanding national needs and priorities**

Development of a National Observing Strategy will enable the NMHS and its national partners to better meet user needs and demands, and will help ensure that it has the best basis for planning its investment in systems, science and people. It will also allow the NMHS and its partners 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 [Global Framework for Climate Services](#) (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.³

The National Observing Strategy provides the overall strategic framework for implementing WIGOS and should take into account the needs and goals of all data 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) [Observing System Strategy](#) (Australia)

³ See also [WMO Integrated Strategic Planning Handbook](#) (WMO-No. 1180).

- (b) [Observations Strategy KNMI](#) (Netherlands)

5.2.2 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 policy, legal and institutional frameworks with clearly defined roles and responsibilities of all stakeholders, and with well-organized coordination and collaboration mechanisms and principles;
- (c) Implementation of the WMO Unified Policy for the International Exchange of Earth System Data;
- (d) Establishment and enhancement of public-private partnerships;
- (e) 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));⁴
- (f) Development of a national contribution to the GBON;
- (g) Gap analysis of WIGOS-related systems, processes, people, governance, issues of compliance;
- (h) 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 WIGOS*;
- (i) Operational implementation of *WIGOS Metadata Standard* (WMO-No. 1192) through populating the [OSCAR/Surface](#) database and keeping its content up to date;
- (j) Operational implementation of WIGOS Station Identifiers;
- (k) Monitoring the availability and quality of observations through the national WDQMS, and taking corrective action as necessary (incident management);
- (l) Systematic and rigorous performance monitoring and evaluation of WIGOS capabilities;
- (m) Increased integration and free and unrestricted sharing of observations from NMHSs and non-NMHSs sources;
- (n) Development and implementation of a data and information framework;⁵
- (o) Implementation of modern data lifecycle management and practices;
- (p) Availability and protection of suitable radio-frequency bands required for meteorological and related environmental operations and research;
- (q) Development of an effective resource mobilization strategy;

⁴ See *Manual on the WIGOS*, 2.2.2, and Chapter 4 of this Guide.

⁵ See example at http://www.bom.gov.au/inside/BoMDataFramework_Final.pdf.

- (r) Development of a risk management plan;
- (s) 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.

5.2.3 Planning

Planning is the first step in the so-called Plan-Do-Check-Act (PDCA) Cycle (see Annex 5.2), 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 Rolling Review of Requirements (RRR) process.⁶

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.

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 Member 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;

⁶ See the *Manual on the WIGOS* 2.2.4, with further details at <https://community.wmo.int/rolling-review-requirements-process>

- (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 free and unrestricted 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 implementation plan.

Members are encouraged to draw on the WIGOS National Self-assessment Checklist; two examples (Australia and Switzerland) are available at: <https://community.wmo.int/implementation-examples>.

A wide range of other materials already exists to guide Members in relation to WIGOS, including the *High-level Guidance on the Evolution of Global Observing Systems During the Period 2023–2027 in Response to the Vision for WIGOS in 2040* (WMO-No. 1334) 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](#). Altogether, those materials help identify national priorities and gaps in observations, systems, processes and capabilities, and provide the basis for developing a national WIGOS implementation 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.

5.2.4 **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 (that is, 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.

5.2.5 **Protection of the radio-frequency spectrum**

Access to the radio-frequency spectrum is critical to the operation of WMO global infrastructure, which underpins the service delivery of all Members. The radio-frequency spectrum is a physically limited and increasingly contested resource, with emerging technologies continually raising demand.

To safeguard the availability of the radio-frequency spectrum for meteorological and related environmental operations and research, it is of prime interest for Members to engage with their respective National Regulatory Authorities (NRAs) and to actively contribute to any matters related to the radio-frequency spectrum at the national, regional and international level, in particular regarding preparation for the International Telecommunication Union (ITU) World Radiocommunication Conference (WRC).

WMO has established a network of national focal points for radio-frequency matters with the following aims:

- To enhance the capabilities of NMHSs and other institutions with relevant mandates worldwide in addressing radio-frequency-related issues;
- To foster close communication between NMHSs and their respective NRA to ensure that they have a comprehensive understanding of the importance of and requirements for radio frequencies for meteorological and related environmental activities;
- To foster the development of new experts in the field of spectrum management in order to sustain the membership of the WMO Expert Team on Radio Frequency Coordination (ET-RFC), addressing capacity development and succession planning risks identified by ET-RFC.

National focal points for radio-frequency matters will receive support from ET-RFC to gain the necessary expertise and skills to ensure that they can address the issues related to the radio-frequency spectrum in accordance with the terms of reference of national focal points (see Annex 5.1).

5.2.6 **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.

5.3 **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 5.1. TERMS OF REFERENCE OF NATIONAL FOCAL POINTS

1. National focal points for WIGOS

The WMO Integrated Global Observing System (WIGOS) national focal points (NFPs) shall:

1. Take the lead in communications on WIGOS with the WMO Secretariat (WIGOS Branch in the Infrastructure Department and the WMO Regional Offices) and the relevant Regional Working Groups/Teams;
2. Monitor and report on the status of the national WIGOS implementation and initial operations, taking into account the guidance provided in the [Guide to the WMO Integrated Global Observing System](#) (WMO-No. 1165);
3. Report to the Regional WIGOS Centres, in coordination with the NFPs on the WIGOS Data Quality Monitoring System (WDQMS) and to the WMO Secretariat on issues and challenges that might impact the implementation and operations of WIGOS in the country/territory and seek advice;
4. Identify and follow-up on WIGOS-related training and capacity-development needs;
5. Contribute to the design of the Global Basic Observing Network (GBON) and the Regional Basic Observing Network (RBON) and identify existing or new stations that could be committed by the Member to GBON and/or RBON, and take actions to reach such commitment; liaise with the Secretariat concerning GBON and with its relevant Regional Working Groups/teams concerning RBON;
6. Liaise with other WIGOS-related NFPs to support the integration of all WIGOS component observing systems, for example, through the WIGOS tools;
7. Coordinate the development of national schema(s) for the assigning of WIGOS Station Identifiers, across all WIGOS component observing systems.

Note: The list of NFPs is available on the [WMO website](#).

2. National focal points for OSCAR/Surface

The Observing Systems Capability Analysis and Review (OSCAR)/Surface NFPs shall:

1. Liaise with the WIGOS NFPs in the country/territory to ensure that all the operators of the relevant observing systems in the country/territory are aware of OSCAR and ready to make the required metadata routinely available in OSCAR;
2. Coordinate user account creation in OSCAR, in order to enable accredited users to manage within OSCAR the relevant metadata from the country/territory;
3. Promulgate the WMO Technical Regulations relevant to OSCAR, as well as the guidance and training materials necessary for an adequate use of OSCAR;
4. Make all efforts to ensure that all accredited users of OSCAR are well-trained to make the right use of the editing tools available in OSCAR;
5. Promote, in collaboration with the WMO Secretariat and in compliance with the required standards, the use of automatic, or semi-automatic, machine-to-machine transfer of information for insertion/updates of metadata within OSCAR, from the relevant observing systems of the Member;
6. Work closely with the established Regional WIGOS Centre (RWC) of the region/subregion;

7. Upon request, provide the WMO Secretariat and the RWC with an overview of the Member WIGOS metadata status in OSCAR;
8. Take, without any delay, actions in order to correct any erroneous and/or missing metadata identified in OSCAR, regarding the Member observing systems;
9. Collaborate with the relevant WMO working bodies and the Secretariat to perform the critical review and gap analysis at national and regional levels, using the OSCAR/Analysis tool.

Note: The list of NFPs is available on the [WMO website](#).

3. National focal points for the WIGOS Data Quality Monitoring System

The WIGOS Data Quality Monitoring System (WDQMS) and NFPs shall:

1. Liaise with the Member's OSCAR/Surface NFP to ensure that metadata from all stations exchanging data internationally are available and updated in OSCAR/Surface;
2. Provide timely answers to all queries and tickets sent by the respective RWC related to issues and incidents with observations from the Member;
3. Initiate and coordinate actions that need to be performed at a national level, related to issues and incidents with observations from the Member, in order to solve them as quickly as possible;
4. Promulgate nationally the WDQMS-related practices and procedures specified in the WMO *Technical Regulations* (WMO-No. 49), Volume I, along with any related guidance and training material;
5. Follow all the procedures agreed at a regional/subregional level in the context of the respective RWC;
6. Liaise with other relevant WMO regional centres in the region, and in particular with regional instrument centres and regional training centres, as appropriate, to find sustainable solutions for the issues and incidents identified by the WDQMS.

Note: The list of NFPs is available on the [WMO website](#).

4. National focal points for radio-frequency matters

The radio-frequency NFPs should:

1. Serve as the national contact for, and contribute to, relevant radio-frequency-related activities nationally, regionally and/or globally;
2. Promote at the national level the WMO positions on the relevant agenda items of the International Telecommunication Union (ITU) World Radiocommunication Conference (WRC), as developed by the Expert Team on Radio Frequency Coordination (ET-RFC), by:
 - a. Actively participating in spectrum management committees and activities led by their National Regulatory Authorities (NRAs), advocating for the WMO positions at relevant committees,
 - b. Ensuring their NRA is provided with a copy of the WMO WRC Position Paper each time a new or revised position paper is approved.
3. Foster the dissemination of relevant radio-frequency guidance, recommendations and other materials that are distributed by the WMO Secretariat, to ensure that it reaches the relevant stakeholders within the meteorological community and beyond;

4. Engage with their respective NRAs to ensure that they have a comprehensive understanding of the importance of and requirements for radio frequencies for meteorological and related environmental activities, and seek NRAs' support in the ITU Radiocommunication Sector (ITU-R) activities, in particular in the ITU WRC preparation process;
5. Participate in the national, regional and/or international activities on relevant radiocommunication regulatory issues and, in particular, get involved in the work of relevant regional telecommunication organizations and ITU-R, especially ITU-R Study Groups 5 and 7 on Terrestrial (including radiolocation) and Science services, respectively;
6. Register adequately all radiocommunication stations and radio frequencies used for meteorological and related environmental operations and research with their NRA;
7. Inform the ET-RFC of any new radio-frequency requirements or usage, in order to initiate appropriate international procedures to obtain the right to deploy and operate new equipment and then ensure their long-term protection. This information is crucial due to the long process to obtain international recognition.
8. Inform the ET-RFC of the outcomes of their domestic discussions with their NRAs that are relevant to the ET-RFC and its work. This could include raising awareness of domestic spectrum proceedings that may be of interest to the wider international meteorological community and beyond. This reporting mechanism aims to raise awareness among ET-RFC members of national RF matters and regulatory proceedings that are of interest to WMO and its Members.

The list of NFPs is available on the [WMO website](#).

ANNEX 5.2. 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), Appendix 2.3, with further details online at <https://community.wmo.int/rolling-review-requirements-process>, is used to compare user observational requirements with the capabilities of present and planned observing systems to satisfy them. The process consists of five stages:

1. An ongoing review of user requirements for observations;
2. An ongoing review of current and planned observing system capabilities, including available or emerging technological opportunities;
3. A Critical Review of the extent to which the capabilities (stage 2) meet the requirements (stage 1) for each application area;
4. Development of Statements of Guidance of Earth System Application Categories based on (stage 3), identifying priorities for action to address gaps, impacts or limitations resulting from these gaps and to improve relevant observing systems; and

5. Development of High-Level Guidance for the Evolution of Global Observing Systems, providing Members with clear and focused guidelines and recommended actions.

The RRR process will issue new Statements of Guidance and High-Level Guidance periodically 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 Figure 7.

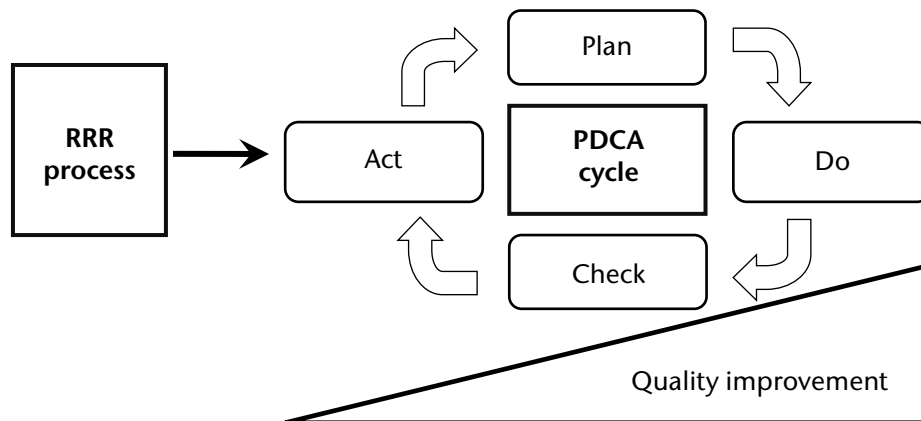


Figure 7. The Rolling Review of Requirements and the Plan-Do-Check-Act cycle

6. GUIDANCE ON WIGOS DATA PARTNERSHIPS

6.1 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 that are well-managed, reliable and 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. In a very simple way, data is at the core of everything that National Meteorological and Hydrological Services (NMHSs) do. Trusted, discoverable, interoperable and responsive data from different sources are converted into essential weather, climate, water and other environmental services.

The implementation of WIGOS is initially focused on the integration of existing WMO observing systems,¹ which are predominantly, though not exclusively, operated by 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.

6.2 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 free and unrestricted 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

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).

Atmosphere Watch (GAW), the Global Cryosphere Watch (GCW), the Global Climate Observing System (GCOS) and the Global Ocean Observing System (GOOS)) are leading the integration of related observations into WIGOS, including the incorporation of observations from partner organizations.

Currently, vast gaps exist over land and sea where essential surface-based observations are missing. In some parts of the world observations are either not made or not exchanged internationally, and in other parts they are not made or exchanged frequently enough.

In response, the Global Basic Observing Network (GBON), established through Resolution 2 (Cg-Ext(2021)) (see *World Meteorological Congress: Abridged Final Report of the Extraordinary Session* (WMO-No. 1281)) sets out an obligation and clear requirements for all WMO Members to acquire and internationally exchange the most essential surface-based observational data at a minimum level of spatial resolution and time intervals. GBON is a landmark agreement and represents a new approach in which the basic surface-based observing network, which is needed to feed numerical weather prediction (NWP) models with input data, is designed, defined and monitored at the global level.

Once fully implemented, GBON, a fundamental element of WIGOS, will significantly increase the availability of the most essential surface-based data. This will have a direct positive impact on the quality of weather forecasts and information and will enable all WMO Members to deliver better, more accurate and timely weather- and climate-related services to their constituencies.

6.3 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 6.5 and 6.6 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 6.7 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 WIGOS*. 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.

6.4 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.

6.5 **GUIDING PRINCIPLES AND RECOMMENDATIONS FOR NATIONAL COLLABORATION ON EARTH SYSTEM DATA**

6.5.1 **Free and unrestricted 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.

The drive for increased national collaboration on Earth system data is similar in nature to the drive for international exchange of data, and it can be articulated simply as follows: data sharing creates mutual benefits for all stakeholders.

Over the last two or three decades, Earth system data have become uniformly recognized as potentially being very valuable economically. More recently, various national and international economic analyses have demonstrated that the highest economic impact of Earth system data is obtained with free and unrestricted data policies, with the benefits of sharing all available Earth system data found to far outweigh the costs. These costs are represented by the loss of prospective revenue from selling the data to users willing and able to pay for them.

The sustainability of the basic infrastructure for data collection, processing and dissemination should be considered the responsibility of the Member as a whole, and not just of its NMHS.

Compliance of all national entities with Resolution 1 (Cg-Ext(2021)) – WMO Unified Policy for the International Exchange of Earth System Data (*World Meteorological Congress: Abridged Final Report of the Extraordinary Session (2021)* (WMO-No. 1281)) should be seen as essential for maximizing the socioeconomic benefits of Earth system data.

Members are strongly encouraged to:

- Undertake necessary actions to promote alignment of national policies and regulations concerning Earth system data sharing and exchange, nationally and internationally, in line with the policy promulgated through this resolution;
- Provide full transparency on conditions of use and reuse when such conditions apply to exchanges of recommended data;
- Accommodate the need for users of recommended data to respect the conditions of use set by the owners of the data, as this will help to facilitate access to the data;
- Facilitate the exchange of data from all stakeholders and sectors at the international level when emergencies and natural disasters occur;
- Build partnerships to enhance the exchange of Earth system data amongst national and regional stakeholders in order to improve integration of data across disciplines and domains;
- Strengthen effective coordination with relevant WMO partners and stakeholders on matters related to data policy and practice and encourage them to adopt similar policies and practices concerning the free and unrestricted exchange of their relevant data in support of WMO programmes.

6.5.1.1 **Provision and exchange of core data**

In applying the WMO Unified Policy for the International Exchange of Earth System Data:

- All stakeholders should commit to comply with relevant national and international legislation and policies with respect to both data provision and avoidance of anti-competitive behaviour;
- Members should ensure that users from all sectors — public, private and academic — are granted free and unrestricted access, without charge and with no conditions on use, to the declared core data specified in Resolution 1 (Cg-Ext(2021));
- As articulated in Resolution 80 (Cg-18) – *Geneva Declaration – 2019 (World Meteorological Congress: Abridged Final Report of the Eighteenth Session)* (WMO-No. 1236)), engagement between public and private sectors should be conducted in a transparent way and should be aimed at enhancing mutual benefits to both public and private sectors for the benefit of society;
- Members should ensure that, in the case of core data purchased from private sector data providers, such datasets are appropriately licensed for free and unrestricted international exchange;
- The technological solutions for access to the internationally exchanged core data should be fully compliant with the principle of free and unrestricted access²;
- Permanent Representatives of Members, who are responsible for authorizing users of the WMO Information System (WIS) in accordance with the *Manual on the WMO Information System* (WMO-No. 1060)), should authorize access to core data with no obstructions.

6.5.1.2 **Provision and exchange of recommended data**

While Members are encouraged to apply the principle of free and unrestricted international exchange to the recommended data they provide, such datasets may have conditions on their use, for example, for commercial purposes. The originators of such conditions should follow the following general principles:

- Fair and transparent setting of the conditions on use;
- Level playing field – the same rules to apply to public and private entities using the datasets for commercial purposes;
- Avoidance of anti-competitive behaviour (such as blocking access to public data with a view to creating competitive advantage for the commercial activities of the public sector entities or their spin-offs) should be regarded as a non-compliance with the high-level policy (see the Geneva Declaration);
- Members should make available a catalogue of recommended data to facilitate their use under the established conditions of use. The experience of Economic Interest Grouping of the National Meteorological Services of the European Economic Area (ECOMET) presents a good practice for such cataloguing as well as for harmonization of the conditions of use imposed by different countries in the same geographic region;
- In exchanging data with conditions on use, the conditions which have been posed by the originator of the data should be made known to initial and subsequent recipients.

² At the time of adoption of Resolution 1 (Cg-Ext(2021)) (*World Meteorological Congress: Abridged Final Report of the Extraordinary Session* (WMO-No. 1281)), the main access to core data provided by Members was through the WMO Information System (WIS); other access options may also be available (ftp servers or similar).

6.5.1.3 **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:³
 - (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:

³ See the example of establishing a successful public-private partnership: <https://wmo.int/files/switzerland-meteoswiss-public-private-partnership-meteogroup>

- (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.

6.5.1.4 **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 Memorandums of Understanding to more formal Letters of Agreement or legally binding contracts. Section 6.6.4 – Establishing and sustaining observation partnerships – provides more details.

6.5.2 **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 6.7.2 below).

6.5.3 **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.

6.5.3.1 **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* (WMO-No. 1192)) 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* (WMO-No. 1192) 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.

6.5.3.2 **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) Transiting the Regional Basic Synoptic Network (RBSN) and the Regional Basic Climatological Network (RBCN) 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.

6.5.3.3 **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.

6.6 **GENERAL GUIDANCE**

6.6.1 **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?

6.6.1.1 **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 WIGOS*. 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.

6.6.1.2 **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.

6.6.2 **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)).

Through their adoption of Resolution 1 (Cg-Ext(2021)) – WMO Unified Policy for the International Exchange of Earth System Data (*World Meteorological Congress: Abridged Final Report of the Extraordinary Session (2021)* (WMO-No. 1281)) (hereinafter “the Unified Data Policy”), Members have committed to establishing the general framework for the free and unrestricted international exchange of weather, climate, water and related environmental data. Approval of the Unified Data Policy provides a comprehensive update of the policies guiding the international exchange of weather, climate, water and related environmental Earth system data between WMO Members. The new policy reaffirms the commitment to the free and unrestricted exchange of data, which has been the bedrock of WMO since it was established in 1950. Specifically for observations, exchange is a must, not a choice, in order for them to have an impact. Even omitting to share observations across sectors at a national level will limit the societal and economic benefits that might otherwise be achieved.

The Unified Data Policy lays out the agreement between WMO Members on the overall principles and scope of the international exchange of Earth system data. Members have a role and responsibility to adapt to and implement the Policy, as both the WMO Convention and the WMO Unified Data Policy recognize the sovereign rights of the Members to decide which data will be exchanged, and how. A policy for the unification of data implies new partnerships within each Member State or Territory.

Alongside these long-standing commitments, WMO Members also approved the *Manual on the WIGOS*, which in its Appendix 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.

6.6.3 **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.⁴

6.6.4 **Establishing and sustaining observation partnerships**

Section 6.5 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 Annex 6.1.

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.

6.6.5 **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.

⁴ <http://www.meteoswiss.admin.ch/home/measurement-and-forecasting-systems/land-based-stations/automatisches-messnetz/partnernetze.html>

6.6.5.1 **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* (WMO-No. 1192). 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.

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.

6.6.5.2 **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.

6.6.5.3 **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.

6.6.5.4 **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.

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.

6.6.5.5 **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.

6.7 **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.

6.7.1 **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.

6.7.2 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 8 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.

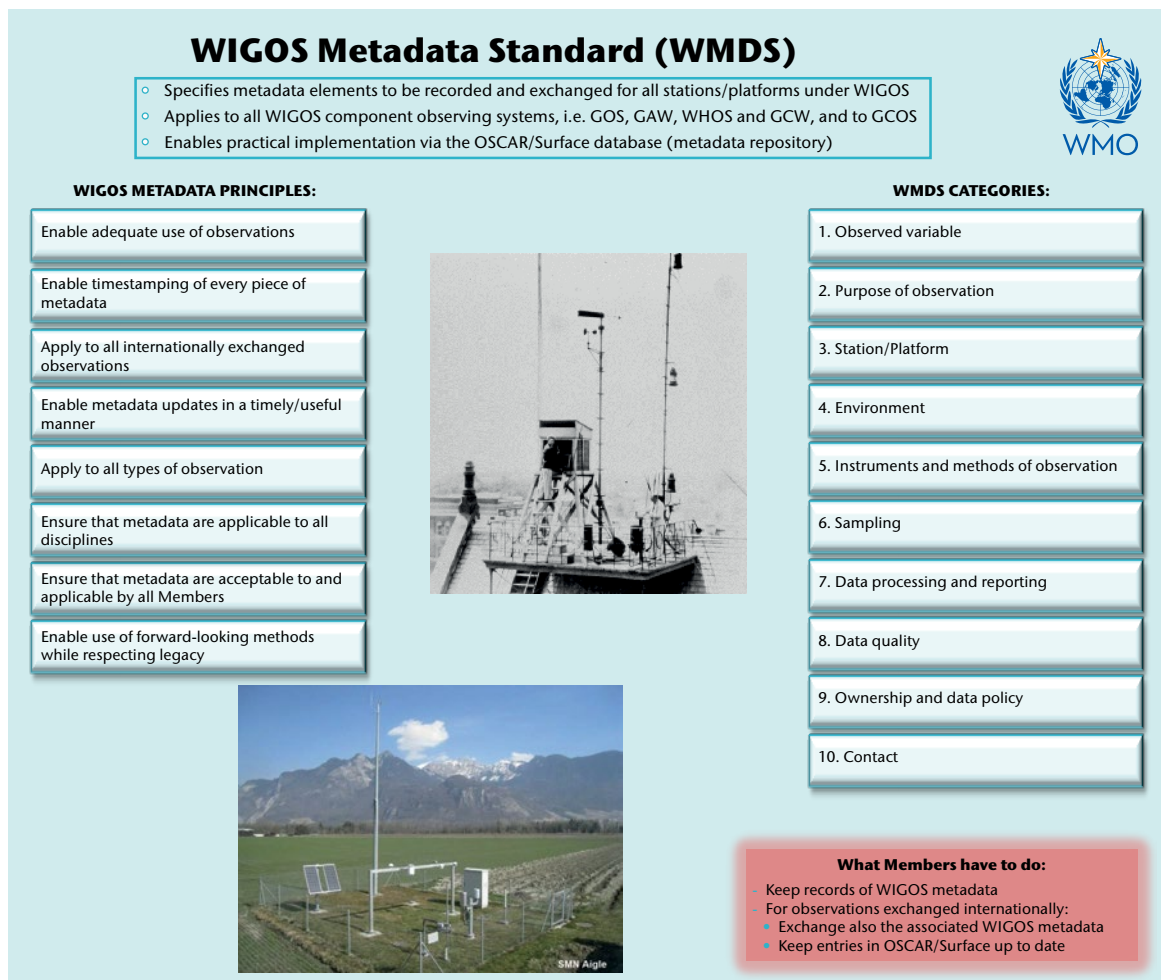


Figure 8. Overview of the *WIGOS Metadata Standard* (WMO-No. 1192)

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.

To facilitate compliance, the *WIGOS Metadata Standard* (WMO-No. 1192) 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* (WMO-No. 1192), 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* (WMO-No. 1192) 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* (WMO-No. 1192) 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* (WMO-No. 1192) 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.

6.7.3 **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 OSCAR/Surface national 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 OSCAR/Surface national 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.

6.7.4 **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 bidirectional, 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.

6.7.4.1 **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.

6.7.4.2 **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).

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 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 6.7.8 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.

6.7.5 **WIGOS Data Quality Monitoring System**

The *Manual on the WIGOS*, 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.

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

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 9). 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.

6.7.7 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* (WMO-No. 1192) 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)

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.



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

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 is covered in detail in the [Manual on the High-quality Global Data Management Framework for Climate](#) (WMO-No. 1238).

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).

6.7.8 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 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 6.1. A MODEL FOR NON-NMHS OBSERVATIONAL DATA INGESTION

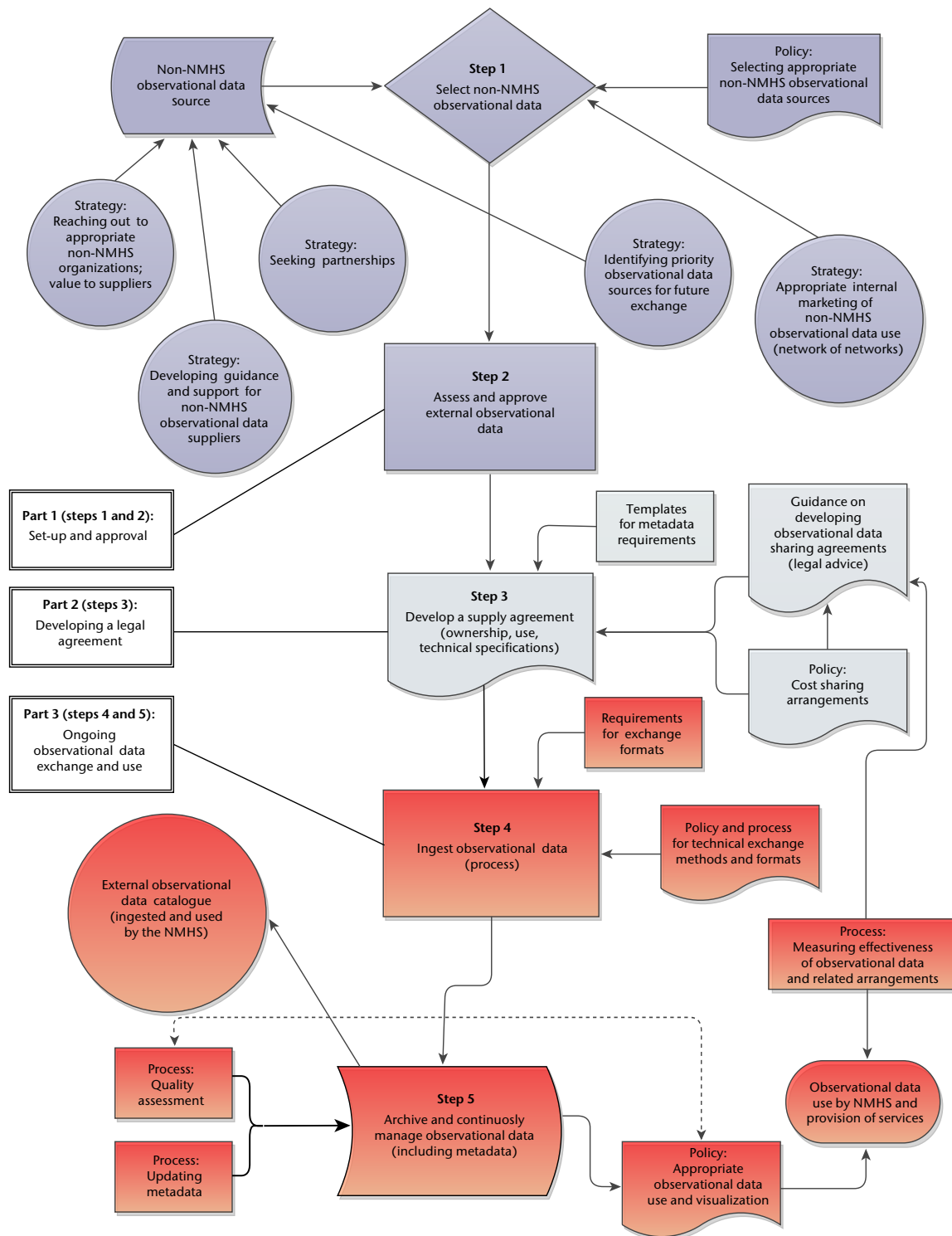


Figure 10. Non-NMHS observational data exchange model

The present 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 10.

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:

- (i) Standard Open Data Licence or other open source agreement;
 - (ii) Understanding of the NMHS readiness to accept risk;
 - (iii) 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 organization 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).

7. ESTABLISHING AND OPERATING A REGIONAL WIGOS CENTRE

7.1 INTRODUCTION

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

7.2 BACKGROUND AND RATIONALE

The Executive Council at its sixty-eighth session (EC-68, 2016) 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 WIGOS*.

The World Meteorological Congress agreed at its nineteenth session (Cg-19), through Resolution 37, that the operational deployment of RWCs is one of the six main priorities of WIGOS in 2020–2023 (*World Meteorological Congress: Abridged Final Report of the Nineteenth Session* (WMO-No. 1326)). The details are provided in the Plan for the WMO Integrated Global Observing System Initial Operational Phase (2020–2023) adopted by the Executive Council at its seventy-third session (EC-73), through Resolution 9 (*Executive Council: Abridged Final Report of the Seventy-third Session* (WMO-No. 1277)).

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

The EC-68, through Decision 30, endorsed the Concept Note on Establishment of Regional WIGOS Centres, as general guidance for regional associations (*Executive Council – Sixty-eighth Session: Abridged Final Report with Resolutions and Decisions* (WMO-No. 1168)). The basic principles for the establishment and operation of RWCs and the specifications of mandatory and optional functions are provided in 7.3.

7.3 REGIONAL WIGOS CENTRES: ESSENTIALS

7.3.1 Purpose and objectives

Under the governance and guidance of the management group of the respective regional association, and with the support of relevant regional working bodies, the overall purpose of the RWCs is to provide support and assistance to WMO Members and Regions for their national and regional WIGOS implementation efforts.

The specific objectives of an RWC depend on its implementation stage, which are described in 7.8 of the present chapter.

7.3.2 **Terms of reference**

7.3.2.1 **Functionalities**

Basic functions of the RWC should be regional coordination, guidance, oversight and support for WIGOS implementation and operational activities at the regional and national levels, as daily activities. The mandatory and optional functions are specified below. For detailed guidance on the mandatory functions see the *Technical Guidelines for Regional WIGOS Centres on the WIGOS Data Quality Monitoring System* (WMO-No. 1224).

7.3.2.1.1 **Mandatory functions**

- (a) (Regional) WIGOS metadata management (working with data providers to facilitate collecting, updating and improving the quality of WIGOS metadata in [OSCAR/Surface](#));
- (b) (Regional) WIGOS performance monitoring, evaluation and incident management (WIGOS Data Quality Monitoring System – WDQMS) and follow-up with data providers in case of data availability or data quality issues.

Chapters 3 and 9 of the present Guide provide more details on OSCAR/Surface and WDQMS, respectively.

7.3.2.1.2 **Optional functions**

Depending on available resources and regional needs, one or more optional functions may be adopted, such as: (a) assistance with the coordination of regional/subregional and national WIGOS projects; (b) assistance with regional and national observing network management; and (c) support for regional capacity-development activities.

7.3.2.2 **Incident management**

RWCs should run the incident management function using the Incident Management System (IMS) provided by WMO, a web tool accessible online. Registered users, including the RWCs, WDQMS NFPs and WIGOS Quality Monitoring Centres, can create incident tickets in IMS.

RWCs should utilize the results of quality evaluation and incident management practices to identify systemic issues that might need to be addressed to improve the performance of stations through proposed modification or changes to processes and procedures.

Results of quality evaluation analyses and resulting changes to the observing system should be notified, recorded and documented in line with national, regional and WMO quality management standards and recommended procedures.

Member engagement in the incident management process, through close collaboration with the RWCs regarding their functions, is essential for allowing improvement to station performance.

7.3.2.3 **Links to other WMO entities**

The RWCs should work closely both with the WMO Secretariat (including Regional Offices) and with their respective regional working bodies to ensure efficient and effective implementation and operation of WIGOS. The RWCs should liaise with relevant existing WMO centres, in particular with the Regional Telecommunication Hubs/Global Information System Centres (RTHs/GISCs), Regional Instrument Centres (RICs), Regional Training Centres (RTCs) and Regional Climate Centres (RCCs) regarding all WIGOS-related activities in the WMO Region.

7.4 IMPLEMENTATION OPTIONS AND RESOURCING

7.4.1 Implementation options

In principle, each Member of any given WMO Region should be covered by an RWC. RWCs may be implemented either centrally, at an overall regional level where a Member or consortium of Members provide support for the entire Region, or at a subregional level, that is, aligned with the natural geographic or linguistic boundaries existing within the Region.

RWCs may be implemented either as monolithic entities (single multifunctional RWC), with a single Member taking on the responsibility for the entire set of required functionalities, or as virtual/distributed centres (an RWC network), in which a consortium of Members share these responsibilities between themselves, possibly under the overall coordination of a lead organization.

7.4.2 Resourcing requirements

The responsibility for resourcing the establishment and operations of an RWC rests with the Member(s) hosting the RWC, which should secure suitable infrastructure, technical, human and other resources for establishment and sustained operations of the centre. The amount and nature of resources required will depend on the intended functionalities of the centre, the number of affiliated Members and the dimension of their respective observing networks.

7.4.2.1 Basic infrastructure

In order to ensure a rapid start-up for an RWC, 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.

7.4.2.2 Technical infrastructure

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

RWCs should have access to information, data and tools that support quality evaluation processes. As a minimum, these include:

1. Observation bulletins in Traditional Alphanumeric Code (TAC) and BUFR, received via WIS/Global Telecommunication System (GTS) and stored in an operational observation database;
2. OSCAR/Surface, WDQMS web tool and IMS;
3. Additional quality monitoring reports and statistics provided by other global, regional or national monitoring systems in a form that allows flexible and rapid use for the quality evaluation process, including rendering of the data for analysis, comparison, plotting and so forth;
4. Data analysis applications and tools.

7.4.3 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) to be allocated to RWC establishment and operations. The staff may be permanent employees from National Meteorological and Hydrological Services (NMHSs) or may be hired on a temporary basis. Where appropriate, some of the responsibilities of an RWC may be fulfilled through secondment of staff from other WMO Members in the WMO Region.

RWC staff should have the following competencies:

1. Detailed understanding of the surface-based system of GOS and GBON (to be expanded in future to other WIGOS observing components, although the functions might be split among multiple RWCs);
2. Sound knowledge of meteorological observations, station metadata and WMO codes, as well as skills in data analysis;
3. Skills and knowledge in quality management systems (in general), and incident management processes (in particular);
4. Skills and knowledge in communication and report writing.

Additional competencies may be required when an RWC's scope expands.

7.4.4 **Financial resources**

The responsibility for funding RWC operations rests with the Member(s) involved. It might be difficult for less well-resourced Members to identify the resources required at the national level for operating an RWC. In such cases, the RWC will have to identify partners and develop effective resource mobilization strategies with a view to deriving maximum benefit from various multilateral funding mechanisms and regional development institutions. The WMO Secretariat is prepared to support all stages of such resource mobilization efforts.

7.5 **RISK ASSESSMENT AND MANAGEMENT**

The main risks, their impact on RWC operations and WIGOS as a whole, and possible mitigation measures should be considered when establishing an RWC. 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 RWC, waning interest from stakeholders, or change in government;
- (b) Financial, such as inadequacy of the financial management system, or lack of resources;
- (c) Human resources-related, such as a lack of skills and/or expertise, or a mismatch between existing and required experience and specialized skills.

A risk management plan should be developed for each implementation activity, including risk mitigation.

7.6 **GOVERNANCE, MANAGEMENT AND PLANNING**

The RWC management (that is, the RWC Manager and RWC Executive) should plan and work closely with the president of the regional association, the management group and the relevant WIGOS working body of the regional association, the WMO Secretariat and other WMO-related entities.

7.7 MONITORING AND EVALUATION

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

The Manager 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 to the RWC operations accordingly.

7.8 IMPLEMENTATION STAGES

The three stages for implementing an RWC are described in the present section, along with their corresponding objectives. The three stages are expected to be sequential, starting with the start-up phase (launch period), leading to a pilot phase/mode and then followed by an operational phase/mode.

7.8.1 Start-up phase

The objectives of this phase are to:

- Define an RWC concept of operations and its framework within the region/subregion;
- Formalize the intention of a Member/group of Members to host and operate an RWC.

The candidate Member(s) for establishing an RWC should follow steps 2 and 3 of the process for the designation, assessment and reconfirmation of Regional WMO Integrated Global Observing System Centres (Annex 7.1).

The application template to be used by a candidate RWC is reproduced in Annex 7.2. The application must include the Terms of Reference, covering the main WIGOS functionalities offered by the Centre, including, at a minimum, the mandatory functions as specified under 7.3.2.1.1, taking into account the type of proposed centre (see implementation options in 7.4.1). Depending on available resources and the willingness of the candidate Member(s), one or more optional functions may be included, for example, assistance with regional and national observing network management, calibration support, education and training.

During the start-up phase, which may last several months, the framework for the 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.

WMO should, wherever possible, encourage the existing WMO regional centres to carry out the RWC activities, thus ensuring optimization of technical and human resources. Already existing structures and mechanisms should be considered when implementing WIGOS at the regional and national levels, including their potential roles in RWCs. Every effort should be made to avoid any duplication with responsibilities and functionalities of already existing WMO regional centres. Instead, possible synergies with such centres should be exploited.

Existing geographic, cultural and linguistic differences within each WMO Region should be taken into account in determining the appropriate establishment and models of operation of RWCs. Therefore, each respective regional association should decide upon its own mechanism for establishing its RWCs with clearly specified Terms of Reference in line with guidance from the Commission for Observation, Infrastructure and Information Systems (INFCOM), reflecting

its needs, priorities, existing capabilities and facilities. The relevant WIGOS working body in the Region should be involved in the process of establishing the RWC and have general oversight once it has become operational.

7.8.2 **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 Manager(s), with methods readjusted as necessary, and with support from the WMO Secretariat.

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 assessment, a set of recommendations on key aspects of such a centre, including institutional set-up, concept of operations and strategy for long-term sustainability. Therefore, the pilot phase should include the development of a long-term funding strategy based on effective resource mobilization where appropriate.

The pilot phase begins following successful results from steps 4 and 5 of the process for the designation, assessment and reconfirmation of Regional WMO Integrated Global Observing System Centres (Annex 7.1). At the beginning of the pilot phase, the RWC Manager(s) will ensure that the required preparatory work is conducted, and that implementation arrangements are put in place in accordance with the RWC application.

At the end of the pilot phase, according to step 6 of the process for the designation, assessment and reconfirmation of Regional WMO Integrated Global Observing System Centres (Annex 7.1), the RWC Manager will prepare and submit a Progress Report to the president of the regional association, the relevant regional WIGOS working body, the management group of the regional association and the WMO Secretariat. In accordance with the template provided in Annex 7.3, the report will contain an evaluation of the RWC performance and sustainability of its results, and will document the experience and lessons learnt during the pilot phase.

7.8.3 **Operational phase**

The objective of an RWC during this phase is to contribute to improving the observational metadata and data that are internationally exchanged from observing stations in the concerned region/subregion, in regard to:

- (a) metadata availability, quality and completeness (in OSCAR/Surface);
- (b) data availability, in terms of reporting frequency and regularity; data quality, in terms of accuracy and completeness; and timeliness of data reporting.

The operational phase begins with the designation of the RWC as being in the operational phase, following successful audit results in steps 6 and 7 of the process for the designation, assessment and reconfirmation of Regional WMO Integrated Global Observing System Centres (Annex 7.1).

During the operational phase, the RWC is annually assessed in accordance with step 8 of the process for the designation, assessment and reconfirmation of Regional WMO Integrated Global Observing System Centres (Annex 7.1). The reconfirmation of designation of the RWC in the operational phase is based on the results of assessments as referred to in step 9 of the same process.

ANNEX 7.1. PROCESS FOR THE DESIGNATION, ASSESSMENT AND RECONFIRMATION OF REGIONAL WMO INTEGRATED GLOBAL OBSERVING SYSTEM CENTRES

1. INTRODUCTION

The process described in the present Annex is intended to support the regular audit of Regional WMO Integrated Global Observing System Centres (RWCs, or Regional WIGOS Centres) to ensure they are delivering according to their Terms of Reference (ToR) and functioning as required by the Regional Association and in line with WMO standards and guidelines.

The overall purpose of the RWCs is to provide support and assistance to WMO Members and the Regional Associations (RAs) for their national and regional WIGOS implementation efforts, as part of the WIGOS initial operational phase.

RAs should do their utmost to establish one or more RWCs within their area of responsibility and ensure unique assignment of each Member of the WMO Region to a relevant RWC.

An RWC can be hosted by one Member and cover all required functions,¹ or it can be a virtual/distributed RWC where several Members host different “nodes” for different functions, with all those nodes comprising one RWC. For effectiveness, and to avoid confusion, RAs should ensure that there is no overlap of the activities and responsibilities of different RWCs, or their individual nodes. Each RWC, including its nodes, will undergo a pilot phase prior to approval as an operational RWC.

Technical evaluation of RWC applications and assessment of RWCs² will be done by the Commission for Observation, Infrastructure and Information Systems (INFCOM), while the designation/reconfirmation will be a decision taken by the relevant RA.

2. PREPARATORY REQUIREMENTS

A candidate RWC should be capable of carrying out mandatory RWC functions as defined in the RWC ToR, before an application is submitted.

3. APPLICATION

The candidate RWC will express its intention to be designated as an RWC in pilot mode by sending an application³ to the president of the relevant RA with a copy to the president of INFCOM and to the Secretary-General of WMO. Should any required information be missing from the application, the WMO Secretariat will communicate the shortcoming(s) to the candidate RWC, which must ensure that the missing information is provided before assessment of the application proceeds.

¹ See the *Guide to the WMO Integrated Global Observing System* (WMO-No. 1165), Chapter 7.

² In case of a virtual/distributed RWC, the process described here applies to the whole RWC, although each node should be evaluated individually, meaning that the outcomes of the evaluation may contain conclusions and recommendations on the performance of the individual nodes or of the whole RWC, or both.

³ The application template for a candidate RWC is available in the *Guide to the WMO Integrated Global Observing System* (WMO-No. 1165), Chapter 7, Annex 7.2.

4. **EVALUATION OF APPLICATIONS**

When a submitted application is complete, the WMO Secretariat, in consultation with the president of INFCOM and the president of the relevant RA, will make arrangements for its evaluation by a team of experts. Membership of the team (hereinafter called the evaluation team) will be approved by the president of INFCOM, in consultation with the president of the RA.

The results of the evaluation process,⁴ together with a recommendation for acceptance/rejection of the application, will be submitted to the president of INFCOM for endorsement on behalf of INFCOM, and will then be conveyed to the Secretary-General of WMO. The Secretary-General will inform the president of the RA and the Permanent Representative (PR) of the Member with WMO of the INFCOM recommendation.

5. **DESIGNATION OF A REGIONAL WIGOS CENTRE IN PILOT MODE**

Upon successful evaluation of the application and positive recommendation of INFCOM, the relevant RA will be invited to designate the new RWC in pilot mode.

Prior to the designation, the RA and RWC will agree on an initial start date of the pilot phase, which will be communicated to all stakeholders.⁵

6. **EVALUATION OF A REGIONAL WIGOS CENTRE IN PILOT MODE**

Evaluation of an RWC in pilot mode will be performed only after the RWC has been operating in pilot mode continuously for a minimum of one year, and has provided regular monthly quality performance reports⁶ and the final progress report of RWC activities to the president of the RA and the WMO Secretariat.

Initiation of the evaluation of an RWC in pilot mode will be communicated by the WMO Secretariat to the PR(s) of Member(s) hosting the RWC in pilot mode, with a copy to the president of the RA and the president of INFCOM.

The RWC in pilot mode will submit a progress report⁷ (each node will submit a separate progress report, in the case of a virtual/distributed RWC) to the WMO Secretariat within one month after the initiation of the evaluation process. The WMO Secretariat will ensure that the report is complete and complemented by any additional relevant information⁸ needed for the evaluation.

The WMO Secretariat, in consultation with the president of INFCOM, will make arrangements for the evaluation by the evaluation team.

The work of the evaluation team will be done in consultation with relevant regional working bodies and, in principle, remotely. However, if necessary, on-site visits by the evaluation team might be arranged.

⁴ The anticipated duration of the evaluation process is three months.

⁵ Whenever possible and adequate, the WMO Secretariat will consult with the relevant Member(s) regarding the actual start of operations, including requests to nominate (or update/review) their NFPs on WIGOS Data Quality Monitoring System (WDQMS), who will be responsible for interaction with the RWC.

⁶ The monthly reports should be developed in accordance with the template provided by the WMO Secretariat.

⁷ The progress report must be developed in accordance with the template provided by the WMO Secretariat.

⁸ This may include, for example, the relevant statistics produced by the global WDQMS Incident Management System (IMS), other relevant reports from the RWC, as well as other supportive material, as appropriate, including any reports or recommendations from relevant regional working groups/teams.

The results of the evaluation process, together with a recommendation,⁹ will be submitted to the president of INFCOM for endorsement on behalf of INFCOM and will then be conveyed to the Secretary-General of WMO.

The Secretary-General will inform the president of the RA and the PR of the Member with WMO of the INFCOM recommendation.

7. **DESIGNATION OF A REGIONAL WIGOS CENTRE IN OPERATIONAL MODE**

Upon positive results and recommendation by INFCOM, the relevant RA will formally designate the RWC in operational mode. In the case of a virtual/distributed RWC, and based on INFCOM's recommendation, the RA may decide to designate only certain individual node(s) as part of an operational RWC.

8. **ASSESSMENT**

According to its ToR, an RWC reports on its activities annually by submitting a progress report (one progress report for each node, in the case of a virtual/distributed RWC) to the WMO Secretariat. The WMO Secretariat will publish the RWC reports on the WIGOS website.

The WMO Secretariat, in consultation with the president of INFCOM, will make arrangements for the regular evaluation of the progress reports by the evaluation team, to assess the compliance of an RWC with its ToR.

The results of each evaluation will be provided to the president of INFCOM, the president of the relevant RA and relevant PR. If necessary, an evaluation team might have to verify RWC capabilities and performances by making on-site visits.

If an RWC fails to report on its activities for at least two consecutive years, or if the evaluation results indicate lack of compliance with the RWC's ToR, the WMO Secretariat will inform the president of INFCOM and the president of the RA that the RWC status should be reassessed.

9. **RECONFIRMATION OF A REGIONAL WIGOS CENTRE**

Prior to each regular Congress, the WMO Secretariat will invite the president of each RA to reconfirm the arrangements with its regional Members for hosting RWCs.

Based on the outcomes of the assessment of an RWC and the written reconfirmation from the PR of the Member hosting the RWC, each RA will be invited to reconfirm its RWC(s), or to take appropriate measures in the event that an RWC has not provided satisfactory services in compliance with its ToR.

⁹ The recommendation(s) can be applicable to individual nodes and/or the RWC as a whole. A recommendation(s) should include, among others, a proposal for either designation or non-designation. In the event that INFCOM finds that an RWC, or its individual node(s), does not meet the necessary requirements for designation, the RA might decide not to proceed with the designation. Instead, the RA might encourage the RWC to improve its performance and might propose re-evaluation once the INFCOM proposals for improvement have been met.

ANNEX 7.2. 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 submit its application, in accordance with the [Guide to the WMO Integrated Global Observing System](#) (WMO-No. 1165), 7.8, in writing through, and with the endorsement of, the Permanent Representative of the Member in which the candidate RWC is situated.

The application 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 nodes within a virtual/distributed RWC which will collectively fulfil the RWC functions):

1. Name of the Member, 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. URLs for pages on the Centre's website where WIGOS-related activities are described;
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 basic 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/consortium of Members);
12. Proposed RWC Manager (name, position, contacts and curriculum vitae);
13. Stakeholders engaged in the current and planned RWC operations;
14. Relevant national focal point(s);
15. RWC proposal:
 - Prepared by (name, position);
 - Approved by (name, position);
 - RWC Executive (name, position);
 - RWC Terms of Reference;

- Implementation period;
- RWC 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:

- World Meteorological Organization (WMO). *World Meteorological Congress: Abridged Final Report of the Eighteenth Session* (WMO-No. 1236). Geneva, 2019.
- World Meteorological Organization (WMO). *Executive Council: Abridged Final Report of the Seventy-third Session* (WMO-No. 1277). Geneva, 2021.
- World Meteorological Organization (WMO). *Executive Council, Sixty-eighth Session: Abridged Final Report with Resolutions and Decisions* (WMO-No. 1168). Geneva, 2016.
- World Meteorological Organization (WMO). *Project Management Guidelines and Handbook*, Parts I and II. Geneva, 2016.
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ANNEX 7.3. TEMPLATE FOR REGIONAL WIGOS CENTRE PROGRESS REPORT

A Member hosting an RWC or a node, that has been recognized by the Regional Association, should use this template to report to the Regional Association on the progress made. The progress report should be prepared by RWCs in accordance with the “Process for the designation, assessment and reconfirmation of Regional WMO Integrated Global Observing System Centres” (Annex 7.1 of the [Guide to the WMO Integrated Global Observing System](#) (WMO-No. 1165)).

The following topics, that are aligned with the application template, should be covered in such a progress report:

| | | |
|-----|---|--|
| 1. | Regional Association | The relevant WMO Regional Association |
| 2. | Member | Name of the WMO Member reporting |
| 3. | Organization and full address | Name of the organization reporting and its full address, including the position of the RWC within the national/ NMHS organization |
| 4. | Period covered by this report | Time period (month and year) covered by this report |
| 5. | Type of RWC (single multifunctional RWC or as virtual/distributed RWC (network) provided by group of Members) | Type of RWC and other RWCs involved if the functions are distributed |
| 6. | Members covered by the RWC | List of Members covered by the RWC |
| 7. | Engagement with affiliated Members | Description of how and how often the RWC coordinates and discusses activities with affiliated Members |
| 8. | Mandate of the Centre relevant to WIGOS activities – Mandatory functions | List of mandatory functions performed by the RWC (only applicable for RWC-nodes as part of a virtual/ distributed RWC network) |
| 9. | Mandate of the Centre relevant to WIGOS activities – Optional functions | List of optional functions performed by the RWC |
| 10. | Software used for the RWC activities in addition to WIGOS tools | Brief description of any software used in performing RWC functions (in addition to WIGOS tools – OSCAR/ Surface , WDAQMS web tool and IMS for RWC) |
| 11. | Website of RWC | URL of any website(s) dedicated to the RWC activities |
| 12. | Operational activities related to the mandatory functions | Description of the activities developed in relation to the mandatory function(s) in the reporting period. In particular, the following items: <ul style="list-style-type: none"> - Number of issues per country identified and followed up - Number of issues per country resolved - Any long-term open and unresolved issues |
| 13. | Operational activities related to the optional functions | Description of the activities developed in relation to the optional function(s), for example training provided by RWC to Members |
| 14. | Other activities relevant to the WIGOS implementation at national and regional levels | Description of other relevant activities developed by the RWC, such as assistance and support in developing National and Regional WIGOS Implementation Plans, or others |
| 15. | Liaison with relevant existing WMO Centres, particularly regional centres | Description of the activities developed in liaison with other WMO Centres, such as Regional Training Centres (RTC), Regional Instrument Centres (RIC), WMO Information System (WIS) Centres, etc. |
| 16. | Staff involved in the daily operations relevant to mandatory functions | Number and competencies of staff involved in the daily operations, including any relevant trainings they have recently attended |

| | | |
|-----|--|--|
| 17. | Description of current facilities, the necessary basic physical infrastructure, and communication systems relevant to RWC mandatory and optional functions | List of relevant facilities/infrastructures being used for the RWC activities, such as, workstations, databases, Internet or other communication systems, etc. |
| 18. | Funding strategy to ensure the long-term sustainability of the RWC | Short description of the funding strategy that has been adopted for the RWC, including for capacity-development activities |
| 19. | Languages offered when interacting with the Members of the WMO Region | Languages offered by the RWC when interacting with the affiliated Members |
| 20. | Lessons learnt and future plans to improve the RWC | Description of any relevant lessons learnt and plans to improve the capabilities and performance of the RWC in the near future |
| 21. | Comments | Any additional comments, complementary information and/or suggestions |

8. WIGOS DATA QUALITY MONITORING SYSTEM FOR SURFACE-BASED OBSERVATIONS

Regulations related to the WIGOS Data Quality Monitoring System (WDQMS) are provided in the *Manual on the WIGOS*.

The *Technical Guidelines for Regional WIGOS Centres on the WIGOS Data Quality Monitoring System* (WMO-No. 1224) provide details for Regional WIGOS Centres (RWCs) and the WDQMS national focal points to successfully run the WDQMS.

WIGOS Data Quality Monitoring System web tool

The [WDQMS web tool](#) is a resource to monitor the performance of the WIGOS observing components. The system is developed by WMO, under the guidance of INFCOM, and is hosted by the European Centre for Medium-Range Weather Forecasts (ECMWF) in accordance with a Memorandum of Understanding between ECMWF and the WMO Secretariat. The web tool displays information provided by contributing Numerical Weather Prediction (NWP) centres, called WIGOS Quality Monitoring Centres (WQMC).

The WQMCs are:

- The European Centre for Medium-Range Weather Forecasts (ECMWF);
- Deutscher Wetterdienst (DWD) (the German weather service);
- The Japan Meteorological Agency (JMA);
- The United States National Centres for Environmental Prediction (NCEP).

The WDQMS web tool monitors in near real time the observations from the Global Observing System (GOS) land-based surface and upper-air stations as well as the observations from both the Global Climate Observing System (GCOS) Surface Network (GSN) and the GCOS Upper-Air Network (GUAN). The NWP module of the web tool monitors the performance of all surface and upper-air (radiosonde) land stations documented in [OSCAR/Surface](#), based on near-real-time monitoring information provided by the WQMCs.

The WDQMS collects 6-hourly quality monitoring (QM) reports (CSV files in a commonly agreed format containing information for each observing station based on data assimilation results) from these four WQMCs and stores the data in the WDQMS database at ECMWF. Figure 11 shows a diagram of the QM data flow for the NWP module of the WDQMS web tool, where the database fed by the NWP QM reports and the web-based application constitute the back and front end of the QM system, respectively. The [online user guide](#) provides more information about the WDQMS web tool.

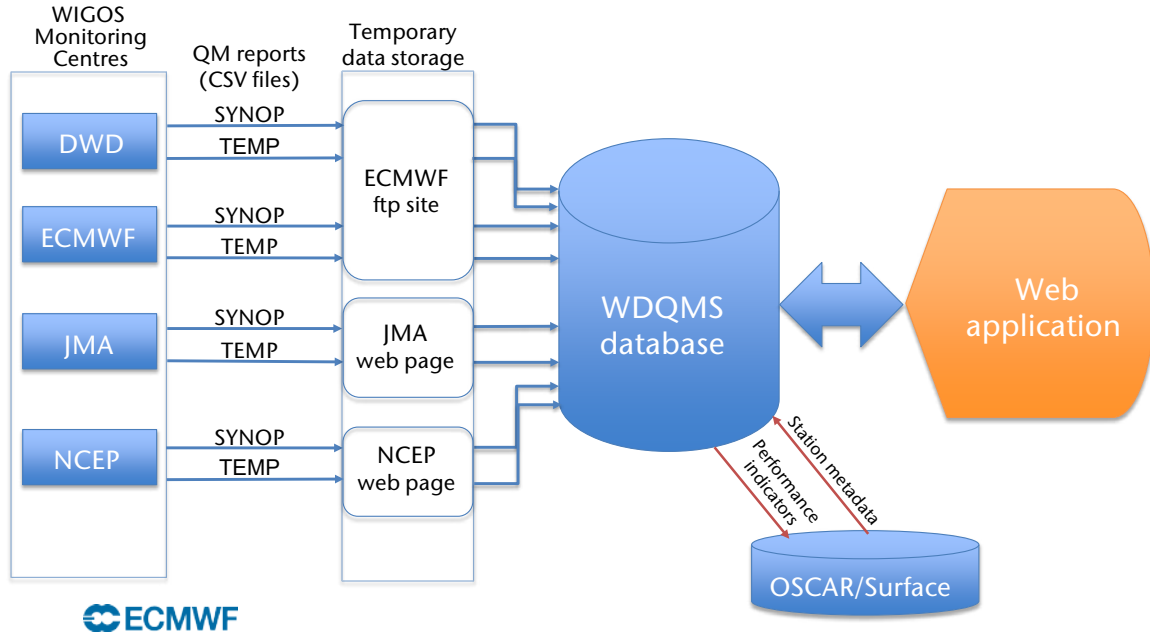


Figure 11. Diagram of high-level WDQMS web tool architecture

The evolution of the WDQMS takes place under the guidance of INFCOM. Any NWP centre willing to contribute to WDQMS can become a WQMC. The [Technical Specifications for WIGOS Quality Monitoring Centres](#) (WIGOS Technical Report No. 2022-1), maintained by INFCOM, specifies the file exchange format and other aspects of operational coordination.

9. GUIDANCE ON THE IMPLEMENTATION OF ATTRIBUTES SPECIFIC TO WIGOS COMPONENT OBSERVING SYSTEMS

9.1 GLOBAL CRYOSPHERE WATCH

9.1.1 Guidance on the definition of the Global Cryosphere Watch stations

The *Manual on the WIGOS*, section 8, defines the attributes specific to the observing component of the Global Cryosphere Watch (GCW).

The GCW surface observing network is comprised of a core component called CryoNet, CryoNet contributing stations, and GCW affiliated stations, generically known as GCW stations. Any GCW station measures one or more components of the cryosphere and one or more variables of each component, for example depth and density of the component snow (see section 9.1.3 below). The GCW network builds on existing cryosphere observing programmes and promotes the addition of standardized cryospheric observations to existing facilities to meet specific observational requirements defined in the *Manual on the WIGOS*.

GCW covers all components of the cryosphere (solid precipitation, snow, glaciers, ice caps, ice sheets, ice shelves, icebergs, sea ice, lake ice, river ice, permafrost, and seasonally frozen ground).

Meteorological observations of air temperature, air humidity, wind speed and wind direction are mandatory observations for CryoNet stations, while they are optional for CryoNet contributing stations.

The observing and measurement practices to be applied at GCW stations, and primarily at CryoNet stations, are those documented in the *Guide to Instruments and Methods of Observation* (WMO-No. 8), in particular Volume II: Measurement of Cryospheric Variables.

A CryoNet station is either Primary or Reference:

- Primary – Has a target (intent) of long-term operation and at least a 4-year initial commitment;
- Reference – Has a long-term operational commitment and long-term (more than 10 years) data records.

A CryoNet station may have one or more additional attributes:

- Cal/val – The station is used for calibration and/or validation of satellite products and/or (Earth system) models, or it has been used for such purposes in the past and still provides the needed facilities;
- Research – In addition, the station has a broader research focus related to the cryosphere.

The CryoNet contributing stations provide useful measurements of the cryosphere, but their data records may be shorter or contain large gaps, for example, stations which are no longer operational or which do not completely follow CryoNet measurement practices. A CryoNet contributing station is required to measure at least one variable of at least one cryospheric component (such as snow, permafrost, sea ice, and the like) from among those indicated in section 9.1.3. Mobile platforms such as ships, drifting stations and buoys may also be CryoNet contributing stations. CryoNet contributing stations may have the attribute “Reference”, that is, have a long-term operational commitment and/or long-term (more than 10 years) data records.

All GCW stations are registered in the WMO [OSCAR/Surface](#) database and make available their data and metadata. OSCAR/Surface allows them to track changes in instrumentation,

traceability, and observation procedures and practices. Their data is made available according to an agreed protocol, in a timely manner, to a data centre which is interoperable with the GCW Data Portal.

A CryoNet cluster is a grouping of stations, generally encompassing an area greater than a conventional observing station and is defined in the *Manual on the WIGOS*, Chapter 8. A CryoNet cluster is comprised of two or more active stations with observing capabilities that are contributing together to monitoring identified cryospheric components. A CryoNet cluster configuration in OSCAR/surface includes at least one CryoNet station, or at least one CryoNet contributing station and another station providing the GCW-required meteorological observations. Together, these two stations meet the criteria for a CryoNet station. When a cluster encompasses several micro-climatological regions or extends over larger altitudinal gradients, further ancillary meteorological stations may be necessary. The stations included in a CryoNet cluster would generally have different WSIs and may be operated by different institutions, while the coordination and the access to data may be provided through one agency or institute. For registration as a CryoNet cluster in the OSCAR/Surface database, each CryoNet cluster must provide a document indicating the stations included, and an outline of their coordination, data management, programmatic or research approach, the proposed attributes, and other relevant information (such as cooperation between different partners).

Attributes of CryoNet clusters are:

- Basic – Monitor single or multiple components of the cryosphere.
- Integrated – Monitor at least two components of cryosphere or at least one cryosphere component and one other component of the Earth system. Integrated sites are particularly important for the study of feedback and complex interactions between components.

9.1.2 Global Cryosphere Watch station observational requirements

The observational requirements for each cryosphere component have been identified by GCW. They provide clarity to station operators aspiring to register their stations as GCW stations (CryoNet station, CryoNet contributing, or GCW affiliated) or as CryoNet clusters.

The cryospheric variables expected to be observed at a GCW station have been identified as recommended or desired.

The *recommended cryospheric variables* are those expected to be observed at candidate CryoNet, CryoNet contributing, and GCW affiliated stations. At least one recommended cryospheric variable is required to be observed at a candidate station. The desired cryospheric variables are further cryospheric variables that can be observed at approved GCW stations, and which are not identified as recommended cryospheric variables.

For each variable, the frequency and method (whether automatic or manual) of the observation or measurement are indicated in the *Guide to Instruments and Methods of Observation* (WMO-No. 8), Volume II, 1.4, Tables 1.1-1.11.

The configuration metadata in the OSCAR/Surface database are represented in the WIGOS Metadata Representation (WMDR) defined within the framework of the *WIGOS Metadata Standard* (WMO-No. 1192).

Proponents are invited to use the Site Description field of OSCAR/Surface to provide any additional relevant information which cannot be captured in the available fields, such as station or cluster attributes, and so forth.

9.1.3 List of the recommended cryospheric variables

Note: This section guides the reader on the expected configuration of stations proposed for registration.

For guidance, the following are the recommended cryospheric variables expected to be observed at GCW stations. The detailed list is included in the *Guide to Instruments and Methods of Observation* (WMO-No. 8), Volume II, 1.4, Tables 1.1-1.11. This information is provided as reference in preparation for registering new GCW stations in OSCAR/Surface.

- Snow cover – The recommended observed variables for snow cover include snow depth, water equivalent of snow cover, snow on the ground, solid precipitation, and snow profiles.
- Glaciers and ice caps – The recommended observed variables for glacier and ice caps include surface accumulation (point), surface ablation (point), glacier-wide mass balance, and glacier area.
- Ice sheets – The recommended observed variables for ice sheets are surface accumulation (point), surface ablation (point), and surface mass balance (point).
- Ice shelves – The recommended observed variables for ice shelves are basal ablation and ice velocity.
- Icebergs – The recommended observed variables for icebergs are iceberg position, iceberg form and size, and concentration (distance) of icebergs.
- Permafrost – The recommended observed variables for permafrost are ground temperature and active layer thickness.
- Seasonally frozen ground – The recommended observed variable for seasonally frozen ground is ground temperature.
- Sea ice – The recommended observed variables for sea ice are sea-ice thickness, sea-ice freeboard, sea-ice concentration, sea-ice class, sea-ice type, form of sea ice, stage of ice development, sea ice phenomena (dates of freeze-up, fast-ice formation/breakout, melt onset, break-up), and sea-ice stage of melting.
- Lake ice – The recommended observed variables for lake ice are ice thickness, ice concentration, ice class (pack, fast ice), ice type (level/rafted/ridged and floe descriptor), form of ice (floe size, fast-ice width), stage of ice development, ice phenomena (dates of freeze-up, fast-ice formation/breakout, melt onset, break-up), and ice stage of melting.
- River ice – The recommended observed variables for river ice are ice thickness, ice concentration, ice class (pack, fast ice), ice type (level/rafted/ridged and floe descriptor), form of ice (floe size, fast-ice width), stage of ice development, ice phenomena (dates of freeze-up, fast-ice formation/breakout, melt onset, break-up), ice stage of melting, river-ice jams and dams, flooding extent caused by jams and dams, and river icings (aufeis).

9.1.4 **Procedure for registration of Global Cryosphere Watch stations**

Process outline

A CryoNet or CryoNet contributing station is evaluated and approved based on the information provided by its proponent in the OSCAR/Surface database. This process has six distinct stages and is summarized in Figure 12. The stages are:

- (1) Expression of Interest: A station operator expresses an interest in registering a CryoNet or a CryoNet contributing station. This is conveyed (either directly or through another party) to the WMO/GCW Secretariat. Preliminary information about the station is shared between the parties.

- (2) **Station Contact:** A Station Contact is agreed upon with the proponent; this is the person responsible for entering the information on the proposed station in OSCAR/Surface. A profile for the Station Contact is created in OSCAR/Surface by the WMO/GCW Secretariat, if not already available.
- (3) **WIGOS Station Identifier (WSI):** Proponents are strongly encouraged to obtain WSIs for their GCW candidate stations from the OSCAR/Surface national focal point of the Member on the territory of which the station is operated. If needed, WMO/GCW Secretariat will facilitate engagement with the appropriate focal point. If a WSI is not obtained from a Member or from another programme, one is allocated by the GCW WSI Issuer, which is the WMO/GCW Secretariat.

Notes:

1. For mobile platforms operating in international waters, [OceanOPS](#) will allocate a WSI if the station includes meteorological observations. If a WSI is not obtained from OceanOPS, a WSI will be issued by the WMO/GCW Secretariat.
2. The WSI is generated according to the guidelines under 9.1.5.
3. Stations which already exist in OSCAR/Surface as part of other programmes already have a WSI.
4. Affiliated stations are expected to be already registered in OSCAR/Surface as part of other WMO Programmes, and, thus, have an active WSI.

- (4) **Station entry in OSCAR/Surface:** The Station Contact creates/updates the proposed station in OSCAR/Surface, by entering information in the OSCAR/Surface fields to demonstrate compliance with the requirements defined in the *Manual on the WIGOS*, Chapter 8. Once the draft station is saved, its status in OSCAR/Surface is "Pending". The station must be associated with GCW and the type of stations proposed (that is, CryoNet or contributing). A notification of the new submission will be automatically generated by OSCAR/Surface to the responsible programme authority, which is the WMO/GCW Secretariat.

Notes:

1. Instructions for the creation/editing of a station are available in the *OSCAR/Surface User Manual* (OSCAR Series No. 1) and the GCW-specific [FAQ](#) on the OSCAR/Surface platform.
2. For registration, a candidate station must observe at least one recommended variable listed in section 9.1.3.
3. If the proponent submits a CryoNet cluster, each new station needs to be entered in OSCAR/Surface, together with an outline of the cluster concept. Once the indicated stations are approved, guidance is provided to link stations belonging to the proposed cluster.

- (5) **Evaluation of the submission:**

- (a) A "Pending" submission is reviewed by the WMO/GCW Secretariat for compliance with the criteria indicated in the *Manual on the WIGOS*, section 8.
- (b) If the submission does not address all requirements as noted at step (4), additional information may be requested from the Station Contact.
- (6) **Approval of station:** Once all requirements are met, the GCW programme authority changes the status of a station to "Approved". At that point the station is published in OSCAR/Surface as a CryoNet or a CryoNet contributing station.

If the criteria referenced at step four cannot be met, the approval is not granted.

Depending on the status of the proposed station, the registration process will commence at different steps in the outlined process.

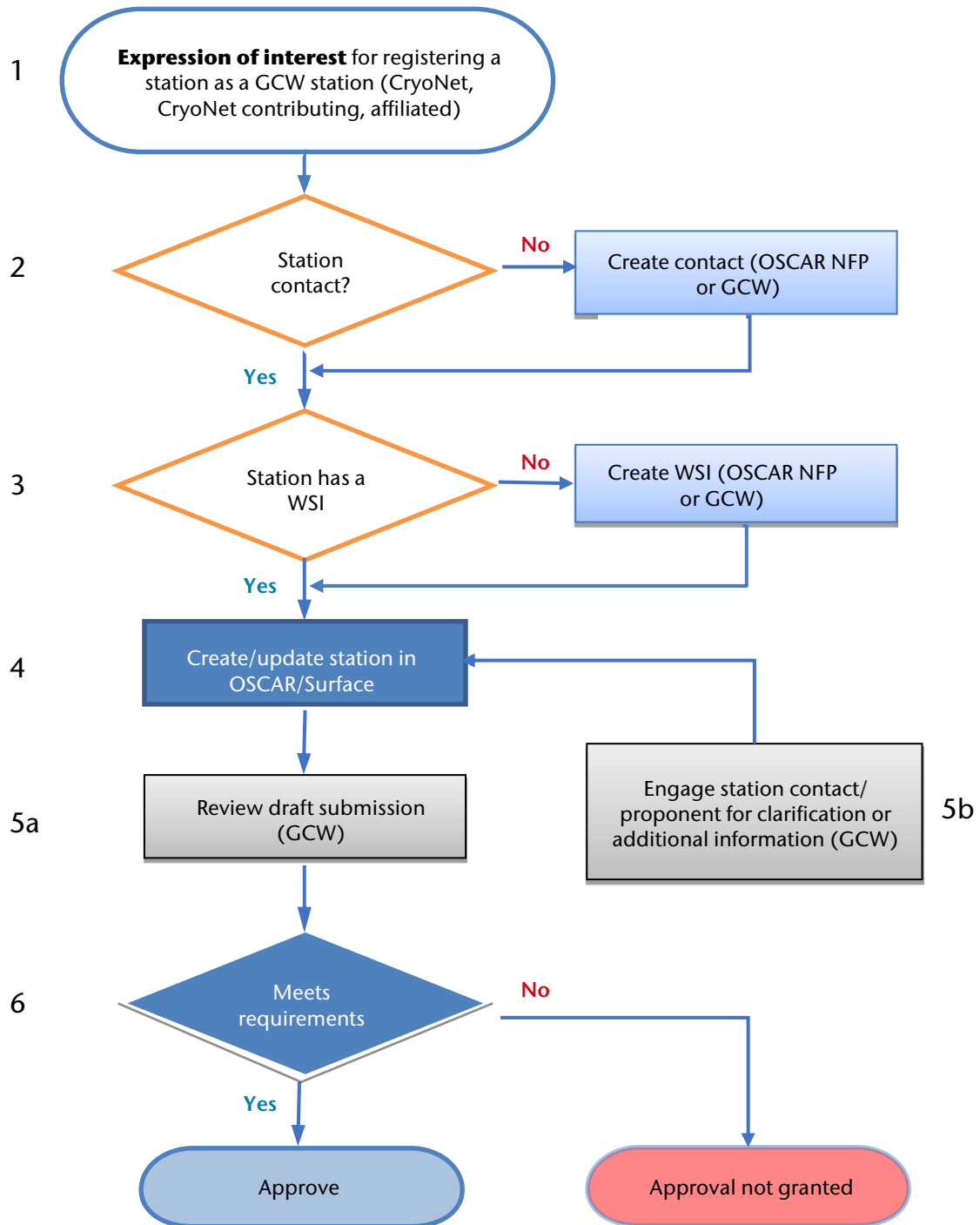


Figure 12. The process for registering a GCW station

9.1.5 Registration of GCW stations in the OSCAR/Surface database

Allocation of WSI by GCW as an issuer

When stations proposed as GCW stations (CryoNet or CryoNet contributing) do not obtain a WSI from the Member on the territory of which the station is operated, or from another programme, the WMO/GCW Secretariat will issue a WSI.

The WSI allocated by the WMO/GCW Secretariat will have the following structure:

| <i>Block in WSI</i> | <i>Component</i> | <i>Description</i> | <i>GCW ranges</i> |
|---------------------|-------------------------------|---|-------------------|
| 1st block | WSI series | Only the WSI series 0 has been defined. This series is used to identify observing stations. | 0 |
| 2nd block | Issuer of identifier (number) | This is a five-digit code which would be assigned by WMO to identify a specific Programme or activity with which the identified station is most closely associated. This does not limit the association with other programmes. GCW-issued WSIs will be identified with "21000" for the issuer of identifier. | 21000 |
| 3rd block | Issue number | This is a number that an organization responsible for issuing an identifier may use to ensure global uniqueness of its identifiers. As GCW is an international activity, the issue number will not identify supervising organizations of GCW stations through this block and will use '0' in this block for all GCW allocated WSI. | 0 |
| 4th block | Local identifier | This is a string of up to 16 alphanumeric characters used as an individual identifier for each station, to uniquely identify a station, globally. The uniqueness is ensured when used in combination with the other 3 blocks, above. The format issued by GCW will comprise 6 characters, as follows: <ul style="list-style-type: none"> - Character "C" which has been arbitrarily selected; - 5 characters reserved for the station identifier which will be used sequentially for the applying stations. Notes: <ul style="list-style-type: none"> - Stations approved as GCW stations before 2020, if receiving WSI through GCW, will receive a WSI for which the last 3 digits represent the ID, as registered in the GCW database; - All stations registered through GCW will receive a WSI in a sequential order starting with C01001. | Cxxxxx |

9.2 GLOBAL OCEAN OBSERVING SYSTEM

9.2.1 Introduction

This section provides guidance on WIGOS Station Identifiers (WSIs) to be used by operators of all Global Ocean Observing System (GOOS) in situ observing networks and allocated by [OceanOPS](#) (formerly known as JCOMMOPS) including:

- Ship observations (Voluntary Observing Ships (VOS), Ship-of-Opportunity Programme (SOOP), Automated Shipboard Aerological Programme (ASAP)) under the Ship Observations Team (SOT), and other ship-based systems (fishing vessels, ferry boxes, and so forth);
- Data Buoy observations (global drifter array, tropical moored buoy array, national/coastal moored buoy networks, high latitude (Arctic/Antarctic) buoys, tsunami buoys, unmanned surface vehicles and miscellaneous fixed platforms) under the Data Buoy Cooperation Panel (DBCP);
- Global tide gauge network under the Global Sea Level Observing System (GLOSS);
- Global profiling float array under the Argo programme;
- Fixed-point time series reference sites under OceanSITES;

- Repeat hydrography programme under the Global Ocean Ship-Based Hydrographic Investigations Programme (GO-SHIP);
- Underwater gliders under OceanGliders;
- Animal Borne Instruments under AniBOS;
- Global High-Frequency Radar Network under HFRNet;
- A number of other ocean observing networks emerging at a regional level, or at the boundary of existing Observations Coordination Group (OCG) observing networks.

The WSI scheme for the observing platforms¹ of GOOS in situ networks presented here builds on the legacy of existing WMO-identifiers (WMO-ID) traditionally used to distribute observing platform/station data on the Global Telecommunication System (GTS). The WMO-ID allocation scheme for ocean platforms has not always ensured the uniqueness of identifiers and was based on a manual allocation system using a set of complex rules. Some Members also sporadically use some random identifiers that do not meet any defined rule. The scheme described here harmonizes the allocation of station identifiers, ensures their uniqueness, and develops a robust and operational workflow through a machine-based allocation system.

OceanOPS has the delegated authority² to issue WSIs for ocean observing platforms operated by Members through its Operational Information System. However, if any Member decides to issue the WSIs for their own platforms, they must use the ISO 3166–1 numeric country code “issuer of identifier” number (see section 2.1.4). In such cases, Members should notify OceanOPS³ about those WSIs, when they are assigned, in order to monitor the overall data and metadata flow.

9.2.2 **Procedures specific to GOOS observing platforms**

9.2.2.1 ***Issuer of identifier***

An issuer of identifier code allocated for GOOS observing platforms administered through OceanOPS is a constant: 22000 (see Chapter 2, Table 4). The use of the previously defined issuer of identifier codes 20002 (for moored buoys, drifting buoys, fixed platforms), 20003 (observing ship with identifier based on ITU call sign), 20004 (observing ship identifier issued nationally) and 20007 (ship IMO number/hull number) will not be used for new deployed platforms.

9.2.2.2 ***Issue number***

An issue number does not have any meaning and is allocated by the machine to secure uniqueness of the identifier and, for example, to resolve the historical reuse of WMO-IDs. In practice, for OceanOPS platforms, the issue number is used to monitor the different redeployments of the same platform (such as a new mission for a glider), or a new installation of an existing platform/station on a new ship or at a fixed site (such as moored buoys, OceanSITES). Those Members issuing the WSIs for their own platforms will decide on the issue numbers, according to their national schema for WSIs.

9.2.2.3 ***Local identifier***

The local identifier is based generally on the historical WMO-ID or other identifiers defined by observing networks.

¹ OceanOPS commonly uses the term “observing platform”. Other synonyms, such as “station” or “observing facility”, are used by different communities.

² See the [Joint WMO/IOC Technical Commission for Oceanography and Marine Meteorology, Abridged Final Report of the Fifth Session](#) (WMO-No. 1208), Decision 25 (JCOMM-5)

³ support@ocean-ops.org

The general form of a WMO-ID⁴ is based on 7 digits:

$$\text{WMO-ID} = A_1 B_w \text{nnnnn}$$

where A_1 = WMO Regional Association⁵ area and B_w is the sub-area.

B_w is designated against the sub-area (1–7) for moored and drifting buoys, while fixed values 8 or 9 are assigned for other platform types.

Legacy 5-digit WMO-IDs ($A_1 B_w \text{nnn}$)⁶ were converted into 7 digits by adding 00 after the $A_1 B_w$ (for example, $A_1 B_w 00\text{nnn}$).

However, there are instances when these rules of identifier allocation according to geographical criteria have not been followed (for example, some floats or drifter deployments). While this geographical distinction makes sense for fixed or anchored platforms, it is less appropriate for mobile platforms moving freely or autonomously within different areas, therefore, $A_1 B_w$ will be used only for fixed platforms.

Data users should be informed not to base their data extraction or assimilation schemes on the A_1 or $A_1 B_w$ formula.

As the WMO-ID (and WSI) allocation system is machine-based, OceanOPS uses the platform deployment location and the WMO area polygons to define A_1 and B_w as appropriate.

Table 6 below illustrates the new rules that simplify local identifier allocation based on platform types and geographical areas.

While WSI management best practice dictates that the WSI content should have no meaning and be simply unique, the rules proposed in Table 6 preserve some of the legacy on the readability of local identifiers by platform types.

Table 6. Rules for new local identifier allocation

| <i>Platform type</i> | <i>Previous local identifier</i> | <i>New local identifier</i> |
|--|---|---|
| Profiling floats, micro floats, ice tethered profilers, polar ocean profiling systems, deep floats, etc. | $A_1 9\text{nnnnn}$ $A_1 = [1-7]$ | $A_1 9\text{nnnnn}$ $A_1 = [1-7]$ random |
| Marine animals | 99nnnnn | 99nnnnn |
| Subsurface autonomous platforms, gliders | $A_1 8\text{xxnnn}$ If $A_1 = 4$ $\text{nnn} = 900-999$ otherwise $\text{nnn} = 500-999$ | 89nnnnn |
| Surface drifters, ice drifters | $A_1 B_w \text{xxnnn}$ $\text{nnn} = 500-899$ $\text{xx} = 00-99$ $A_1 = [1-7], B_w = [1-7]$ | $A_1 8\text{nnnnn}$ $A_1 = [1-7]$ random |
| Other autonomous surface instruments (saildrones, wave gliders, etc.) | $A18\text{xxnnn}$ If $A_1 = 4$ $\text{nnn} = 900-999$ otherwise $\text{nnn} = 500-999$ | $A10\text{nnnnn}$ $A_1 = [1-7]$ random |

⁴ See the *Manual on Codes – International Codes* (WMO-No. 306), Volume I.2, table Class 01 – BUFR/CREX Identification, Table Reference 0 01 011

⁵ See the *Manual on Codes – International Codes* (WMO-No. 306), Volume I.1, Page A-243, Table 0161

⁶ See the *Manual on Codes – International Codes* (WMO-No. 306), Volume I.1, Page A-9, List of Code Forms with Notes and Regulations

| <i>Platform type</i> | <i>Previous local identifier</i> | <i>New local identifier</i> |
|---|---|---|
| Fixed systems, moored buoys, mooring sites, HF radars, tide gauges, etc. | moored buoys: A ₁ B _w xxnnn nnn = 000–499 xx = 00–99 A ₁ = [1–7], B _w = [1–7] fixed platforms: A ₁ B _w xxnnn nnn = 000–499 xx = 00–99 A ₁ = [1–7], B _w = [1–7] | A ₁ B _w nnnnn nnnnn random A ₁ = [1–7], B _w = [1–7] matching WMO areas/ subareas |
| Any ship-based instruments | ship call sign | 7-digit reference (also called SOT-ID) is created randomly by the machine with characters 2, 3 and 7 being letters, the others being letters or numbers (Reference Decision 32 (JCOMM-5)) |
| Reserve of free blocks for future platform types 81nnnnn, 82nnnnn, 83nnnnn, 84nnnnn, 85nnnnn, 86nnnnn, 87nnnnn | | |

The WIGOS Station Identifiers allocated by OceanOPS will have then the following form:

| <i>WIGOS Identifier Series (number)</i> | <i>Issuer of Identifier (number)</i> | <i>Issue Number (number)</i> | <i>Local Identifier (characters)</i> |
|---|--------------------------------------|------------------------------|--------------------------------------|
| 0 | 22000 | 0 to 65534 | 7-digit string |

9.3 GLOBAL ATMOSPHERE WATCH

9.3.1 Introduction

9.3.1.1 Background

The [WMO Global Atmosphere Watch \(GAW\) Implementation Plan: 2016–2023](#) (GAW Report No. 228) explains how observing facilities (stations) can become affiliated to the WMO GAW Programme as either Global, Regional, Local or Mobile GAW Stations, or as a station of a Contributing Programme.

Note: The specifications provided in the referenced GAW implementation plan remain valid beyond the specified period of the plan.

All observing facilities, including those from other GAW related programmes (“GAW Other Elements”), need to be registered in the GAW Station Information System (GAWSIS) to be considered for affiliation with GAW. GAWSIS is the WMO designated catalogue of surface-based observing facilities, and represents the metadata source for OSCAR/Surface for GAW observations.

When registered in GAWSIS, at least one WIGOS Station Identifier (WSI) is assigned to each observing facility. Additional programme-specific identifiers can be assigned but are not

the subject of this Guide. Only stations that measure GAW variables can be affiliated with the programme as either Global, Regional, Local or Mobile GAW Stations, or as a station of a Contributing Programme, following regulations outlined in the *Manual on the WIGOS*, Chapter 6.

GAW is recognized as an “Issuer of WIGOS Station Identifiers” (or WSI Issuer) with delegated authority to issue WSIs for observing stations that contribute to the GAW Programme. The following sections describe the process of issuing and assigning a WSI for a GAW-related station, in compliance with section 2.1, in order to register an observing facility under GAW.

9.3.1.2 **Programmes/networks under Global Atmosphere Watch**

The application procedure to become affiliated with the GAW Programme is described in the WMO Global Atmosphere Watch (GAW) Implementation Plan: 2016–2023 (GAW Report No. 228), Annex B, and in the *Manual on the WIGOS*, section 6.2. It involves registration with GAWSIS-OSCAR/Surface and approval by a governing body, depending on the type of programme affiliation desired. The structure of programmes/networks organized under GAW is specified under the WMO Codes Registry (codes.wmo.int/wmdr/ProgramAffiliation).

9.3.2 **WSI procedures specific to Global Atmosphere Watch observing facilities**

9.3.2.1 **Issuer of identifier for observing facilities registered by a Member**

Institutions wishing to register and affiliate observing facilities for a programme/network under GAW may do so by contacting the national focal point (NFP) for GAW of the WMO Member in which the station is located, who is nominated by the respective Permanent Representative. The NFP for GAW in coordination with the OSCAR/Surface NFP will then create/register a station in GAWSIS-OSCAR/Surface. The issuer of identifier should be the ISO 3166–1 numeric code assigned to the corresponding country or territory.

9.3.2.2 **Issuer of identifier for observing facilities registered through the Global Atmosphere Watch Programme**

If a Member is unable to issue a WSI, the WMO Secretariat will do this. In such a case, the institution wishing to register a GAW station, and the Member concerned (according to the previous paragraph) will contact the WMO Secretariat. The Secretariat will then analyse the request, decide upon the registration of the station in GAWSIS-OSCAR/Surface and assign a WSI for the GAW Programme. The issuer of identifier value for observing facilities affiliated with GAW is 20008.

9.3.2.3 **Issuer number for observing facilities registered through the Global Atmosphere Watch Programme**

To guarantee global uniqueness, the WMO Secretariat responsible for support of the GAW Programme has assigned a unique issue number to World Data Centres (0), to each Programme/network contributing to GAW wishing to register additional observing facilities (100–199), and to other elements that are performing atmospheric composition measurements (200–299) in GAWSIS-OSCAR/Surface, as listed in Table 7. This list is maintained by the WMO Secretariat and is available from the WMO Codes Registry (codes.wmo.int/wmdr/ProgramAffiliation).

9.3.2.4 **Local identifier for observing facilities registered through the Global Atmosphere Watch Programme**

The local identifier in the WSI corresponds to the 3-letter GAW ID. At present, GAW IDs are managed in GAWSIS-OSCAR/Surface. All GAW related observing facilities must be assigned

a 3-letter GAW ID, which limits the number of possible GAW IDs to a total of 17 576 from AAA to ZZZ. The requirement for a 3-letter GAW ID may be dropped in future in favour of a more flexible approach.

9.3.2.5 **Global Atmosphere Watch Programme-specific identifiers**

Managers of programmes/networks under GAW may wish to document up to one programme-specific station identifier in GAWSIS-OSCAR/Surface in addition to the WSI. There are no constraints on such identifiers, and GAWSIS-OSCAR/Surface makes no attempt at guaranteeing global uniqueness of such identifiers, which is beyond the scope of this Guide.

Table 7. List of the issue number initially assigned to GAW World Data Centres and programmes/networks affiliated with GAW

| <i>Issue number</i> | <i>Programme or network name</i> | <i>WMDR notation</i> |
|---------------------|----------------------------------|---|
| 0 | WDCs | -- |
| 1 ... 99 | Reserved | -- |
| 100 | ADNet | http://codes.wmo.int/wmdr/ProgramAffiliation/ADNet |
| 101 | CASTNET | http://codes.wmo.int/wmdr/ProgramAffiliation/CASTNET |
| 102 | EANET | http://codes.wmo.int/wmdr/ProgramAffiliation/EANET |
| 103 | EARLINET | http://codes.wmo.int/wmdr/ProgramAffiliation/EARLINET |
| 104 | IAGOS | http://codes.wmo.int/wmdr/ProgramAffiliation/IAGOS |
| 105 | IMPROVE | http://codes.wmo.int/wmdr/ProgramAffiliation/IMPROVE |
| 106 | INDAAF | http://codes.wmo.int/wmdr/ProgramAffiliation/IDAF |
| 107 | LALINET | http://codes.wmo.int/wmdr/ProgramAffiliation/LALINET |
| 108 | MPLNET | http://codes.wmo.int/wmdr/ProgramAffiliation/MPLNET |
| 109 | NADP | http://codes.wmo.int/wmdr/ProgramAffiliation/NADP |
| 110 | TCCON | http://codes.wmo.int/wmdr/ProgramAffiliation/TCCON |
| 112 | NDACC | http://codes.wmo.int/wmdr/ProgramAffiliation/NDACC |
| 113 ... 199 | Reserved | -- |
| 200 | AEROCAN | https://codes.wmo.int/wmdr/ProgramAffiliation/AEROCAN |
| 201 | German AOD Network | http://codes.wmo.int/wmdr/ProgramAffiliation/germanAODnetwork |
| 202 | PHOTONS | http://codes.wmo.int/wmdr/ProgramAffiliation/_PHOTONS |
| 203 | PolarAOD | http://codes.wmo.int/wmdr/ProgramAffiliation/_polarAOD |
| 204 | SKYNET | http://codes.wmo.int/wmdr/ProgramAffiliation/_skynet |
| 205 | SibRad | http://codes.wmo.int/wmdr/ProgramAffiliation/_sibRad |
| 206 | CAPMoN | http://codes.wmo.int/wmdr/ProgramAffiliation/CAPMoN |
| 207 | CLN | http://codes.wmo.int/wmdr/ProgramAffiliation/CLN |
| 208 | EMEP | http://codes.wmo.int/wmdr/ProgramAffiliation/_EMEP |
| 209 | SHADOZ | http://codes.wmo.int/wmdr/ProgramAffiliation/_SHADOZ |
| 210 | CIS-LiNet | http://codes.wmo.int/wmdr/ProgramAffiliation/_CIS-LiNet |
| 211 | ACTRIS | http://codes.wmo.int/wmdr/ProgramAffiliation/_ACTRIS |
| 212 | AGAGE | http://codes.wmo.int/wmdr/ProgramAffiliation/_AGAGE |
| 213 | AERONET | http://codes.wmo.int/wmdr/ProgramAffiliation/_AERONET |
| 214 | NOAA-GML | http://codes.wmo.int/wmdr/ProgramAffiliation/_NOAAGML |
| 215 ... 65555 | Reserved | |

9.4 **WMO RADAR DATABASE**

9.4.1 **Introduction**

The WMO Radar Database (WRD), currently maintained and operated on behalf of WMO by the Turkish State Meteorological Service (TSMS), is the recommended portal through which WMO Members should submit their operational weather radar metadata in support of OSCAR and the WMO Rolling Review of Requirements – see Chapter 3, section 3.3.1.3.

9.4.2 **Allocation of WSIs to weather radar stations by WMO Radar Database**

In relation to the assignment of WIGOS station identifiers for weather radar stations, if not provided by the responsible Member within OSCAR/Surface, the WRD has authority to assign identifiers for weather radar stations utilizing a specific issuer of identifier code. The assignment of WIGOS identifiers is then made using the following schema as described and depicted in Figure 13.

- A WIGOS identifier in the form <0.20010.0.WMO-No> will be assigned for weather radar stations, to be registered in WRD, that were operational before 1 July 2016, with a previously assigned WMO-No of the form NNNNN.
- For all other weather radars, the WRD will assign a WIGOS identifier using the WRD-specific issuer of identifier (21010) and a local identifier assigned by the WRD and confirmed as unique with respect to all radars in the WRD. In such cases the WIGOS identifier will therefore take the form: <0.21010.0.WRD-Lid>, where “WRD-Lid” will be a simple series of integers.

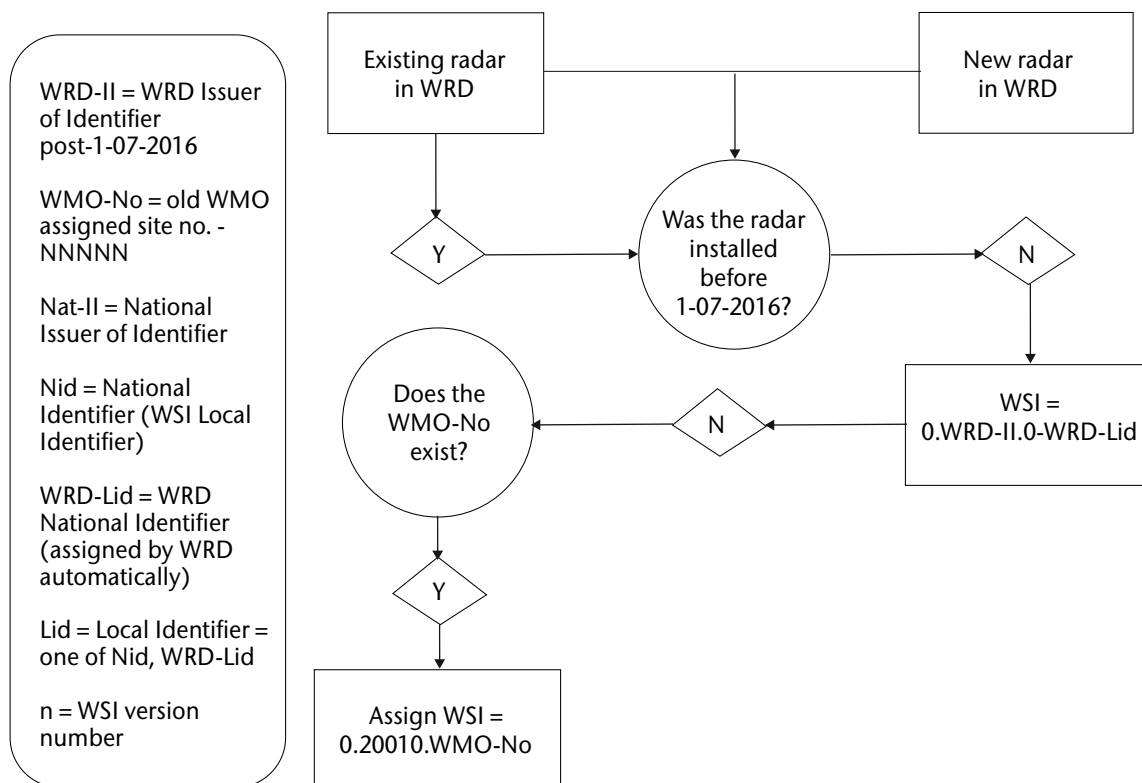


Figure 13. WRD WIGOS identifier assignment

9.4.3 **Registration of weather radar stations and synchronization with OSCAR/Surface**

- (1) A weather radar station can be registered in the WRD by a NFP nominated by the Permanent Representative of the WMO Member where the weather radar is located.
- (2) The assigning of WSIs is automatically done by WRD, which then synchronizes the weather radar's metadata with that in OSCAR/Surface.
- (3) A WSI will be assigned to a weather radar station only if the following minimum metadata elements are provided:
 - (a) Radar station name
 - (b) Country
 - (c) Station operating status
 - (d) Supervising organization
 - (e) Station type
 - (f) Installation date
 - (g) Latitude
 - (h) Longitude
 - (i) Elevation
 - (j) Owner name

9.5 **WMO HYDROLOGICAL OBSERVING SYSTEM**

9.5.1 **Allocation of WIGOS Station Identifiers for hydrological stations**

The purpose of this section is to provide guidance on the recommended procedures for allocating WIGOS Station Identifiers (WSIs) for hydrological stations.

Members may include in the WSIs for hydrological stations references to national or local classification schemes, as described below. Therefore, organizations issuing WSIs for hydrological stations are strongly advised to document their procedures in their quality management system. Figure 14 indicates the various elements that make up a WSI for hydrological stations.

Note: The International Hydrological Code (IHC) (from the *Manual on Codes* (WMO-No. 306), Volume II: see section F of each regional Chapter) is a hydrological observing station identification number. It allows the identification of the WMO Region (A), country (Ci), river basin or group of basins (BB) and the station (iHiHiH). The lists of Ci and BB are published in the *Manual on Codes* (WMO-No. 306), Volume II, while the iHiHiH value has to be set in a unique way at the national level.

9.5.1.1 **Procedure A**

In Procedure A (see, for example, Table 8), hydrological stations are registered through the NFP on WIGOS of the Member issuing the WSI, where the issuer of identifier is identified by its ISO 3166 Country Code (three digits).

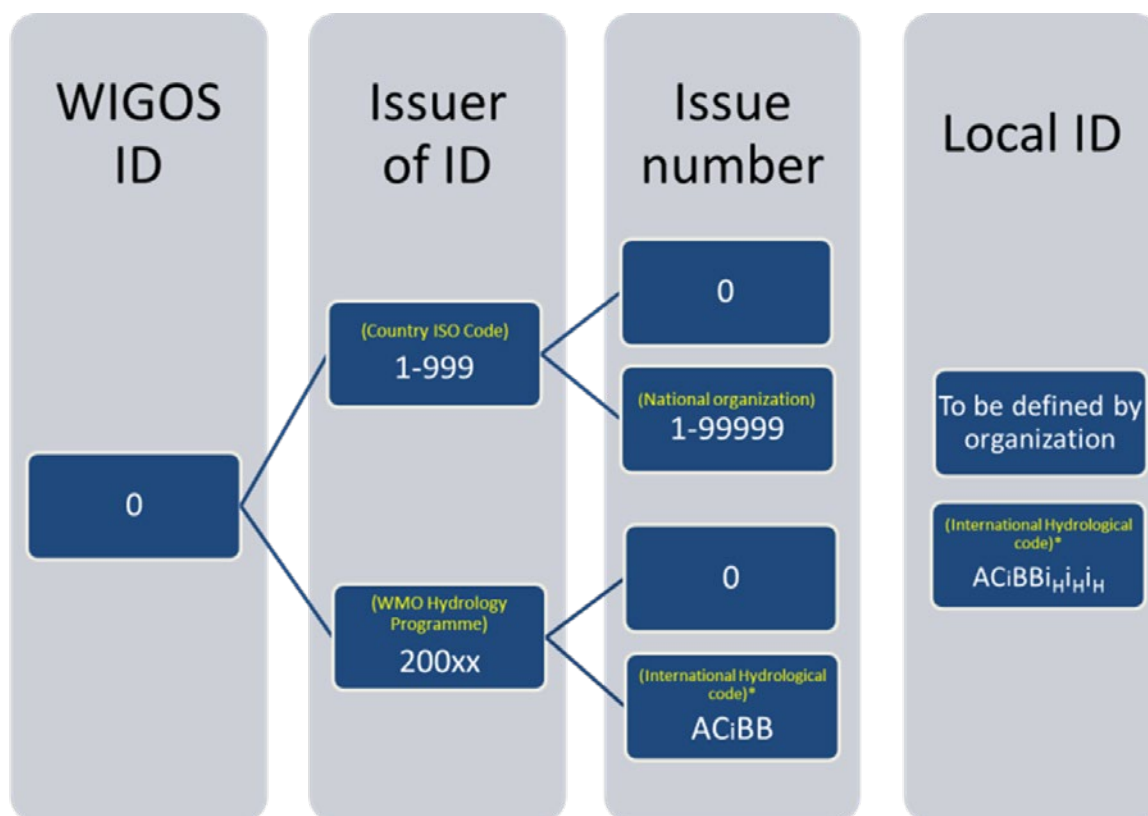


Figure 14. Structure of WIGOS Station Identifier for hydrological stations

The Member defines its own national schema for assigning the issue number and the local identifier. As this can be quite overwhelming and some Members might not have an agreed schema, procedures A1 and A2 below are proposed options.

Table 8. Structure of WSI for A1 and A2 procedures

| Procedure | WIGOS Identifier Series | Issuer of Identifier ISO Country Code | Issue number | Local Identifier |
|-----------|-------------------------|---------------------------------------|-------------------------------|-------------------------------|
| A1 | 0 | 1-999 | 0 | To be defined by Member |
| A2 | 0 | 1-999 | 1-99 (national organizations) | To be defined by organization |

Procedure A1

The Member assigns 0 to the Issue number, and directly provide a local identifier. The Member may choose to use an existing national identifier as the local identifier for the observing facility (station).

Table 9 illustrates this procedure, with Canada as an example of the issuer of identifier and with the local identifier being the Hydrometric Station Number Index for the Yukon river at Dawson, used by the Water Survey of Canada.

Table 9. Example of A1 procedure

| <i>WIGOS Identifier Series</i> | <i>Issuer of Identifier Canada ISO Code</i> | <i>Issue number</i> | <i>Local Identifier Hydrometric Station Number Index (Yukon river at Dawson)</i> |
|--------------------------------|---|---------------------|--|
| 0 | 124 | 0 | 09EB001 ⁷ |

The advantage of this procedure is that it simplifies the process by having a single Issuer of WSIs (the Permanent Representative via the NFP) and by fixing the issue number to 0. The disadvantage might be a slower process of allocating identifiers, as it depends on one entity (usually the National Meteorological Services), to which all other organizations must refer.

Procedure A2

The Member chooses to define the issue number, to allow delegation of the task of allocating WSIs in which the local identifiers are issued by various entities responsible for managing individual observing networks. These organizations could be the National Meteorological Service, National Hydrological Service, National Transport Departments, Environmental Agencies, and so forth.

If the organization is only responsible for allocating local identifiers for their WSIs, then it is sufficient for it to ensure that it does not assign the same local identifier to more than one observing facility under its responsibility. It may choose to use an existing national identifier as the local identifier for the observing facility or to define new identifiers.

Brazil, Côte d'Ivoire and Italy proposed their own national WSI allocation schemas, which all follow procedure A2, but in three different ways, as shown by way of example in Table 10.

Table 10. Examples of A2 procedure

| <i>WIGOS Identifier Series</i> | <i>Issuer of Identifiers ISO Country Code</i> | <i>Issue number National organizations</i> | <i>Local Identifier</i> |
|--------------------------------|---|---|-------------------------------|
| 0 | (Brazil) 076 | (NMET) 100 (DECEA) 101 (DHN) 102 (ANA) 103 (...) | GGGGGGTNNNNN ⁸ |
| | (Côte d'Ivoire) 384 | (NMS stations) 1–199 (NMS partners' stations) 200–299 (...) 9000–9999 | To be defined by organization |
| | (Italy) 380 | 1-2-3-(...) | 1-2-3-(...) |

The benefit of Procedure A2 is that multiple entities are issuing identifiers. Therefore, local identifiers will be categorized, and the process of registration may be faster. One possible disadvantage would be the non-uniqueness of local identifiers.

Based on these two procedures, the risk of allocating the same identifier to different stations is managed in procedure A1 by the presence of a unique issuing entity, and in procedure A2 by the presence of several issuing entities with unique issue numbers.

⁷ https://wateroffice.ec.gc.ca/station_metadata/station_index_e.html?type=stationName&stationLike=A

⁸ GGGGGG = Official County Geocode; TT = Type of station; NNNNN = Station number (new or old WWW number)

Procedure A1 can adapt well to Members with a hydrometeorological service having relations with other hydrological monitoring institutions. Procedure A2 is better suited to a national context, with several entities in charge of the monitoring. However, Members may choose to follow either procedure A1 or procedure A2.

9.5.1.2 Procedure B

In the case where it is challenging to obtain WSIs from the Permanent Representative of the Member, the alternative procedure is to allocate WSIs for hydrological stations via a delegated authority from the observing component of the WMO Hydrological Observing System (WHOS) in case of non-meteorological service observing stations, that is, research organizations, basin authorities/organizations, and so forth. This procedure is characterized by a worldwide unique issuer of identifier that directly identifies the station as a provider of hydrological data (see, for example, Table 11). The allocation of WSIs for hydrological stations in this procedure is the responsibility of the WMO Secretariat.

Table 11. Structure of WSI for B procedures

| Procedure | WIGOS Identifier | Issuer of Identifier WHOS | Issue number | Local Identifier |
|-----------|------------------|---------------------------|-------------------------|---|
| B1 | 0 | 21XXX | 0 | ACiBBiHiHiH (International Hydrological Code) |
| | | | | To be defined by: <ul style="list-style-type: none"> • WHOS or • Organization |
| B2 | 0 | 21XXX | ACiBB (Basin indicator) | To be defined by: <ul style="list-style-type: none"> • WHOS or • Organization |

Procedure B1

In procedure B1, the issue number is fixed to the 0 value and there are two options for the local identifier: the International Hydrological Code (IHC) or another identifier defined by WHOS.

The IHC (from the *Manual on Codes* (WMO-No. 306), Volume II: see section F of each regional Chapter) is a hydrological observing station identification number. It allows the identification of the WMO Region (A), country (Ci), river basin or group of basins (BB) and the station (iHiHiH). The lists of Ci and BB are published in the *Manual on Codes* (WMO-No. 306), Volume II, while the iHiHiH value has to be set in a unique way at the national level.

The same example as set out in Table 9 with the Yukon river in the Yukon basin (Canada) is used in Table 12. The value allocated to WHOS is simply for illustration. The local identifier refers to the WMO Region (4), country (2), river basin (03) and station (010 given randomly).

Table 12. Example of B1 procedure

| WIGOS Identifier Series | Issuer of Identifier WMO WHOS | Issue number | Local Identifier |
|-------------------------|-------------------------------|--------------|------------------|
| 0 | 21016 | 0 | 4203010 |

The IHC is not widely used by Members. Because of the two-digit number for the basin (BB), some small basins are grouped into one: it is necessary to check in order to ensure that these basin indicators are coherent with basin authorities/organizations. Also, this basin identification system might just complexify the allocation of WSIs.

Procedure B2

In the case of Procedure B2, a part of the IHC is allocated to the issue number. The region (A), country (Ci) and basin (BB) identifiers are used (see, for example, Table 13). Procedure B2 enables the issuer of an identifier to categorize stations, allows basin organizations to issue WSIs independently and limits duplicates.

Table 13. Example of B2 procedure

| <i>WIGOS Identifier Series</i> | <i>Issuer of Identifier WMO WHOS</i> | <i>Issue number</i> | <i>Local Identifier</i> |
|--------------------------------|--------------------------------------|---------------------------|---|
| 0 | 21016 | 4203 (Basin indicator) | To be defined by: (i) WHOS or (ii) Organization |

The Global Runoff Data Centre (GRDC) has produced maps of the WMO Hydrologic Regions and Subregions and a numbering system derived from the region and basin indicators used in Table 11 (see [Example of a WMO hydrological regions and sub-regions numbering system](#)). It illustrates well the concept applied for the issue number in this procedure.

9.6 COPERNICUS CLIMATE CHANGE SERVICE

9.6.1 Introduction

9.6.1.1 Background

The Copernicus Climate Change Service (C3S) is managed by the European Centre for Medium-Range Weather Forecasts (ECMWF), the entity entrusted by the European Commission. The service exists to enable access to and use of climate data by a broad range of stakeholders. Data served includes observational data, observationally-based data products, including reanalyses, and climate model data.

9.6.1.2 Activities of relevance under Copernicus Climate Change Service

The C3S programme includes a set of contracts concerned with recovery, management and provision of historical in situ data holdings from a variety of observing platforms in support of climate applications. The work is undertaken in partnership with other entities including the World Data Centre for Meteorology-Asheville (hosted by the National Centers for Environmental Information of the United States' National Oceanic and Atmospheric Administration (NOAA-NCEI)).

The holdings being managed under these activities contain data for many tens of thousands of stations (which include marine platforms), many of which are long-closed stations which may previously have been operated individually by National Meteorological and Hydrological Services (NMHS) or their antecedent organizations, or which have only ever been operated by third parties. To be able to provide access to users to these climate data holdings, using WSIs, requires those stations without a currently assigned identifier to be assigned a WIGOS identifier.

9.6.2 WSI procedures specific to Copernicus Climate Change Service

9.6.2.1 Copernicus Climate Change Service check for existing WIGOS identifier

A first step for every station to be issued a new WSI by C3S is for C3S to check whether it is registered in [OSCAR/Surface](#) under an existing WSI. If it is, that identifier will be used by C3S and

no further action is required. The check will involve multiple metadata aspects (station name, including possible antecedent names such as colonial place names, country, coordinates, and so forth) to ensure that the station is truly unique within OSCAR/Surface.

9.6.2.2 **Check for stations still in operation**

For some data used by C3S, the station is presently operational but has no WSI. This could arise because the station is owned/operated by citizen science programmes (such as the Community Collaborative Rain, Hail and Snow Network (CoCoRAHS)) or by a non-NMHS data provider (for example, various mesonets) and has not been registered in OSCAR/Surface. For such stations still in operation, a check will be made with the PRs of the relevant Members as to whether they plan to assign them a WSI and register them in OSCAR/Surface in the first instance. C3S will proceed to issue a WIGOS identifier, in accordance with the *Manual on the WIGOS*, Attachment 2.2., only for those stations whose PRs do not plan to register or do not reply within a reasonable time frame, and to register the station in OSCAR/Surface.

9.6.2.3 **Issuer of identifier for Copernicus Climate Change Service**

The issuer of identifier codes for all WSIs issued by C3S is 23001, as per Table 2.5 in 2.4.4.

9.6.2.4 **Issuer number for Copernicus Climate Change Service**

The issuer number for C3S identifier block assignments is based upon the in situ contractor responsible for issuing the identifier as per Table 14. Each in situ contract lead entity is responsible for managing the local identifiers issued under its issuer number. There are presently three contracts in operation, each of which has been assigned an issuer number. The three contracts are coordinated by ECMWF and agreements are in place as to how to manage the data overlaps where they exist. Paul Poli is the C3S In situ Observations Manager (paul.poli@ecmwf.int) coordinating the assignment of WSIs on behalf of ECMWF.

Table 14. Issuer number details for Copernicus Climate Change Service including the observation types likely to be registered (current as of 26/7/22)

| <i>Issuer</i> | <i>Issuer number</i> | <i>Responsible entity</i> | <i>Contact</i> | <i>Type of data</i> |
|----------------|----------------------|--|--|--|
| C3S2 311 Lot 1 | 1 | Maynooth University (Ireland) | Peter.thorne@mu.ie | Global land and marine surface observations |
| C3S2 311 Lot 2 | 2 | National Research Council (CNR) (Italy) | Fabio.madonna@imaa.cnr.it | Radiosonde and upper-air remote sensing |
| C3S2 311 Lot 3 | 3 | Royal Netherlands Meteorological Institute (KNMI) (Kingdom of the Netherlands) | gerard.van.der.schrier@knmi.nl | Land surface observations over the European domain at daily resolution |

9.6.2.5 **Local identifier for Copernicus Climate Change Service**

C3S will observe and honour the rules for all WSI local identifiers as set out in preceding sections. An identifier of up to 16 characters (avoiding spaces and reserved special characters) will be assigned to each station. These WSI local identifiers will avoid any use of information that may point to a specific location or data type being available.

To aid users and Members, and for historical legacy purposes, under issuer number 1 for this block for some stations registered that appear in the Global Historical Climatology Network daily (GHCNd) and monthly (GHCNm) archives, the FIPS code (<https://www.geodatasource.com/resources/tutorials/international-country-code-fips-versus-iso-3166/>) may constitute the initial characters in the local identifier. This identifies the territory but without prejudice as to the exact station location or the type of observations that are/were being performed.

An example of such a station is given at <https://www.ncdc.noaa.gov/cdo-web/datasets/GHCND/stations/GHCND:US1NCBC0121/detail>. In the C3S issuer identifier schema, assuming the corresponding PR did not wish to register the station, this station would be assigned 0-23001-1-US1NCBC0121 which would enable backward compatibility to the GHCNd holdings. The FIPS code usage is a historical legacy of NOAA-NCEI practices.

This practice would pertain only to issuer number 1 under the 23001 block and would be limited to stations with legacy use in existing global holdings managed by NOAA-NCEI.

9.6.3 **Resolving subsequent identifier conflicts**

The C3S identifier is a low-ranking identifier. NMHS are encouraged to periodically review the C3S WSI holdings registered in OSCAR/Surface and are encouraged to claim identifiers for those stations under their auspices, augmenting available metadata where possible. Where an NMHS wishes to claim stations initially registered under the C3S issuer of identifier, the C3S will use the new national identifier registration in all applications. The C3S-based identifier will point to the nationally registered identifier which will take precedence within OSCAR Surface.

9.7 **SPACE-BASED SUBSYSTEM OF WIGOS**

9.7.1 **Assignment and allocation of WIGOS station identifiers for satellites**

The purpose of the present section is to provide guidance on the recommended procedures for allocating WSIs for satellites in the space-based subsystem of WIGOS.

As satellites are not often owned and operated by WMO Members, and as they are not always part of a national observation network, WIGOS station identifiers for satellites are assigned by the WMO Space Programme, in collaboration with the entity responsible of the satellite (for example, a Member, a space agency or another owner of the satellite). The assignment of WIGOS station identifiers is then made using the schema as described in 9.7.2.

9.7.2 **WIGOS station identifier scheme for satellites**

As described in 2.4, the WMO Space Programme has been allocated the issuer of identifier value of 20009 within the WSI scheme, for satellites launched before July 2016. According to 2.4.2, the issuer of identifier value of 21009 is used for satellites launched after July 2016. The Issue Number is set to 0, and the local identifier is set according to the three-digit identifier given in Common Code Table (CCT) C-5 of the *Manual on Codes – International Codes* (WMO-No. 306), Volume 1.2), using leading zeros as needed. CCT C-5 was defined to allow a consistent approach across all the code forms.

For each satellite, CCT C-5 specifies the code figure for I6I6I6 and the corresponding code figures for BUFR and GRIB. The entries in CCT C-5 are grouped in the following way:

- Even deciles indicate polar orbiting satellites. For example, 223 is the entry for NOAA-19, launched in 2009, and consequently the issuer of identifier is 20009 (the decile is 22).

The example of the assigned WSI is: NOAA-19 0-20009-0-223;

- Odd deciles indicate geostationary satellites. For example, 174 is the entry for Himawari-9, launched in Nov 2016, and consequently the issuer of identifier is 21009 (the decile is 17).

The example of the assigned WSI is: Himawari-9 0-21009-0-174.

This approach ensures a very simple mapping between CCT-C5 and the WSI. It does not, however, address the embedding of implicit metadata, such as the use of the decile value to describe the type of orbit within the CCT-C5 value assignment. There is scope to use the Issue Number in order to make this information explicit.

9.7.3 **Recording WIGOS station identifiers in WMO OSCAR/Space**

The WMO Observing System Capability Analysis and Review tool for space-based capabilities (OSCAR/Space) is a publicly available, online resource established and maintained by the WMO Space Programme Office (WMO SP) in the context of the WMO Integrated Global Observing System (WIGOS). OSCAR/Space contains information on more than 900 satellites and 1 100 instruments.

WSIs shall be recorded in the OSCAR/Space portal, as part of the details recorded for each satellite: see, for example, https://space.oscar.wmo.int/satellites/view/metop_c. The WMO Space Programme is responsible for updating and maintaining the WSI records in OSCAR/Space.

10. THE GLOBAL BASIC OBSERVING NETWORK

10.1 INTRODUCTION

The WMO Global Basic Observing Network (GBON), designed and defined at a global level, is the basic surface-based observing network that is essential to support Global Numerical Weather Prediction (NWP). GBON is a component of the surface-based subsystem of the WMO Integrated Global Observing System (WIGOS), used in combination with the space-based subsystem and other surface-based observing systems of WIGOS, to contribute to meeting the requirements of global NWP, including reanalysis in support of climate monitoring.

Over the last several decades, NWP has emerged as the common foundation of all weather and climate services for nations big and small. Thus, Members are increasingly depending on model data products provided by global and regional modelling and prediction centres for the generation and delivery of services to their constituencies. However, these centres and products are in turn completely reliant on a constant supply of reliable observations from all parts of the globe to ensure the quality of their weather and climate products.

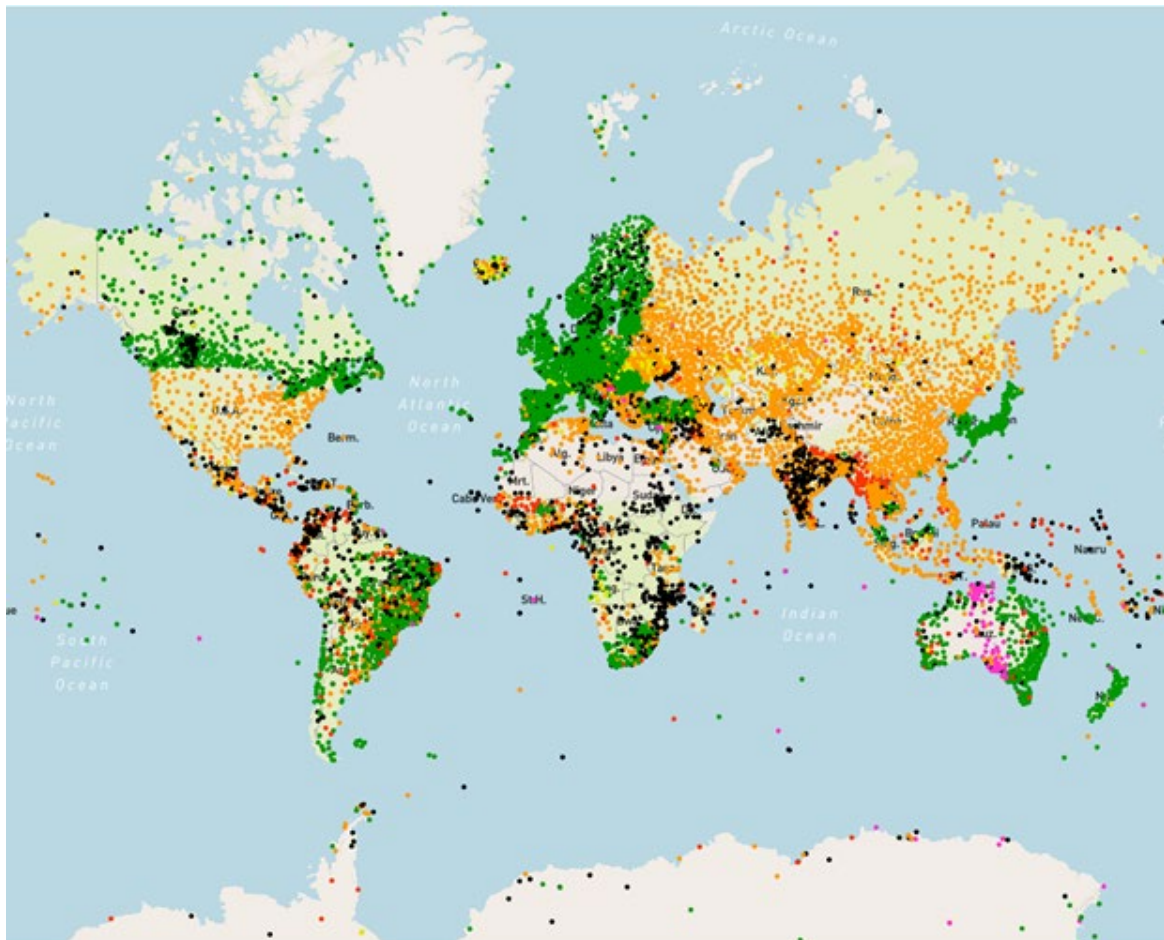


Figure 15. Surface land pressure observations received by one or more WIGOS monitoring centres on 2 January 2023, 00 UTC. (Colour coding relates to GBON baseline requirements: fully-reporting stations are shown in green, partly-reporting stations in orange or red, silent (non-reporting) stations in black, and stations that report at a frequency greater than required by GBON in pink).

Note: WIGOS monitoring centres are global NWP centres contributing to the WIGOS Data Quality Monitoring System (WDQMS), namely, the German weather service Deutscher Wetterdienst (DWD), the European Centre for Medium-Range Weather Forecasts (ECMWF), the Japan Meteorological Agency (JMA) and the United States National Centers for Environmental Prediction (NCEP).

In Figure 15 (from January 2023), large gaps exist over land and sea where essential surface-based observations are missing. For instance, surface pressure observations are not available to WIGOS monitoring centres from stations that are silent (“non-reporting”), shown by black dots. Red or orange dots show where observations are available but are not currently shared internationally at the required temporal frequency.

In response to the persistent geographical gaps in data coverage, the adoption of GBON by the WMO Members represents a new approach in which the basic surface-based observing network, necessary for feeding the NWP models with input data, is designed, defined and monitored at the global level.

Improvements in the international exchange of observational data due to GBON will flow through the weather value chain to deliver benefits that are estimated to amount to more than 5 billion US dollars annually (see the information brief [The Value of Surface-based Meteorological Observation Data: Costs and Benefits of the Global Basic Observing Network](#)).

The benefits of increasing surfaced-based observations through GBON will be felt most over areas from which observations are currently missing, including some of the regions that are most vulnerable to climate change and its impacts. However, given the global nature of weather and climate, benefits of GBON will be realized both in the countries where the improvements are made and across the globe.

In order for WMO Members to fully implement GBON and realize the benefits mentioned above, additional investment and capacity development will be needed for many developing countries. WMO is therefore working closely with the international development and climate finance communities to facilitate this, including through the establishment of the Systematic Observations Financing Facility (SOFF). More information on how SOFF is working to help close the GBON gap can be found in the [SOFF Operational Manual](#).

The provisions in the *Manual on the WIGOS*, section 3.2.2, relating to GBON are based on current observational requirements for global NWP as defined by technical experts working under the WMO Commission for Observation, Infrastructure and Information Systems (INFCOM) and the Global Climate Observing System. Drawing on more than 20 years of NWP observational data impact studies coordinated by WMO, the provisions specify – in clear, quantitative terms – the obligations of WMO Members to acquire and exchange these critically needed observations: which parameters to measure, how often, at what horizontal and vertical resolution, and which measurement techniques to use.

Satellites provide global coverage and can measure parameters for both atmosphere and surface, and satellite data make a very substantial contribution to forecast skill. However, global NWP systems still have a critical reliance on surface-based observations for certain key parameters that cannot yet be reliably measured from space: in particular, atmospheric surface pressure, the vertical distribution of winds and subsurface ocean parameters. Surface-based observations are essential over land and over snow and ice surfaces; they are essential tools for verification of model predictions, and they play critical roles for calibration and validation of space-based data.

Given the critical role of surface-based observations and the persistent gaps in the surface-based observing networks, the GBON regulations currently encompass surface-based data only. The implications of the WMO Unified Data Policy for satellite data are still being elaborated between WMO and the satellite operators.

10.2 GBON REQUIREMENTS

10.2.1 GBON standard requirements

The overall purpose of GBON is to secure adequate supply of observational data to the global NWP centres that serve all Members with model products. "Adequate supply" means (i) measurement of the most important variables, (ii) measurements made at a sufficient spatial density, and (iii) measurement reported at a sufficient temporal frequency.

The variables to be observed by Members at a set of surface land stations/platforms are, at a minimum, atmospheric pressure (SLP), air temperature (T), humidity (H), horizontal wind (W), precipitation (P) and snow depth (SD), where applicable.

The variables to be observed by Members at a set of upper-air stations/platforms over land are, at a minimum, air temperature (T), humidity (H) and horizontal wind (W).

The variables to be observed by Members at a set of surface marine meteorological observing stations/platforms within their Exclusive Economic Zone, or the corresponding marine areas of their jurisdictions, are, at a minimum, atmospheric pressure (SLP) and sea-surface temperature (SST).

Guidance on the measurement of all variables specified for GBON is provided in the *Guide to Instruments and Methods of Observation* (WMO-No. 8).

Table 15 below provides a summary of station-level GBON requirements for different types of observing stations in terms of space and time requirements according to the "shall" (bold) and "should" provisions of GBON.

Table 15. Summary of GBON requirements for different types of observing stations, with "shall" provisions in bold type

| | <i>Horizontal Resolution</i> | <i>Vertical Resolution</i> | <i>Observing cycle</i> | <i>Variables</i> | <i>Other requirements</i> |
|--|--|----------------------------|------------------------|--------------------------------------|---|
| Surface land stations | 200 km¹ 100 km ² | n/a | 1 h | SLP, T, H, W, P, SD | Exchanged in real time through WIS 2.0 |
| Upper-air stations operated from land | 500 km³ 200 km | 100 m | 2/24 h | T, H, W | Up to 30 hPa, exchanged in real time through WIS 2.0 |
| Subset of upper-air stations | 1 000 km ⁴ | 100 m | 24 h | T, H, W | Up to 10 hPa, Exchanged in real time through WIS 2.0 |
| Surface marine stations in Exclusive Economic Zones | 500 km | n/a | 1 h | SLP, SST | Exchanged in real time through WIS 2.0 |

¹ For Members for whom the surface area of the Exclusive Economic Zone (EEZ) is significantly larger than the land surface area, the horizontal resolution for surface land stations is defined at 500 km, applied to the entirety of the area of observing responsibility including land surface and EEZ. These Members retain responsibility for surface marine stations in EEZs.

² High-density requirement is mandatory for data exchange where capability exists. See details in section 10.2.2.

³ For Members for whom the surface area of the EEZ is significantly larger than the land surface area, the horizontal resolution for the upper-air stations operated in the EEZ is defined at 1 000 km, applied to the entirety of the area of observing responsibility including land surface and EEZ.

⁴ Requirement is mandatory for data exchange where capability exists.

| | <i>Horizontal Resolution</i> | <i>Vertical Resolution</i> | <i>Observing cycle</i> | <i>Variables</i> | <i>Other requirements</i> |
|--|------------------------------|----------------------------|------------------------|------------------|---|
| Upper-air stations operated in Exclusive Economic Zones | 1 000 km | 100 m | 2/24 h | T, H, W | Up to 30 hPa, exchanged in real time through WIS 2.0 |
| Aircraft data | 100 km at flight level | 300 m for profiles | 1 h | T, H, W | Data exchange per licensing agreement |
| Remote sensing profiler observations | Where available | 100 m | 1 h | T, H, W | n/a |

10.2.2 **GBON high-density network requirements**

GBON high-density requirements apply where Members operate networks of surface land observing stations/platforms at horizontal resolutions of 100 km or higher, and networks of upper-air stations/platforms providing horizontal resolutions of 200 km or higher. According to the *Manual on the WIGOS*, sections 3.2.2.8 and 3.2.2.13, Members should operate their networks at such density. At the same time, sections 3.2.2.9 and 3.2.2.16 respectively, state that Members who do operate at these higher densities shall make all GBON observations available internationally through WIS in real time or near-real time.

Accordingly, for surface land observing networks, GBON compliance monitoring will be performed against both the 200 km standard density and 100 km high-density requirement, providing two distinct targets, regardless of whether Members are operating their networks in the standard or high-density configuration.

Similarly, for upper-air networks, the GBON compliance monitoring will be performed against both the 500 km standard density and 200 km high-density requirement.

GBON compliance reports will then show which Members are operating their surface land and upper-air networks at high density and which Members are operating them at standard density configuration.

10.2.3 **Interpretation of horizontal resolution requirements for GBON land stations/platforms**

The GBON target numbers for surface land stations and upper-air stations over land were initially communicated to Members through the WMO GBON Global Gap Analysis in January 2022. Those numbers are the defining target for assessing Members' GBON compliance. They were determined by dividing the land surface area of the Member, or the sum of the land surface area and Exclusive Economic Zone (EEZ) surface area for small island developing States (SIDS), by the respective horizontal resolution (Table 15) squared. In specific cases, where the size or shape of the country/territory does not allow for the GBON target requirements calculated in this way to be properly addressed, Members may wish to adjust the calculation method and determine their own network station distribution. In such cases, the WMO Secretariat should be consulted, and an exemption under Article 9 of the WMO Convention can also be requested. Regardless of the number of stations that can be sponsored by different initiatives and that can ensure a number of stations that is higher than the required number, the GBON target number for compliance monitoring remains the same as defined for the standard density requirements. Members that operate networks with densities higher than the high-density requirements, are encouraged to assign such stations to GBON and make data from those stations available internationally through WIS.

10.3 ASSIGNMENT OF GBON STATIONS/PLATFORMS

10.3.1 Process for the assignment of GBON stations/platforms

The composition of GBON is updated according to the proposals of Members with regard to the assignment of GBON stations/platforms in OSCAR/Surface.

Members have the authority to assign stations/platforms to GBON, either on the basis of the global gap analysis or one performed by the Member.

All marine stations/platforms registered in OSCAR/Surface that report observations of the variables defined in provisions 3.2.2.10 and 3.2.2.15 of the *Manual on the WIGOS* are considered GBON stations/platforms, due to the short life span and moving nature of many of the observing platforms.

The process to be followed by all stakeholders for the monitoring of GBON stations is regulated according to Appendix 3.1 of the *Manual on the WIGOS* and is reproduced here for convenience:

1. The list of GBON stations/platforms is drawn from the list of all available stations/platforms in WIGOS as registered in OSCAR/Surface by the Members, and monitored by the WDQMS for data quality.
2. The assignment of the subset of Members' stations/platforms to GBON is based on sections 3.2.2.7–3.2.2.10 and 3.2.2.12–3.2.2.15.

Note: All marine stations/platforms registered in OSCAR/Surface that report observations of the variables defined in provisions 3.2.2.10 and 3.2.2.15 are considered GBON stations/platforms.

3. INFCOM undertakes a regular analysis of the status of the GBON implementation that provides, for each Member, the number of surface stations/platforms and the number of upper-air stations/platforms that are required for the Member to meet its obligations under 3.2.2.7–3.2.2.10 and 3.2.2.12–3.2.2.15.
4. For each Member, INFCOM reviews its assigned contribution as per 3.2.2.21 and assesses whether it meets the requirements specified in 3.2.2.7–3.2.2.10 and 3.2.2.12–3.2.2.15, and informs the Member in writing of its findings.
5. The maintenance of GBON stations/platforms and the new assignment or removal of GBON stations/platforms are made and recorded in OSCAR/Surface by Members' national focal points for OSCAR/Surface. All assigned GBON stations/platforms will then automatically appear on the dedicated GBON web tool.

Notes:

1. When removing GBON stations/platforms from their networks, Members must ensure that the integrity and quality of GBON are maintained.
2. Assignment and removal of the stations as described here do not apply to the surface marine stations/platforms.

To facilitate the GBON assignment and monitoring process, Members are urged to undertake the following actions:

- (a) Ensure that a national focal point (NFP) for OSCAR/Surface is nominated and has the authority to assign GBON stations (see the [list of designated national focal points](#)).
- (b) Regularly conduct a national gap analysis against GBON requirements (see guidelines and template in section 10.5 on the Management of GBON).
- (c) Set and update their national targets for GBON and their National GBON Contribution Plan (see guidelines in section 10.5.3).

10.3.2 **Removal of GBON affiliation from GBON land stations**

Members may wish to remove GBON affiliation from GBON land stations for the following reasons: the station is no longer operational; the station was moved to another location and assigned a different WIGOS Station Identifier; the National Meteorological and Hydrological Services (NMHSs) or partner organization operating the station no longer has capacity to operate the station according to GBON requirements; the station duplicates other GBON stations, and so forth. In such cases, the stations are not removed from OSCAR/Surface, and their affiliation to GBON is not deleted: the OSCAR/Surface NFP must only indicate the date at which GBON affiliation stops in OSCAR/Surface.

10.4 **GBON COMPLIANCE**

The definition of GBON compliance includes two parts: (a) Station-level compliance, and (b) Member-level compliance.

(a) Station-level compliance

This is achieved when a given station reports the required measurements, at the required temporal frequency, with the required reporting quality.

Note: For marine stations/platforms, compliance is considered for the Member operator of an instrument making a GBON measurement, which may differ from the station/platform owner.

(b) Member-level compliance

This is achieved when a given Member is operating a sufficient number of compliant GBON stations to satisfy the horizontal density requirements.

All GBON stations must be registered in OSCAR/Surface and include the network affiliation to GBON.

10.4.1 **General considerations**

10.4.1.1 **Network density/coverage**

Stations are assigned to a network which by design delivers the required density/horizontal coverage. Assessing density/horizontal coverage compliance through regular monitoring of stations reporting would be very complex. Therefore the current approach is to assign a number of stations to each State/Territory, which might include some redundancy, and then to proceed to an assessment of whether the number of compliant stations is equal to or greater than the number required.

10.4.1.2 **Availability**

Currently, the primary performance measure for assessing WMO observational compliance is based on data availability with the following generally accepted practices:

- Most WMO networks are monitored by stations reporting to an international data centre (that is, monitoring of reports received rather than observations made);
- Daily/weekly/monthly compliance monitoring tends to relate to the total number of reports for the period, rather than specifically to the temporal requirements;
- Most monitoring only assesses whether a report has been received or not, rather than assessing the content of the report;

- The WQMS web tool uses statistics generated by the WIGOS monitoring centres (global NWP centres) and thus is able to assess against the different variables within the reports;
- Not all stations will necessarily report all the GBON mandatory variables.

The GBON upper-air requirements include also criteria on vertical range (burst height and resolution) which are not always able to be assessed in availability statistics.

10.4.1.3 **Timeliness**

All reports must be sent in near-real time over WIS. For example, if data are not received by the NWP centres by a certain time, they cannot be used. At a national level, and for some regional activities (such as EUMETNET), the timeliness has been agreed primarily to align with the NWP assimilation runs and the cut-off to use the measurements.

In future, WIS 2.0 will attribute a “time of receipt” to received reports, which will allow the timeliness to be calculated by comparing the time of receipt with the time of the observations. Once implemented, this will be considered in a future upgrade of the WQMS web tool.

Regardless of how delayed a report is, there are some applications (namely, reanalysis and climate monitoring) which can still make use of the data. However, some of the data routing processes have a fixed time cut-off (such as > 24 hours) beyond which the report is automatically rejected.

10.4.1.4 **Quality**

If reported data are not of sufficient quality then the NWP systems will reject the data. In addition, if sufficient metadata are not recorded in the OSCAR/Surface database then this will directly impact on the quality monitoring of GBON.

Most reports of surface (land and marine) and upper-air (land and marine) stations contain no information about the quality of the measurements. Often, the operational processes and instrumentation used have an implied quality, which has been assessed through intercomparisons and test campaigns.

Most operational quality monitoring of NWP systems is undertaken as a quality evaluation process by comparing the measurements against a background field (that is, NWP model) and computing statistics of Observation – First Guess (OB-FG) field or Observation – Analysis (OB-AN) field.

The NWP assimilation also has a rejection process so as to prevent gross errors from negatively impacting the quality of the model products. Although the rejection criteria are often much more relaxed than the “threshold” limits in the WMO RRR, they can be useful in identifying stations/platforms with gross errors.

10.4.1.5 **Format**

According to the *Manual on the WIGOS*, section 2.4.4.1, Members shall report and make available observations in real time through the WIS in the standard formats specified in the *Manual on Codes* (WMO-No. 306), Volumes 1.2 and 1.3., such as the Binary Universal Form for the Representation of meteorological data (BUFR). For example, minimum 100 m vertical resolution of the upper-air measurements requires that the measurements are taken every 20 s, which can only be achieved through the complete BUFR code.

10.4.2 Station-level compliance monitoring

10.4.2.1 Station-level compliance criteria

The compliance criteria to be met for each GBON surface land and marine station/platform are presented in Table 16, while those for GBON upper-air land and marine stations are shown in Table 17. The criteria are applicable for each measured variable defined in section 10.2.1.

Table 16. Compliance criteria for GBON surface land and marine meteorological observing station/platform

| Mark | Name | Description | Criteria |
|--------------------------------|--------------------------|---|----------|
| S _{SL} 1 ^a | Monthly availability (%) | No. of received monthly reports ^b / (Days per month x 24 ^c) | ≥ 80% |
| S _{SL} 2 | Timeliness (%) | No. of late reports ^d / (Days per month x 24) | < 5% |
| S _{SL} 3 | Monthly quality (%) | No. of rejected monthly reports ^e / (Days per month x 24) | < 5% |

Notes:

- S = number of stations, SL = surface land
- Monthly aggregation of observed variables from surface observation reports, received by at least one of the NWP centres monitored by WDQMS web tool
- If a station is manually operated but is not operational 24 hours per day, this number can be reduced to the operational hours (hourly reporting, that is 0800–1700 = 10 reports) as recorded in OSCAR/Surface. This needs to be registered as an exception to GBON regulations.
- Monthly aggregation of reports that missed the time cut-off from NWP centres/WIS
- Monthly aggregation of rejected reports from NWP centres. Could also be gross errors or outside of OB-FG threshold.

Table 17. Compliance criteria for GBON upper-air land and marine observing station/platform

| Mark | Name | Description | Criteria |
|--------------------------------|----------------------------------|--|----------|
| S _{UA} 1 ^a | Monthly availability (%) | No. of received monthly profile (to 30hPa) reports ^b / (Days per month x 24 ^c) | ≥ 80% |
| S _{UA} 2 | Vertical resolution ^d | Vertical resolution is at least 100 m | Yes |
| S _{UA} 3 | Timeliness (%) | No. of late reports ^e / (Days per month x 24) | < 5% |
| S _{UA} 4 | Monthly quality (%) | No. of rejected monthly reports ^f / (Days per month x 24) | < 5% |

Notes:

- S = number of stations, UA = upper-air
- Monthly aggregation of observed variables from upper-air observation reports, received by at least two of the NWP centres monitored by WDQMS web tool
- If a radiosonde station is only able to undertake one sounding per day, this number can be reduced to the scheduled reporting as recorded in OSCAR/Surface. This needs to be registered as an exception to GBON regulations.
- For high-resolution data (BUFR) received, confirmed by at least one of the NWP centres monitored by WDQMS web tool
- Monthly aggregation of reports that missed the time cut-off from NWP centres/WIS
- Monthly aggregation of rejected reports from NWP centres. Could also be gross errors or outside of OB-FG threshold.

10.4.2.2 GBON station compliance assessment

At present, station compliance is assessed using the criteria outlined in Tables 16 and 17, applicable only to surface and upper-air land stations.

To enable compliance assessment, a GBON station must be registered in OSCAR/Surface and include the network affiliation to GBON. If the station does not meet this requirement, it will be assessed as non-compliant.

A surface land observing station/platform is found to be GBON compliant if all three criteria (SSL 1 – SSL 3) from Table 16 are met, for at least the measurement of atmospheric pressure.

A marine meteorological observing station/platform is found to be GBON compliant if all three criteria (SSL 1 – SSL 3) from Table 16 are met, for at least the measurement of sea level pressure.

An upper-air land observing station/platform is found to be GBON compliant if all four criteria (SUA 1 – SUA 4) from Table 17 are met, for at least the measurement of air temperature.

10.4.3 **Member-level compliance monitoring**

10.4.3.1 **Member-level compliance criteria**

The compliance criteria to be met on the Member level compare, on the one hand, the number of the Member's stations that meet station compliance criteria described in section 10.4.2.1 with the number of stations estimated by the GBON global gap analysis (GGGA), on the other hand. The criteria are as follow:

M1: For surface land GBON-compliant stations

The number of the Member's surface-land GBON-compliant stations (S) is greater than, or equal to, the required number of surface-land GBON stations (RS) from GGGA:

$$S \geq RS$$

M2: For upper-air land GBON-compliant stations

The number of the Member's upper-air land GBON-compliant stations (U) is greater than, or equal to, the required number of upper-air land GBON stations from (RU) from GGGA:

$$U \geq RU$$

M3: For surface marine meteorological GBON-compliant stations (M), in Exclusive Economic Zones

The number of the Member's surface marine GBON-compliant stations (M)* in Exclusive Economic Zones is greater than, or equal to, the required number of surface marine GBON stations (RM) from GGGA:

$$M \geq RM$$

* This number includes all contributions from all Members having stations/platforms within the EEZ of the Member in question.

10.4.3.2 **GBON Member compliance assessment**

GBON Member compliance is assessed against the criteria M1, M2 and M3 if a Member has a coastline, as outlined in section 10.4.3.1 on a monthly basis.

A Member without a coastline is found to be GBON compliant only if the criteria for both M1 and M2 are met.

A Member with a coastline is found to be GBON compliant only if all three criteria are met.

Note: Under certain circumstances, for example when a Member's territory is relatively small or of an irregular shape, some GBON-compliant stations from the neighbouring Member(s) can be included in the Member's compliance assessment. In such circumstances, the Member concerned must provide written proof that the neighbouring Member(s) agrees to include its stations in the GBON assessment of the Member concerned, and must report this to the Secretariat, as described in section 10.4.5.

10.4.4 **Compliance status and reporting**

GBON compliance at the station and Member levels will be routinely assessed and the results made available using tools such as the WDQMS web tool. Station-level compliance results, aggregated on a monthly basis, will be automatically produced and made available online from the WDQMS web tool. Member-level assessments will be undertaken and provided on a quarterly basis by the INFCOM Standing Committee on Earth Observing Systems and Monitoring Networks (SC-ON) assisted by the Secretariat, on the basis of data provided by the WDQMS web tool. It is recommended that Members review these quarterly assessments and take action if needed. The Regional WIGOS Centres (RWCs), and the OceanOPS as appropriate, will also assist in this regard by alerting Members to non-compliance issues and discovered incidents. An annual compilation of national GBON assessment reports based on the Members' quarterly assessments, taking into account Members' feedback if available, will be produced by SC-ON, with the assistance of the Secretariat, and published.

Members are invited to be aware of their compliance status and to undertake their own compliance monitoring, with the goal of evolving their observing networks towards full GBON compliance, if this is not already the case.

10.4.5 **Exemption under Article 9 of the WMO Convention**

Compliance status of Members invoking Article 9 of the WMO Convention

Article 9 (b) of the WMO Convention published in the *Basic Documents No. 1* (WMO-No. 15) states that "If ... any Member finds it impracticable to give effect to some requirement in a technical resolution adopted by Congress, such Member shall inform the Secretary-General of the Organization whether its inability to give effect to it is provisional or final, and state its reasons therefor".

The *Technical Regulations* (WMO-No. 49), Volume I, General Provisions, paragraph 6 states:

In accordance with the above definitions, Members shall do their utmost to implement the standard practices and procedures. In accordance with Article 9 (b) of the Convention and in conformity with Regulation 101 of the General Regulations, Members shall formally notify the Secretary-General, in writing, of their intention to apply the standard practices and procedures of the Technical Regulations, except those for which they have lodged a specific deviation. Members shall also inform the Secretary-General, at least three months in advance, of any change in the degree of their implementation of a standard practice or procedure as previously notified and the effective date of the change.

Accordingly, the following conditions, criteria and implications on compliance status of a Member invoking Article 9 (b) concerning their contribution to GBON are as follows:

- Concerning the horizontal resolution requirement, a Member invoking Article 9 (b) concerning its commitment to GBON should clearly indicate: the reasons; the part of its territory for which it is seeking an exemption from meeting GBON requirements; its level of commitment to meeting the GBON horizontal resolution requirement for the rest of its territory; the period during which it believes such part of its territory would be exempted; and whether it has any plan to improve the situation;

- Concerning the temporal resolution requirements, a Member invoking Article 9 (b) concerning its commitment to GBON should clearly indicate: the subset of its GBON observing stations or the part of the Member’s territory that will not be meeting the temporal resolution requirements; the reasons why the requirements cannot be met; the period during which it believes such subset of stations or such part of the Member’s territory would be exempted; and whether it has any plan to improve the situation.

An independent committee of experts designated by the INFCOM president in consultation with the INFCOM management group will coordinate with the Member to review the basis of the Article 9 (b) exemption. The committee will consider if there are any potential ways to resolve the issue, such as existing contributing stations nearby but just outside the Member's border. The committee will factor that review into determining if a Member submitting an exemption under Article 9 (b) should be regarded as GBON compliant on the basis of the following criteria:

- (a) A substantial part of the Member’s territory is compliant with GBON horizontal requirements (for small Members, if the horizontal requirements for GBON are being met thanks to the GBON commitment of a neighbouring Member(s), the Member may still be regarded as GBON compliant if it is committing at least one observing station to GBON);
- (b) A substantial number of the GBON stations committed by the Member comply with GBON temporal resolution requirements.

If the independent committee of experts considers that the Member is GBON compliant, such status will be reflected in the overall compliance status of all Members. On the contrary, the Member will be informed about its non-compliance status by the Secretary-General, and will be urged to take steps to become compliant. The INFCOM president will inform the Executive Council about the independent committee’s decision.

10.5 MANAGEMENT OF GBON

10.5.1 Roles and responsibilities

Table 18 clarifies the roles and responsibilities of the main stakeholders involved in the process for establishing the initial composition of GBON. Responsibilities of national focal points are detailed in the present Guide, Chapter 5, Annex 5.1.

Table 18. Roles and responsibilities of the main stakeholders in establishing the initial composition (January 2023) of GBON

| <i>Stakeholder</i> | <i>Role</i> |
|--------------------|--|
| Members | <ul style="list-style-type: none"> • Nominate WIGOS, OSCAR/Surface and WDQMS national focal points (NFPs) and brief them on their role in support of GBON implementation; make sure NFPs will receive appropriate support from their management to undertake their role. • Consider GBON requirements; identify opportunities for committing GBON stations and filling identified gaps; implement GBON requirements; take action as needed for complying with them. • Review GBON compliance assessment reports and take action as needed. • Assign additional GBON stations, including, for example, existing stations not currently reporting internationally or stations from partner organizations for which a Memorandum of Understanding (MoU) to commit the stations to GBON could be negotiated and established at the national level. • Least developed and small island developing States (SIDS) to apply for SOFF funding. • Other developing countries to make use of capacity-development opportunities, including SOFF technical support where applicable. |

| <i>Stakeholder</i> | <i>Role</i> |
|---|--|
| WIGOS monitoring centres (global NWP centres contributing to WDQMS) | <ul style="list-style-type: none"> Assimilate GBON data and provide the information needed for the WDQMS web tool on the GBON compliance monitoring. |
| WIGOS national focal points | <ul style="list-style-type: none"> Contribute to the design of GBON and identify the existing or new GBON stations to be committed by their country/territory, and promote or coordinate the necessary actions nationally to reach such commitment. Perform a National GBON Gap Analysis and inform the WMO Secretariat of their country's/territory's capabilities and any possible non-achievable requirements. Negotiate with partner organizations and encourage non-NMHS observing stations to be made available when they meet GBON requirements. |
| OSCAR/Surface national focal points | <ul style="list-style-type: none"> Make sure that candidate GBON stations' WIGOS metadata are recorded and kept updated in OSCAR/Surface. |
| WDQMS national focal points | <ul style="list-style-type: none"> Check and monitor compliance of GBON stations nationally, using the WDQMS web tool, and address any incident that may have been reported by the Regional WIGOS Centre. |
| Regional WIGOS Centres (RWCs) | <ul style="list-style-type: none"> Monitor compliance of GBON observing stations with GBON requirements, and alert Members via their WDQMS NFPs about identified incidents. |
| Regional associations' working groups on infrastructure | <ul style="list-style-type: none"> Promote regional cooperation and exchange of data across political boundaries; share benefits, share space, propose prioritization mechanism(s) for such cooperation, e.g. in support of disaster risk reduction; facilitate exchange of GBON data using existing global and regional infrastructure (e.g. WIS centres, WIS 2.0 in a box). |
| WMO Secretariat | <ul style="list-style-type: none"> Provide technical support to INFCOM teams for the design of GBON composition and GBON compliance monitoring, including: <ul style="list-style-type: none"> Liaise with WIGOS NFPs to obtain information on Members' capabilities and the candidate observing stations they wish to commit to GBON. Perform global gap analysis and make proposals on the assignment of GBON stations. Propose updates to guidance material on GBON as needed. Consider how to make the best use of WIGOS tools (WDQMS, OSCAR/Surface), and assist INFCOM teams in determining how these tools should evolve or be used for GBON. Assist SC-ON with station- and Member-level assessments and the production of corresponding reports. Assist INFCOM teams to produce Member-level assessment reports (quarterly and annually), as well as other relevant related tasks. |
| SOFF Secretariat | <ul style="list-style-type: none"> Coordinate the implementation of SOFF according to the SOFF Secretariat Terms of Reference. Provide support to Members concerning the understanding of SOFF operational elements in support of GBON implementation to fill the gaps. Collaborate with the WMO Secretariat and INFCOM teams to develop and provide specific guidance and training for SOFF peer advisors. Collaborate with the WMO Secretariat and INFCOM teams in identifying GBON Member opportunities for SOFF programming decision-making. Collaborate with the WMO Secretariat and INFCOM teams in establishing the functions of WMO as SOFF Technical Authority. Collaborate with the WMO Secretariat and INFCOM teams in developing specific WDQMS reports, and OSCAR/Surface features for SOFF. |
| INFCOM president | <ul style="list-style-type: none"> Designate an independent committee of experts, in consultation with the INFCOM management group, to review Members' submissions for exemptions under Article 9 (b), and determine any impact on GBON requirements compliance. Inform the Executive Council about the independent committee's findings. |
| INFCOM teams/SC-ON | <ul style="list-style-type: none"> Produce Member-level assessment reports (quarterly and annually) with assistance from the WMO Secretariat. Develop technical guidelines, processes and procedures needed to ensure expedient and efficient implementation of GBON, and to prepare for effective performance and compliance monitoring of GBON. |

10.5.2 National GBON Gap Analysis

To implement GBON at a national level, Members are encouraged to complete the National GBON Gap Analysis in order to understand the existing gap in the required observing networks and to identify their national contributions to the composition of GBON for filling the identified gaps.

The gap analysis is the starting phase for implementing the GBON regulations. The objective of the analysis is to define the gap between the GBON requirements and the existing surface, upper-air and marine observing networks. In other words, it serves as the basis for identifying the number of observing stations that need to be installed or improved in order to become compliant with the requirements of the GBON regulations.

The guidance outlined in 10.5.2.1 provides a step-by-step process for defining the National GBON Gap Analysis for GBON requirements. The results serve to help Members to assess whether their current network is meeting the requirements, to plan actions to upgrade the observing networks as necessary and to assign the first stations to the GBON network.

The completed National GBON Gap Analysis serves as the objective and quantitative basis for the preparation of the National GBON Contribution Plan (detailed in 10.5.3), which considers the best approaches and activities for complying with the GBON regulations. Section 10.2 provides a summary of the GBON regulations.

10.5.2.1 Gap analysis steps

The global gap analysis provides a quantitative estimate of the number of surface and upper-air observing stations over land per Member that are needed in order to meet the GBON requirements. The WMO Secretariat completes the global analysis of which stations are internationally sharing the data, based on the information available through the WDQMS web tool. This global gap analysis serves as a baseline for the national assessment of existing observation networks against the target number of stations.

A Template for the National GBON Gap Analysis report is available on the [References to GBON material](#) web page.

Step 1 – Analysis of the GBON horizontal resolution requirements

In this step, the Member-specific GBON horizontal resolution requirements are analysed based on the global GBON gap analysis performed by the WMO Secretariat and the final adjustment by the Member. While the global gap analysis is a simplified analysis, the number of target GBON stations should be reviewed and adjustments made as needed by every Member. The global gap analysis does not include a full investigation of the Exclusive Economic Zone (EEZ), and therefore, no target number for marine observing stations is given. For Members with an EEZ, the initial GBON target needs to be assessed in terms of the surface marine observing network. Those Members whose territories are split across separate locations should assess the GBON requirements for such territories individually.

Elements in step 1 (Table 19):

- (a) GBON horizontal resolution requirements: The GBON regulations, as published in the *Manual on the WIGOS*;
- (b) GBON target: The number of surface and upper-air stations required, based on the GBON global gap analysis completed by the WMO Secretariat and adjusted by the Member as necessary;
- (c) Reporting: the number of surface, upper-air and marine stations reporting internationally to WIS;

- (d) Gap improve: The number of surface, upper-air and marine stations that could a priori be improved to meet GBON requirements, for example, by increasing the number of shared observations (the default position being the global gap analysis);
- (e) Gap new: The number of new surface, upper-air and marine stations that need to be established and installed (the default position being the global gap analysis);
- (f) Gap total: The total number of stations that need to be either improved or newly installed (the default position being the global gap analysis).

Table 19. GBON network requirements for horizontal resolution

| <i>GBON horizontal resolution requirements</i> | <i>GBON target</i> | <i>Reporting</i> | <i>GAP improve</i> | <i>GAP new</i> | <i>GAP total</i> |
|--|--------------------|------------------|--------------------|----------------|------------------|
| Surface stations standard density, 200 km | | | | | |
| Surface stations, high density, 100 km | | | | | |
| Upper-air stations over land, standard density, 500 km | | | | | |
| Upper-air stations over land, high density, 200 km | | | | | |
| Upper-air stations over marine, 1 000 km | | | | | |
| Surface marine stations, 500 km | | | | | |

Caveats to the global gap analysis results:

- (a) The reporting threshold for GBON upper-air stations over land was one daily sounding, noting that the GBON requirement is two soundings per day;
- (b) For SIDS, the EEZ area has been added to the total surface area, which is the basis for the target number of stations;
- (c) The surface area was computed based on a geographic information system model and may slightly deviate from official records.

Step 2 – Analysis of existing GBON stations and their status against GBON requirements

In step 2 (Table 20), the Member assesses the existing national observing networks and stations. This includes stations operated by the NMHS and other governmental agencies or the private sector which could potentially be included in the national GBON network. Stations' operational status is assessed, along with the variables reported and maps provided to indicate the station distribution.

First, the assessment is done for observing networks operated by NMHS and the by third party operators at a network level. The networks are evaluated based on the mandatory GBON requirements as described in the left column of Table 15 in section 10.2.1.

The elements to be analysed in step 2 are:

| Station name | Station type (S/UA/M) | Owner (NMHS/ third party) | GBON variable measured | | | | | | Reporting cycle | GBON compliant (Y/N) |
|--------------|-----------------------|---------------------------|------------------------|---|---|---|---|----|-----------------|----------------------|
| | | | SLP | T | H | W | P | SD | | |
| | | | | | | | | | | |
| | | | | | | | | | | |
| | | | | | | | | | | |
| | | | | | | | | | | |

Key:

S: Surface; UA: Upper-air; M: Marine; Owner: Owner of the station (name of NMHS or third party); SLP: Atmospheric pressure; T: Temperature; H: Humidity; W: Wind; P: Precipitation; SD: Snow depth; Reporting cycle: Number of observation reports exchanged internationally per day (0–24); GBON compliant: whether the station is compliant (Yes/No)

Step 3 – GBON gap analysis results

The results of steps 1 and 2 are summarized to Table 22. The table is to be completed with: the number of stations required by the GBON regulations (GBON target); the number of existing stations compliant with the GBON requirements; and the new and to improve GBON stations needed (new and to improve) for surface, upper-air and marine networks.

A map of existing stations is developed with the location of gaps indicated in circles of a 200 km radius (surface) and 500 km radius (upper-air and marine) around the existing stations.

Table 22. Results of the National GBON Gap Analysis

| GBON requirements | GBON target | Stations compliant with GBON | Stations needed against GBON requirements | |
|--|-------------|------------------------------|---|------------|
| | | | New | To improve |
| Surface station standard density, 200 km | | | | |
| Surface station high density, 100 km | | | | |
| Upper-air stations over land, standard density, 500 km | | | | |
| Upper-air stations over land, high density, 200 km | | | | |
| Upper-air stations over marine, 1 000 km | | | | |
| Surface marine stations, 500 km | | | | |

Note: Members should include in the analysis, along with the above information, maps of existing surface, upper-air and marine networks with gaps indicated.

A list of surface, upper-air and marine stations which are compliant with the GBON regulations and assigned to GBON is summarized in Table 23.

Table 23. Surface, upper-air and marine stations to be assigned to GBON

| Station name | Station type (S/UA/M) |
|--------------|-----------------------|
| | |
| | |
| | |
| | |

The Template for the National GBON Gap Analysis report is available on the [References to GBON material](#) web page.

10.5.2.2 **Further considerations for GBON implementation and operations**

The gap analysis does not investigate the reasons behind the gap. Based on the results from the National GBON Gap Analysis, the detailed National GBON Contribution Plan will be developed where the national GBON target will be defined and which will address corresponding actions to fully comply with the GBON regulations.

Each Member must assign, at a minimum, the required number of surface, upper-air and marine stations as their contribution to GBON. Those stations which already comply with the GBON regulations should be considered as an initial subset of stations, and assigned to GBON by registering the stations in OSCAR/Surface and addressing the metadata requirements.

If the national observing network does not meet a certain GBON requirement, and for some reason, actions to comply with the requirement are not going to be taken, the reason must be reported to the WMO Secretary-General by seeking an exemption in accordance with Article 9 of the WMO Convention (see section 10.4.5). As an example, an exemption might be sought if a GBON requirement is not applicable in the territory of the Member because the requirement is not technologically possible or economically viable.

The GBON regulations are a comprehensive set of provisions which not only drive a certain density for the observation network, but also require a long-term commitment to GBON operations, with expectations for high-quality and timely observational data to be made available for all WMO Members. Therefore, operational observation network management practices should be reviewed, and capacity-development activities considered as part of the National GBON Contribution Plan for guaranteeing the sustainable operations of GBON.

A Member can adjust and extend the templates provided in the present Guide based on the national operational practices, as needed. The WMO Secretariat and INFCOM are available for responding to questions, providing support and sharing best practices in every phase of GBON implementation.

10.5.2.3 **Environmental sustainability considerations**

INFCOM has requested, through Resolution 4 (INFCOM-1) (*INFCOM: Abridged Final Report of the First Session* (WMO-No. 1251)), that the future development and implementation of GBON addresses the environmental impact of observing systems and methods.

Members are encouraged to consider environmental sustainability as foundational in the design and evolution of networks to achieve GBON horizontal and temporal resolution requirements. Pragmatic and sustainable approaches to achieving GBON observation requirements are to be considered along the full weather and climate data value chain, including:

- The development and use of specifications that consider environmental sustainability for procurement of measurement instrument equipment to meet the GBON requirements;
- Integration of sustainability considerations into regulatory compliance for the management of operations of GBON-compliant weather and climate stations, including with regards to installation, calibration, and maintenance;
- Careful material selection for the development, shipping and day-to-day operations of GBON-compliant stations, with a focus on the development and use of reusable instruments and sustainable methods of observation (for example, elimination of single-use plastics).

Recommendations related to environmental sustainability will be considered for future amendments to WIGOS regulatory material and GBON guidance, with the long-term goal of advancing more environmentally friendly weather and climate observing systems, technologies and practices. These recommendations will evolve and become more detailed over time as new information is gathered, analysed and translated into requirements.

10.5.3 **National GBON Contribution Plan**

The National GBON Contribution Plan (the Plan) constitutes the basis for Member plans and efforts to become GBON compliant. The National GBON Gap Analysis, completed prior to the development of this Plan, serves as an analytical basis to develop the Plan. Based on the results from the analysis, the Member sets a GBON target, as well as the activities required to achieve that target, in the Plan.

The objective of the National GBON Contribution Plan is to identify the observing infrastructure, human and institutional capacity needed to achieve a progressive target towards GBON compliance and a sustainable level of operations and maintenance of the national observing network.

The guidance is structured into five modules that constitute the building blocks of the Plan. These five modules are undertaken in parallel so that the final plan is consistent with each output of the modules.

10.5.3.1 **Development of the National GBON Contribution Plan**

The guidance outlined in the present chapter is structured across five modules that cover different areas required for the implementation of GBON. It provides, for each module, a list of activities and expected outputs which should be addressed in terms of the current facilities and capabilities in the national observing infrastructure.

The modules of the Plan are:

- **Module 1. National GBON target:** National target towards GBON compliance that considers the Member's circumstances.
- **Module 2. Institutional capacity development:** Institutional capabilities required to operate, maintain and manage the GBON observing network.
- **Module 3. Infrastructure development:** Observing network infrastructure required to achieve the national target and compliance with the GBON regulations.
- **Module 4. Human capacity development:** Human capacity needed to manage, operate and maintain the GBON observing network.
- **Module 5. Risk management:** Observing network operational risks and required mitigation measures.

Each module lists recommended activities and their expected deliverables. The key activities and best practices should align with the national strategy for observing networks, as relevant for the Member. Existing operational systems, processes and practices be utilized where appropriate. The preliminary timeline and financial implications should be considered as a part of the Plan for each module.

The modules provide a standard approach which can be adjusted based on the national needs and expectations.

The activities are planned to meet the national target toward GBON compliance in each module. The Plan should be reviewed regularly with an aim to advance the activities defined for achieving full GBON compliance in a sustainable manner.

Module 1: National GBON target

Based on the results from the National GBON Gap Analysis, the Member sets a national GBON target towards progressive GBON compliance. The target should be progressive so that the elements of the target are increased periodically, aiming for the Member to achieve full GBON compliance in a reasonable period of time. The target reflects the level of ambition of the Members, taking into account the gradual process, national circumstances and the feasibility of implementing the activities to achieve such a target. Activities and outputs for Module 1 are summarized in Table 24.

Table 24. Activities and outputs to be undertaken and delivered for Module 1

| <i>Item</i> | <i>Activity</i> | <i>Outputs</i> | <i>Relevant guidance material</i> |
|-------------|---|---|-----------------------------------|
| 1.1 | Conduct the National GBON Gap Analysis | Results of the gap analysis as the baseline | See 10.5.2 above |
| 1.2 | Establish the national target towards GBON compliance | Based on the gap analysis, set a target in terms of number of new/improved stations and percentage of reports exchanged | |

Module 2: Institutional capacity development

In this module, the Member's institutional capabilities, including NMHS partnerships with other national governmental and private partners and with subregional and regional GBON stakeholders, and the Member's financial capabilities, are assessed in terms of their capacity for strengthening the resources and activities required to operate and maintain the observing network.

This module also includes an assessment of the Member's existing strategies for developing and improving observing networks and an assessment of the national legislation in terms of GBON regulations. Activities and outputs for Module 2 are summarized in Table 25.

Table 25. Activities and outputs to be undertaken and delivered for Module 2

| <i>Item</i> | <i>Activity</i> | <i>Outputs</i> | <i>Relevant guidance material</i> |
|-------------|--|---|--|
| 2.1 | Assess governmental partner organizations for supporting GBON operations | 1. Assessment of governmental partners and stakeholders and their potential contribution to GBON network operations: (a) Existing partners and relationships (b) Potential new partners and collaborators and their role | <i>Guide to the WMO Integrated Global Observing System</i> (WMO-No. 1165), Chapter 5 |
| 2.2 | Assess private sector entities providing meteorological observations in the Member's territory and potential partnerships for supporting GBON operations | 1. Assessment of private sector operators providing meteorological observations and data services in the Member's territory 2. Business model for public-private collaboration for the implementation of the Plan, including identified potential private sector operators for the collaboration | <i>Guidelines for Public-Private Engagement</i> (WMO-No. 1258) |

| <i>Item</i> | <i>Activity</i> | <i>Outputs</i> | <i>Relevant guidance material</i> |
|-------------|--|---|-----------------------------------|
| 2.3 | Assess potential subregional contributors for supporting GBON operations | <ol style="list-style-type: none"> 1. Identified neighbouring countries and regional organizations of relevance for potential subregional collaboration 2. Plan for potential optimization of the observing network through subregional network design and other optimization arrangements for the implementation of the Plan | |
| 2.4 | Assess the Member's financial model | <ol style="list-style-type: none"> 1. Assessment of current funding sources, budget allocations and financial status related to operations of the national observing infrastructure 2. Sustainable financial management plan to operate the GBON infrastructure in line with the proposed public-private business model, in the form of a: <ol style="list-style-type: none"> (a) Financial plan for operating the modernized infrastructure (b) Business plan over 5 to 10 years supporting an increase in financing for operations of GBON network | |
| 2.5 | Assess existing national strategies and projects for developing and improving observing networks | <ol style="list-style-type: none"> 1. Review of the national strategies for developing and improving observing networks 2. Plan for harmonizing the activities defined in the general strategy of Member observation services along with this Plan 3. Review of existing or planned hydrometeorological development projects related to GBON and consideration of any action for avoiding duplications | |
| 2.6 | Review the national legislation in terms of GBON regulations | <ol style="list-style-type: none"> 1. Review of the legislation in terms of the national responsibility for measuring and providing weather observations related to GBON 2. Review of the legislation related to procurement, importation and customs processes to enable smooth implementation of the Plan 3. Recommendation on how to address any constraints imposed by the national legislation needed to implement GBON | |

Module 3: Infrastructure development

Based on the gaps identified in the National GBON Gap Analysis, the Member develops a detailed plan for all components of the observing infrastructure and investments needed to meet the national target toward GBON compliance. The plan should follow the national strategy for the development and management of observing networks so that the components of the modernized infrastructure and operation practices are harmonized with the existing network.

The *Manual on the WIGOS*, the *Manual on Codes* (WMO-No. 306), Volumes I.1, I.2 and I.3, the *Manual on the WMO Information System* (WMO-No. 1060) and the *Manual on the Global*

Telecommunication System (WMO-No. 386) are the key WMO Technical Regulations to be followed for the establishment of a network, and for reporting and making observations and metadata internationally available through the WIS and WMO OSCAR/Surface metadata management system.

Activities and outputs for the Module 3 are summarized in Table 26.

Table 26. Activities and outputs to be undertaken and delivered for Module 3

| <i>Item</i> | <i>Activity</i> | <i>Outputs</i> | <i>Relevant guidance material</i> |
|-------------|---|--|---|
| 3.1 | Design the surface, upper-air and marine observing networks and observational practices, including networks operated by third parties | <ol style="list-style-type: none"> 1. Based on the National GBON Gap Analysis and the National GBON Target, a completed, harmonized observing network design, including: <ol style="list-style-type: none"> (a) A map of observing network design and a list of new/rehabilitated GBON stations (b) Siting and instrumentation of new and improved stations, and a list of observation instruments and systems per site (c) Plan for the investments and activities needed for the installation of any new stations and the improvement of existing stations (d) Articulation of environmental sustainability considerations in network design and implementation (new stations, instruments, etc.) 2. Observational practices defined per network 3. Preliminary maintenance plan for existing and improved/new stations, including calibration practices 4. Technical specifications for new instruments and observing systems for the procurement process, including sustainability considerations | <p><i>Manual on the WIGOS</i></p> <p><i>Guide to the WMO Integrated Global Observing System</i> (WMO-No. 1165)</p> <p><i>Guide to Instruments and Methods of Observation</i> (WMO-No. 8)</p> <p><i>Generic Automatic Weather Station (AWS) Tender Specifications</i> (WMO Instruments and Observing Methods Report No. 136)</p> |

| Item | Activity | Outputs | Relevant guidance material |
|------|--|---|---|
| 3.2 | Design the ICT infrastructure and services | 1. ICT infrastructure and services design for solutions on data transmission from an observing station to the national real-time data management system and to GTS and WIS 2.0 including: <ul style="list-style-type: none"> (a) Detailed description of the ICT infrastructure and services design (b) Technical specifications for the data collection system from observing station to collection point (c) Technical specifications of the data services (compatible with the requirements of WIS 2.0) (d) Detailed description of the measures to ensure resilience and continuity of the full data-processing chain | <i>Manual on Codes</i> (WMO-No. 306), Volumes I.1, I.2 and I.3 <i>Manual on the WIGOS</i> <i>Manual on the Global Telecommunication System</i> (WMO-No. 386) WIS 2.0 requirements http://docs.wis2box.wis.wmo.int |
| 3.3 | Design the data management system | 1. Requirements for a data management system that aims to provide access to data used by operational applications on a real-time basis, and that has the capability to deliver data to a Climate Data Management System (CDMS) for long-term archiving purposes. The system should provide: <ul style="list-style-type: none"> (a) Short-term data storage and access through the services and protocols required by applications for national and international operational activities (b) Exchange of data to and from WIS/GTS, WIS 2.0 and other national or international sources required for operational activities (c) Data delivery to the national CDMS (d) Discovery and descriptive metadata management (e) Monitoring of data, processing and services | <i>Manual on the WIGOS</i> <i>Manual on Codes</i> (WMO-No. 306), Volumes I.1, I.2 and I.3 <i>Manual on the WMO Information System</i> (WMO-No. 1060), <i>Manual on the Global Telecommunication System</i> (WMO-No. 386) Climate Data Management System Specifications (WMO-No. 1131) |

Module 4: Human capacity development

Human capacity development is the backbone of GBON implementation and critical to ensure the sustainability of the observing network. Modernized observation infrastructure requires increased knowledge and skills of the staff, to overcome future challenges in the operations of the network.

The Member assesses human capacity gaps and designs capacity-development activities needed to close those gaps. The capacity-development activities should target technical staff to maintain the modernized observation infrastructure, and senior management to manage long-term strategic implementation of the Plan.

The type of human expertise and training depends on the infrastructure design chosen and the Member's human capacity gaps. The emphasis should be on maintaining essential capacity related to the generation and exchange of observations. In the case of opting for private sector partners, it is important to ensure that the Member has the expertise and capacity to engage in, monitor and manage the contractual relationships and control the services purchased. Activities and outputs for Module 4 are summarized in Table 27.

Table 27. Activities and outputs to be undertaken and delivered for Module 4

| <i>Item</i> | <i>Activity</i> | <i>Outputs</i> | <i>Relevant guidance material</i> |
|-------------|--|---|---|
| 4.1 | Assess human capacity gaps | 1. Inventory of staff skills, education levels and capacity gaps for technicians, experts and management | <i>Guide to Competency</i> (WMO-No. 1205) <i>Guidelines for Trainers in Meteorological, Hydrological and Climate Services</i> (WMO-No. 1114) |
| 4.2 | Design capacity-development activities for technical staff | 1. A plan for the training activities and recruitments needed for technical staff in: (a) Instrument and station maintenance at site (b) Calibration and maintenance at the workshop (c) Network monitoring (d) ICT system operations | <i>Guide to the Implementation of Education and Training Standards in Meteorology and Hydrology</i> (WMO-No. 1083) |
| 4.3 | Design capacity-development activities for senior management | 1. A plan for the training activities and recruitments needed for management in: (a) Strategic and financial planning (b) Project management | <i>Guidelines for Applying for a WMO Fellowship</i> (WMO-No. 1104) <i>A Compendium of Topics to Support Management Development in National Meteorological and Hydrological Services</i> (ETR-No. 24) |

Module 5. Risk management

Proactive risk management activity consists of trying to anticipate deviations from the Plan and implementing mitigation actions so that the objectives are reached despite the risks. Risks that materialize may prevent the infrastructure from satisfying the specified requirements, and prevent the successful implementation and the sustainability of operations of the modernized observation infrastructure.

The Member should assess the most relevant and expected operational risks for the implementation of the Plan and define mitigation measures. For this, the risk and control matrix should include the following:

- Identified risks and their effects
- Risk category
- Likelihood and impact scoring with total impact
- Mitigation action
- Responsibility

Activities and outputs for Module 5 are summarized in Table 28.

Table 28. Activities and outputs to be undertaken and delivered for Module 5

| <i>Activity item</i> | <i>Activity</i> | <i>Outputs</i> | <i>Relevant guidance material</i> |
|----------------------|--|---|--|
| 5.1 | Assess the operational risks for the implementation of the Plan and define mitigation measures | 1. A matrix to manage risks and proposed mitigation activities, including: <ol style="list-style-type: none"> (a) Identification of operational risks (b) Analysis of risks (c) Actions for mitigating the risks (d) Mechanism for monitoring and evaluating risks following implementation of mitigation actions | <i>Guide to the Implementation of Quality Management Systems for National Meteorological and Hydrological Services and Other Relevant Service Providers</i> (WMO-No. 1100) |

The Template for the National GBON Contribution Plan Report is available on the [References to GBON material](#) web page.

10.6 REGULATIONS FOR REPORTING GBON PARAMETERS

10.6.1 Reporting of hourly observations

In accordance with the *Manual on the WIGOS*, section 3.2.2, GBON surface land observing stations and upper-air stations shall observe a minimum number of required variables. Reporting practices for these GBON required variables are specified in the *Manual on Codes* (WMO-No. 306), Volume I.2, Part C, e, Regulations for reporting GBON parameters.

10.6.2 Additional WIS guidance

Following Resolution 34 (EC-76) - Implementation Plan Update of the WMO Information System 2.0 (*Executive Council: Abridged Final Report of the Seventy-sixth Session* (WMO-No. 1314)), Members are requested to exchange GBON observations through GTS and WIS in accordance with the *Manual on the Global Telecommunication System* (WMO-No. 386) and the *Manual on the WMO Information System* (WMO-No. 1060), Volume I until WIS 2.0 becomes operational in 2024. Parallel dissemination of data through GTS and WIS 2.0 is recommended from the start of the pilot phase in 2023.

Further details are provided in the *Guide to the WMO Information System* (WMO-No. 1061).

Exchange of GBON observations through WIS 2.0 will be regulated by the *Manual on the WMO Information System* (WMO-No. 1060), Volume II.

10.7 GBON-SPECIFIC METADATA IN OSCAR/SURFACE

OSCAR/Surface is the official source of information for WIGOS metadata from all surface-based stations/platforms, in accordance with the *Manual on the WIGOS* and with the *WIGOS Metadata Standard* (WMO-No. 1192). The repository serves to record and retain all current and historical WIGOS metadata.

GBON stations are identified in OSCAR/Surface by linking a station with the GBON programme/network affiliation. GBON stations are displayed in OSCAR/Surface.

Guidance on how to assign stations to GBON and search for them is available in the [OSCAR/Surface User Manual](#) in the WMO e-Library, in the six WMO languages.

10.8 **WDQMS PERFORMANCE MONITORING**

The GBON module of the WDQMS web tool provides Members with timely feedback about the station-level performance in relation to the GBON provisions. The system is based on the GBON compliance criteria adopted by INFCOM. The GBON module of the WDQMS web tool also provides the quantitative data which contributes to the Member-level GBON compliance monitoring.

More information about the GBON module of the WDQMS web tool can be found in the online [WDQMS User Guide](#).

11. THE REGIONAL BASIC OBSERVING NETWORK

Note: In the present chapter, reference is made to the regional associations and their management groups, which rely on their working groups on infrastructure (RA/WG-I). However, for Antarctica, the corresponding bodies are the Executive Council and its Panel of Experts on Polar and High Mountain Observations Research and Services (EC-PHORS), which can rely in turn on the INFCOM Global Cryosphere Watch (GCW) Advisory Group (GCW-AG) for technical work. For ease of writing and understanding of the process described in the present chapter, for the Antarctica RBON design process, references to “regional associations” should therefore be interpreted as “Executive Council”, to the “management group” as “EC-PHORS” and to “working group on Infrastructure” as “GCW-AG”. See also Resolution 49 (Cg-18) on the Antarctic Observing Network.

The present chapter describes the design process of the Regional Basic Observing Network (RBON) by the regional associations.

11.1 COORDINATION OF THE DESIGN PROCESS, ROLES AND RESPONSIBILITIES

11.1.1 The Regional Association Working Group on Infrastructure

The Regional Association Working Group on Infrastructure (RA/WG-I) is responsible for applying and coordinating the design process for RBON in consultation with the Members of the region and the Points of Contact of the Rolling Review of Requirements (RRR) application areas. In doing so, it promotes regional cooperation and exchange of data across boundaries, shares benefits, shares resources, optimizes the deployment of observing stations geographically and proposes prioritization mechanism(s) for such cooperation, for example, in support of disaster risk reduction. It also helps facilitate the processing and exploitation of RBON data and the use of existing global and regional infrastructure (such as WMO Information System (WIS) centres).

To undertake and coordinate the design process, the RA/WG-I may wish to establish a task team on RBON design.

11.1.2 Members and other bodies

Members play a key role in the design of RBON since it is the Members that invest in and provide commitments to RBON. Annex 11.1 provides a summary of the role of Members and other bodies regarding the design of RBON. Such other bodies include: the Regional WMO Integrated Global Observing System (WIGOS) Centres (RWCs); regional associations and their presidents, management groups and RA/WG-I (or their established task team on RBON design); national focal points (NFPs) for WIGOS, [OSCAR/Surface](#) and the WIGOS Data Quality Monitoring System (WDQMS¹); and the Secretariat. In particular, the WIGOS NFPs nominated by Members will assist the RA/WG-I in its work and help assess the Members’ capabilities and identify those existing and planned GBON stations that could be upgraded to meet RBON requirements.

Note: See Terms of Reference for the WIGOS NFPs in Annex 5.1 to Chapter 5 of the present Guide.

11.2 REQUIREMENTS, GAP ANALYSIS AND DESIGN OF RBON

11.2.1 Key regional weather, climate, water and other environmental challenges

The regional association, in consultation with its Members and key stakeholders, will select a small number of key regional weather, climate, water and other environmental challenges to be addressed in order to bring substantial socioeconomic benefits to the region through the use of RBON data.

¹ <https://wdqms.wmo.int>

Criteria for selecting the key regional challenges may include:

- (a) Likelihood of an event and the severity of its impact on society, or the substantial benefits brought to society by accurate forecasting of the event;
- (b) Commonality of the challenges across WMO application areas;
- (c) Substantial impact of the use of the RBON data on addressing the key regional challenges based on the results from impact studies.

The regional association may also wish to consider what impact studies to conduct at the regional level in order to better assess the impact of RBON data on the candidate key regional challenges.

The list of key regional challenges to be considered for RBON design is proposed by the RA/WG-I, following consultation with regional association Members and the key stakeholders and then decided by the president of the regional association in consultation with the management group. Examples of key regional weather, climate, water and other environmental challenges are provided in Annex 11.2.

For each key regional challenge, the regional association will identify the application areas that will substantially benefit from addressing the challenge, and the key variables to be observed for each application area (consideration will be given to the relative priorities of variables).

It is to be noted that the observational user requirements for Global Numerical Weather Prediction (GNWP) and climate data reanalysis at the breakthrough² level are already considered for the design of the GBON; these requirements are more stringent than the RBON requirements, and only the key regional challenges not already addressed by GBON should be considered for RBON design.

11.2.2 Regional requirements

Once the key regional weather, climate, water and other environmental challenges and the WMO application areas are identified, the regional association may wish to define regional requirements for some top-level high-priority variables to be observed for these application areas. By default, the global requirements in [OSCAR/Requirements](#) are used. Regional requirements are proposed by the RA/WG-I, approved by the president of the regional association in consultation with the management group and then recorded in OSCAR/Requirements through the Rolling Review of Requirements (RRR) Points of Contact of the relevant application areas.

The RA/WG-I will then produce a table of requirements (an example is set out in Table 29) synthesizing the regional requirements by top-level high-priority variables, with an indication of the most stringent threshold³ and breakthrough requirements to be met across the relevant application areas. The table focuses on horizontal resolution, observing cycle and timeliness, and which observing technology can be used. Other criteria, such as vertical resolution, uncertainty and stability can be addressed when RBON stations are proposed and discussed with the Members to assess whether such stations meet the RBON requirements or whether they could or should be upgraded to meet them.

The following methodology is proposed:

- Identify the application areas which are expected to substantially benefit from addressing the key regional challenges;

² The “breakthrough” is an intermediate level between “threshold” and “goal” which, if achieved, would result in a significant improvement for the particular application that registered this requirement. The “goal” is an ideal requirement above which further improvements are not necessary.

³ The “threshold” is the minimum requirement to be met to ensure that data are useful.

- For each such application area, identify the top-level high-priority variables to be observed;
- Identify the main observing technologies that are used or could be used to observe the identified top-level high-priority variables. Information on available technologies by variable is available in the *High-level Guidance on the Evolution of Global Observing Systems During the Period 2023–2027 in Response to the Vision for WIGOS in 2040* (WMO-No. 1334);
- Start with one requirement table for each of the relevant application areas and consult the OSCAR/Requirements database to find the threshold requirements to be used for observations (see example in Table 29). Consideration will be given to the most important criteria to be considered (for example, horizontal resolution, observing cycle, timeliness, and so forth). Regional subject matter experts may wish to propose regional requirements different from the global ones in the database. In such cases, they should consult with the Rolling Review of Requirements Points of Contact of the relevant application areas to have these requirements assessed, agreed upon and entered in the database if consensus is achieved;
- Merge the obtained requirement tables into one table, considering the most stringent requirements for top-level high-priority variables to be observed across the various application areas (Table 29 also provides an example). One example could be where “precipitation intensity at surface (liquid or solid)” is one of the top-level high-priority variables to be observed for the key regional challenge “Forecasting and management of high-impact weather events (e.g. flood)”. The two application areas identified as benefiting from improvements of observations for such a variable are Global Numerical Weather Prediction (NWP) and real-time monitoring and high-resolution NWP. In this case, it will be the most stringent threshold requirement of high-resolution NWP (which is 10 km as opposed to 50 km) that will be used for the horizontal resolution.

Table 29. Example of required top-level high-priority variables, the targeted key regional weather, climate, water and other environmental challenges, horizontal resolution, observing cycle and timeliness requirements and the available observing technologies

| <i>Key variable</i> | <i>Targeted key regional challenges</i> | <i>Horizontal resolution (threshold)</i> | <i>Observing cycle (threshold)</i> | <i>Latency (threshold)</i> | <i>Observing technologies⁴</i> |
|--|---|--|------------------------------------|------------------------------|--|
| Precipitation intensity at surface (liquid or solid) | Forecasting and management of high-impact weather events (e.g. flood) | 10 km ⁵ or TBD by regional expert | 2h or TBD by regional expert | 2h or TBD by regional expert | Satellites, Weather radars, Precipitation gauges |
| Wind profile (PBL) | Forecasting of convective events and associated hazard | 10 km or TBD by regional expert | 12h or TBD by regional expert | 2h or TBD by regional expert | AMDAR/MODE-S at airport, Wind profiler, Weather radars, Radiosonde |
| Temperature profile (PBL) | Forecasting of convective events and associated hazard | 10 km or TBD by regional expert | 3h or TBD by regional expert | 2h or TBD by regional expert | Aircraft (AMDAR or Mode-S), Raman lidar |

11.2.3 Assessment of capabilities

All surface-based observing stations that can potentially contribute to RBON must be recorded in OSCAR/Surface so that the RA/WG-I can make an informed assessment of the observing

⁴ See *High-level Guidance on the Evolution of Global Observing Systems During the Period 2023–2027 in Response to the Vision for WIGOS in 2040* (WMO-No. 1334)

⁵ Here based on the most stringent threshold requirements for global and regional NWP

capabilities of the region. The [WDQMS](#) can also be used to identify which stations are actually reporting and which data are used by global NWP and other types of centres. Further consultation with Members will also allow identification of additional existing observing infrastructure currently not reporting internationally or not included in RBON, and which could potentially and immediately be used for inclusion in RBON at a relatively limited cost (for example, by adding the data exchange mechanism at the required reporting frequency).

11.2.4 **Gap analysis**

On the basis of the key regional challenges, regional requirements (Table 29) and existing capabilities, and taking into account the composite nature of the observing system (including in situ and remote sensing, surface-based and space-based observing stations), the RA/WG-I performs a gap analysis and identifies the gaps that ought to be filled. To assess capabilities, the gap analysis can be done using tools such as OSCAR/Requirements, [OSCAR/Space](#) and OSCAR/Surface and the WDQMS, as well as through consultation with Members in the region.

The outcome of the gap analysis should be a table summarizing the following information:

- Key gap name;
- Short description of the gap, including the key regional challenges, application areas negatively impacted by the gap, and the top-level high-priority variables to be observed;
- Main requirement criteria to be addressed, among the following (one or more):
 - Description of the geographic area lacking data (for example, latitude/longitude box, name of an area, and so forth);
 - Horizontal resolution of additional RBON observations needed to achieve assessed requirements, and the number of observation sites that would be needed in the specified geographic area to fill the gap;
 - Vertical resolution;
 - Data availability including observing cycle and latency;
 - Long-term commitment for operating the station under RBON, at least four (4) years.
- Potential observing technologies that could be proposed as good candidates for RBON station(s) (see Annex 2 of *High-level Guidance on the Evolution of Global Observing Systems During the Period 2023–2027 in Response to the Vision for WIGOS in 2040* (WMO-No. 1334));
- Other existing observing technologies that complement RBON data, for example, research or partner or private sector observing stations;
- Possible approaches for the longer term (such as use of emerging technologies,⁶ use of capacity-development instruments, negotiation with partner organizations regarding specific types of data, and so forth).

11.2.5 **Options for the selection of stations**

The outcome of the gap analysis is communicated by the RA/WG-I to Members via their WIGOS national focal points; dialogue is initiated with Members to identify candidate observing stations to be committed to RBON according to the criteria provided in 11.2.6. Approaches for the longer

⁶ The *High-level Guidance on the Evolution of Global Observing Systems During the Period 2023–2027 in Response to the Vision for WIGOS in 2040* (WMO-No. 1334) also provides, in its Annex 2, information on emerging technologies, by variable.

term are also discussed. The Members' goal is to develop an updated and consolidated list of national observing stations committed to RBON, together with a national RBON implementation plan for the longer term. The Regional WIGOS Centres may also assist in the process.

Options for the selection of stations include the following:

- (a) Existing observing stations that already meet RBON requirements, whether or not they are already part of RBON.
- (b) Existing observing stations that do not fully meet RBON requirements, but could be easily upgraded to meet them. For example, for stations which meet all requirements except the requirement for data exchange, it could be decided to make the data internationally available.
- (c) Partner observing stations that could be committed to RBON, provided that a Memorandum of Understanding (MoU) is negotiated and signed at the national level between the Permanent Representative (PR) of the Member and the partner organization, to ensure that the RBON requirements will be met. Partnerships for sharing resources can also be considered, that is, when a station upgrade is necessary to meet all RBON requirements.
- (d) New observing stations to be implemented and start operations in the foreseeable future (that is, less than one year after the regional association decides on the updated composition of RBON). This scenario would be for addressing some remaining critical gaps (by observed variable) which should be filled. The Members should investigate whether investments could be made in order to implement such stations. Developing countries may wish to consider using some of the capacity-development instruments, such as the WMO Country Support Initiative (CSI),⁷ for making such investments.
- (e) In some instances, it is recognized that a Member may find that the horizontal and/or temporal resolutions required according to the RBON-related sections 3.2.3.7 and/or 3.2.3.9 of the *Manual on the WIGOS* are not practically achievable for the observing network within parts of its territory. In that case, the Member shall inform the Secretary-General of the reasons, as per Article 9 (b) of the WMO Convention, and paragraph 6 of the General Provisions of the *Technical Regulations* (WMO-No. 49), Volume I.

When investments at the national level are needed, and implementation cannot be realized quickly enough for the stations to be ready to report within one year after the regional association is expected to decide on the new RBON composition, a national RBON implementation plan with a clear timeline should be provided to the RA/WG-I. The national implementation plan will then be part of the regional implementation plan for RBON.

11.2.6 **Criteria for the selection of stations**

The following criteria are applied by Members when selecting existing stations that could contribute to RBON:

11.2.6.1 **Observing network design principles**

Observing network design principles (ONDP) are followed in accordance with the *Manual on the WIGOS*, 2.2.2.1 and Appendix 2.1. Most of the design principles are already met by simply complying with RBON or WIGOS technical regulations, namely the *Manual on the WIGOS*, as detailed in Table 30. Focus should therefore be placed on the following principles (principles 4, 5 and 6, also outlined in Table 30), which are not directly addressed by such technical regulations:

⁷ <https://alliancehydromet.org/soff/country-support-initiative/>

- i. ONDP #4: Designing appropriately spaced networks;
- ii. ONDP #5: Designing cost-effective networks;
- iii. ONDP #6: Achieving homogeneity in observational data.

More details on how to apply these principles can be found in Chapter 4 of the present Guide.

Table 30. Observing network design principles and how they are considered in RBON

| No. | Principle | Comments |
|-----|---|---|
| 1 | Serving many application areas | Addressed by definition through RBON provisions 3.2.3.7 , 3.2.3.9 , 3.2.3.10, 3.2.3.11 of the <i>Manual on the WIGOS</i> |
| 2 | Responding to user requirements | Addressed by definition through RBON provisions 3.2.3.7 , 3.2.3.8, 3.2.3.9 , 3.2.3.10, 3.2.3.11 of the <i>Manual on the WIGOS</i> |
| 3 | Meeting national, regional and global requirements | Addressed by definition through RBON provisions 3.2.3.7 , 3.2.3.8, 3.2.3.9 , 3.2.3.10, 3.2.3.11 of the <i>Manual on the WIGOS</i> |
| 4 | Designing appropriately spaced networks | To be considered in the design process by the RA/WG-I. See Chapter 5 and paragraph 11.2.6.8 of the present Guide. |
| 5 | Designing cost-effective networks | To be considered in the design process by the RA/WG-I. See Chapter 5 of the present Guide. |
| 6 | Achieving homogeneity in observational data | To be considered in the design process by the RA/WG-I. See Chapter 5 of the present Guide. |
| 7 | Designing through a tiered approach | RBON forms baseline network |
| 8 | Designing reliable and stable networks | Addressed by definition through 4-year/10-year commitment of Member, as per RBON provision 3.2.3.5 and 2.2.1.2 of the <i>Manual on the WIGOS</i> |
| 9 | Making observational data available | Addressed by definition through commitment of Member, as per RBON provision 3.2.3.4 of the <i>Manual on the WIGOS</i> |
| 10 | Providing information so that the observations can be interpreted | Addressed through commitment of Member to submit WIGOS Metadata in OSCAR/Surface, as per WIGOS provisions 2.5.1.1 , 2.5.1.2 of the <i>Manual on the WIGOS</i> |
| 11 | Achieving sustainable networks | Addressed by definition through 4-year/10-year commitment of Member, as per RBON provisions 3.2.3.5, 2.2.1.2 of the <i>Manual on the WIGOS</i> |
| 12 | Managing change | Addressed by definition through commitment of Member, as per these principles and provision 3.2.3.6 and 3.4.6 of the <i>Manual on the WIGOS</i> |
| 13 | Advancing environmental sustainability | Addressed through commitment of Member to consider the environmental impacts of observing networks in their design and operation |

11.2.6.2 **Observing station technologies considered for RBON**

All surface-based observing technologies can a priori be considered for inclusion in RBON. These include the technologies used for the traditional former Regional Basic Synoptic Network (RBSN) and Regional Basic Climatological Network (RBCN) stations, but also aircraft observing

systems, operational weather radars and other surface-based remote-sensing observing stations, hydrological observing stations, agricultural meteorological stations, marine observing stations (fixed or mobile), and so forth.

11.2.6.3 **Compliance with RBON requirements**

The station (or network in case of mobile stations) can contribute to meeting the RBON requirements (some upgrade may be needed). See Table 31.

11.2.6.4 **Willingness of Member to commit**

The Member is willing to commit the station (or network, in the case of mobile stations) to RBON according to the RBON requirements, and to upgrade it if necessary. In accordance with the *Manual on the WIGOS*, 3.2.3.5, there is at least a 4-year minimum commitment, and at least 10 years is recommended, according to 2.2.1.2.

11.2.6.5 **Former Regional Basic Synoptic and Climatological Networks**

Former Regional Basic Synoptic Network and Climatological Network (RBSN and RBCN) stations are preferably kept in RBON for continuity of the time series, although they may have to be upgraded for compliance with RBON requirements.

11.2.6.6 **Consideration of the High-level Guidance on the Evolution of Global Observing Systems during the period 2023–2027 in Response to WIGOS Vision 2040 (WMO-No. 1334)**

The Infrastructure Commission has developed the *High-level Guidance on the Evolution of Global Observing Systems during the Period 2023–2027 in Response to the Vision for WIGOS in 2040* (WMO-No. 1334), whose purpose is to provide guidance to WMO Members for key activities to be implemented within the five years from 2023 to 2027 to accomplish the scenario of the [Vision for the WMO Integrated Global Observing System in 2040](#) (WMO-No. 1243). The guidance consists of principles of a general nature that should be considered for the development of implementation plans by Members, agencies and other operators of observing networks. It identifies urgent specific actions arising as a consequence of WMO's Earth System approach and in response to the priorities of WIGOS, WMO programmes and existing data gaps. Elements and priority actions from this document should be considered during the design of RBON for the selection of observing stations.

11.2.6.7 **Avoid duplication and overlap**

If the station (or network, in the case of mobile stations) is included in RBON, it should not duplicate or overlap with other existing RBON observations or other existing sources of data made available to WMO Members (such as satellite data) from the considered area. Indeed, RBON stations are expected to add value in terms of meeting the threshold up to breakthrough requirements for top-level high-priority variables to be observed in support of priority application areas. For example, the horizontal resolution requirements are very demanding for some applications, such as high-resolution NWP (HRNWP) and Nowcasting/very short-range forecasting (VSRF), even at the threshold level. Such requirements are likely to be met by RBON only over very limited domains but not over regional or global domains. In this case, the design of RBON would need to take into account how its surface stations/platforms could complement the observations available from space or other surface-based remote-sensing observing platforms (for example, lower tropospheric wind (horizontal) for HRNWP).

11.2.6.8 ***Even distribution of stations***

The horizontal resolution of observations by variable (possibly coming from different types of observing stations) should be relatively even across the region or specific climate zone. The distribution of the RBON stations across Members should be fair and equitable among Members, taking into account their capabilities and the available resources.

11.2.6.9 ***Small size Members***

Members whose geographical area is below the most stringent threshold requirement for horizontal resolution across applications for the observed variables should commit at least one RBON station, unless the requirements are already met with the data from other surrounding RBON stations or from satellite or other remote-sensing observations. These Members can rely on the RBON stations from the surrounding Members to have the spatial resolution requirements met at least at the threshold level.

11.2.6.10 ***Members with larger geographical coverage***

Members with larger geographical coverage will design and propose their own national observing network contributing to RBON. However, for the stations to be committed near⁸ their borders they are urged to consult with neighbouring Members and with the RA/WG-I regarding options to be considered for the best selection of RBON stations.

11.2.6.11 ***Mobile stations commitment***

For mobile stations, the commitment is made for a national network or for a national contribution to another observing network (for example, to the Data Buoy Cooperation Panel (DBCP) for drifting buoys, or to the Voluntary Observing Ship (VOS) scheme for ships). Members will have to define what their commitment to such a network will be in terms of: (i) geographic coverage and area of operations or deployment; (ii) duration of the programme and long-term commitment; and (iii) targeted network density or number of committed stations. Once such a network of mobile stations is approved by the regional association to be part of RBON, its observing stations are then automatically affiliated to RBON as they are deployed, without the need for the regional association to re-apply the RBON design process or approve them individually.

Table 31. Summary of the RBON requirements according to the *Manual on the WIGOS*

| <i>Requirement</i> | <i>Mandatory requirements (shall)</i> | <i>Recommended requirements (should)</i> |
|--|---------------------------------------|--|
| Respond to user requirements as specified in OSCAR/Requirements | 3.2.3.3, 3.2.3.6 | n/a |
| International exchange of the data in real time or near-real time | 3.2.3.4 | n/a |
| 4-year operations commitment | 3.2.3.5 | n/a |
| 10-year operations commitment | n/a | 2.2.1.2 |
| Set of stations/platforms to enable RBONs to meet [for the identified top-level high-priority variables], at threshold levels or better, observational requirements of all [prioritized] WMO application areas | 3.2.3.7 | n/a |

⁸ In this context, the term “near” is interpreted as being at a distance from the border of less than half of the horizontal resolution required.

| <i>Requirement</i> | <i>Mandatory requirements (shall)</i> | <i>Recommended requirements (should)</i> |
|--|---------------------------------------|--|
| Sub-set of stations that enables RBONs to meet [for identified top-level high-priority variables] observational requirements of at least some application areas at the breakthrough level or better | n/a | 3.2.3.8 |
| Sub-set consisting of stations/platforms that observe [key] surface variables with an hourly or more frequent observing cycle, sufficient to meet the threshold observing cycle requirements of all [prioritized] application areas | 3.2.3.9 | n/a |
| Enough stations/platforms that observe surface pressure to enable RBON to have horizontal resolution of 100 km or better for surface pressure observations Note: The GBON requirement is 200 km over land and 500 km over the ocean in Exclusive Economic Zones (EEZs). | n/a | 3.2.3.10 |
| Enough upper-air stations/platforms to enable RBON to have horizontal resolution of 100 km or better for vertical profile observations of the horizontal wind vector. Note: The GBON requirement is 500 km over land and 1000 km over the ocean in EEZs. | n/a | 3.2.3.11 |
| Monitor RBON performance and rectify identified non-conformance | 3.2.3.17, 3.2.3.18 | n/a |

11.3 **PROCEDURE FOR ASSIGNMENT OF RBON STATIONS AND RBON EVOLUTION**

11.3.1 **Information provided by Members to the Regional Association Working Group on Infrastructure**

Members will provide the Regional Association Working Group on Infrastructure (RA/WG-I) with their updated list of stations to be committed to RBON (see Template for the proposed updated composition and selection of RBON stations addressing the key gaps in Annex 11.3), together with their draft national plan on the evolution of RBON to address remaining gaps over the longer term (work with partners, timeline for implementation of new stations, promotion of new studies, use of new technologies, use of capacity-development instruments such as the Country Support Initiative (CSI), and so forth) (see Template for the draft national or regional plan on the evolution of RBON to meet remaining gaps over the longer term in Annex 11.4).

11.3.2 **Synthesis of the updated composition of RBON**

Based on guidance from the management group, in particular with regard to the key regional weather, climate, water and other environmental challenges to be met with RBON observations, and based also on interactions and input from Members as described in 11.3.1, the RA/WG-I will finalize the design of RBON and submit to the regional association management group the following material for its consideration:

- (a) The list of key regional challenges with a summary of regional requirements for some top-level high-priority variables to be observed by RBON (global requirements are used by default) (Table 29);
- (b) The gap analysis summary describing the key gaps and a proposal for technologies to potentially be used to fill the gap;

- (c) The proposal for an updated composition and selection of RBON stations addressing the key gaps (it is understood that there may still be remaining gaps). See Template for the proposed updated composition and selection of RBON stations addressing the key gaps in Annex 11.3;
- (d) The draft plan on the evolution of RBON or road map to fill the remaining gaps in meeting the requirements of the key regional challenges over the longer term (work with partners, timeline for implementation of new stations, promotion of new studies, use of new technologies, use of capacity-development instruments such as the CSI, and so forth). See Template for the draft national or regional plan on the evolution of RBON to meet remaining gaps over the longer term in Annex 11.4.

11.3.3 **Assignment of RBON stations, and the plan or road map for the evolution of RBON by the regional association**

RBON stations are assigned by Members in OSCAR/Surface. Once the stations are assigned to RBON they will be included in the regular compliance monitoring as described in 11.4.4. The regional association decides on the plan or road map for the evolution of RBON to fill the remaining gaps.

11.4 **FOLLOW-UP ACTIONS AND COMPLIANCE MONITORING**

11.4.1 **Reflecting updated composition of RBON in OSCAR/Surface**

Once a Member has decided on its contribution to RBON, the OSCAR/Surface NFP must affiliate the committed stations to RBON in OSCAR/Surface and have the stations' WIGOS metadata recorded. Possible discrepancies in metadata will be discussed with the WIGOS NFP or Member (if no WIGOS NFP), in consultation with the RA/WG-I.

11.4.2 **Recommendations to address remaining gaps**

It is understood that the agreed composition of RBON in the region may not entirely meet the observational user requirements for the region and that gaps may remain, essentially due to a lack of capacity of some Members from developing or least developed countries. The use of capacity development and other financing instruments should therefore be considered for filling the gaps over the longer term. Proposed actions will be detailed in the regional plan or road map for the evolution of RBON.

11.4.3 **Review cycle of the RBON performance, composition and evolution**

The performance, composition and evolution of RBON is reviewed every four years. However, Members can make adjustments in the meantime in accordance with the *Manual on the WIGOS*, 3.2.3.16.

11.4.4 **Monitoring of compliance with the RBON requirements**

Compliance of RBON with the requirements specified in the *Manual on the WIGOS* is routinely monitored by the Regional WIGOS Centres (RWCs), which regularly report on issues, inconsistencies or gaps. Members are tasked with taking actions as needed on the identified issues and discrepancies. The RA/WG-I takes the information from the RWCs into account when proposing an updated composition of RBON to the regional association.

Note: RA/WG-I will also be provided with a brief national plan with a timeline for the further evolution of the national contribution to RBON.

ANNEX 11.1. SUMMARY OF THE ROLE OF VARIOUS BODIES IN THE RBON DESIGN PROCESS

| <i>Body</i> | <i>Role</i> |
|---|--|
| Members | <p>Nominate WIGOS, OSCAR/Surface and WIGOS Data Quality Monitoring System (WDQMS) NFPs.</p> <p>Propose and commit existing stations (consider national partnerships and upgrading stations to meet RBON requirements if needed).</p> <p>Take action to fill remaining gaps.</p> <p>Implement new RBON station(s) as committed. Developing countries may wish to make use of capacity-development instruments, e.g. Country Support Initiative (CSI), Systematic Observations Financing Facility (SOFF, applicable to GBON requirements only).</p> <p>Record station metadata in OSCAR/Surface.</p> <p>Correct compliance issues.</p> |
| WIGOS NFPs (see Chapter 5, Annex 5.1) | <p>Assist the RA/WG-I regarding RBON design.</p> <p>Inform on country/territory capabilities.</p> <p>Negotiate with partner organizations and encourage non-NMHS observing stations to be made available when they meet RBON requirements.</p> <p>Identify potential candidate RBON stations.</p> <p>Identify which stations are to be upgraded to meet RBON requirements.</p> <p>Task OSCAR/Surface NFPs to (i) affiliate station to RBON, and (ii) record metadata in OSCAR/Surface.</p> |
| OSCAR/Surface NFPs (see Chapter 5, Annex 5.1) | <p>Assign WIGOS Station Identifiers to RBON stations.</p> <p>Enter and maintain WIGOS metadata of RBON stations in OSCAR/Surface.</p> <ul style="list-style-type: none"> - Assign appropriate stations to RBON. - Un-assign stations from RBON in OSCAR/Surface when such stations can no longer be committed to RBON by the Member. |
| WDQMS NFPs (see Chapter 5, Annex 5.1) | <p>Address identified compliance and incident issues.</p> |
| Regional associations | <p>Appoint subject matter and observing network design experts to be working within or with the RA/WG-I on RBON design.</p> <p>Task the RA/WG-I to undertake RBON design (there may be a need to update their Terms of Reference; and the RA/WG-I may wish to establish a Task Team on RBON design).</p> <p>Decide on a small number of key regional weather, climate, water and other environmental challenges to be used for RBON design.</p> <p>Decide on regional requirements based on the key regional challenges to be used for RBON design.</p> <p>Decide on the regional plan for the evolution of RBON to address remaining gaps.</p> |
| Regional association management groups | <p>Advise on key regional weather, climate, water and other environmental challenges to be addressed by the RBON design.</p> <p>Review proposals from the RA/WG-I with regard to the draft plan on the evolution of RBON to address remaining gaps.</p> <p>Advise the president of the regional association on these proposals.</p> |

| <i>Body</i> | <i>Role</i> |
|---|--|
| RA/WG-I (or its established task team on RBON design) | <p>Promote regional cooperation and exchange of data across boundaries: share benefits and resources and optimize the deployment of observing stations geographically; propose prioritization mechanism(s) for such cooperation, e.g. in support of disaster risk reduction; and facilitate processing of RBON data and the use of existing global and regional infrastructure (e.g. WMO Information System (WIS) centres). Coordinate the design process at the regional level.</p> <p>Propose regional requirements (to be recorded in OSCAR/Requirements) based on the list of high-priority regional weather, climate, water and other environmental challenges, and the top-level high-priority variables to be observed to address such challenges.</p> <p>Conduct gap analysis (compare requirements with Members' observing capabilities).</p> <p>Consult with and provide information on the regional requirements to the Rolling Review of Requirements (RRR) Points of Contact of WMO application areas so that these and regional priorities can also be considered in OSCAR/Requirements and the Statements of Guidance.</p> <p>Share efforts and knowledge to carry out and coordinate impact studies, as or if needed.</p> <p>Obtain proposals from Members on candidate observing stations to be included in RBON.</p> <p>Propose to regional association (in consultation with Members): a plan on the evolution of RBON to address remaining gaps (promote new studies, use new technologies, use capacity-development instruments e.g. CSI, etc.).</p> |
| Regional WIGOS Centres | <p>Assist RA/WG-I on RBON design. Monitor compliance of RBON. Alert Members on non-compliance issues.</p> |
| Secretariat | <p>Check and confirm affiliation to RBON in OSCAR/Surface. Discuss possible issues with NFPs and Members, if needed, in consultation with RA/WG-I. Assist Members to fill remaining gaps by advising on existing capacity-building instruments such as CSI or SOFF.</p> |

ANNEX 11.2. EXAMPLES OF KEY REGIONAL WEATHER, CLIMATE, WATER AND OTHER ENVIRONMENTAL CHALLENGES

1. EVENT TYPES AND EXAMPLES OF CHALLENGES

Key definitions

Key regional weather, climate, water and other environmental challenges (in the context of RBON) are weather, climate, water and other environmental phenomena to be addressed in order to bring substantial socioeconomic benefits to the region through the use of RBON data.

Note: warnings of hazardous events are challenges, however there are other types of challenges that are not related to issuing warnings of hazardous events (for example, challenges related to support to aviation, agricultural meteorology and irrigation).

***Hazard.** A process, phenomenon or human activity that may cause loss of life, injury or other health impacts, property damage, social and economic disruption or environmental degradation.

***Hazardous Event.** The manifestation of a hazard in a particular place during a particular period of time. Annotation: Severe hazardous events can lead to a disaster as a result of the combination of hazard occurrence and other risk factors.

***Disaster.** A serious disruption of the functioning of a community or a society at any scale due to hazardous events interacting with conditions of exposure, vulnerability and capacity, leading to one or more of the following: human, material, economic and environmental losses and impacts.

*Source: United Nations Office for Disaster Risk Reduction (UNDRR) open-ended intergovernmental expert working group on indicators and terminology relating to disaster risk reduction (<https://www.undrr.org/terminology>)

The WMO Event Types List below contains a standard list of event types that can be potentially associated with hazardous events. The list is intended to be a living list that can be amended through the appropriate WMO governance mechanism with input from WMO Members and regional associations, as well as collaborating institutions having a mandate on other hazards. The Event Types list will facilitate the standardization of event terminology across various domains of applications. Event definitions can be accessed in the relevant WMO technical regulations.

The “priority hazards” as identified by the Early Warnings for All initiative are marked in bold.

EVENT TYPES LIST

1. Avalanche
2. Cold wave
- 3. Drought/Dry spell**
4. Dust storm/Sandstorm
5. Extratropical cyclone
- 6. Flood**
7. Fog
8. Forest fire
9. Freezing rain
10. Frost
11. Hail
12. Haze/Smoke

13. Heatwave

14. High Seas/Rogue waves etc.
15. High UV radiation
16. Icing
17. Landslide/Mudslide and debris flow
18. Lightning
19. Pollen pollution/Polluted air
20. Rain/Wet Spell
21. Snow
22. Snowstorm
23. Space weather event
24. Storm surge/Coastal flood

25. Thunderstorms/Squall lines

26. Tornado

27. Tropical cyclone

28. Tsunami
29. Volcanic ash
30. Wildland fire
31. Wind

The WMO Event Types List can be considered by the regional associations when designing their RBON networks. Regional associations normally consider a small number of challenges to be addressed at the regional level when designing their RBON networks.

In addition, for planning (risk assessment), preparing (forecasting) and responding (warning and informing) to multi-sectoral impacts, regional associations can consult the following list of key regional weather, climate, water and other environmental challenges:

- Heavy rainfall; pluvial, fluvial and groundwater flooding; flash floods;
- Coastal inundation, storm surge, large waves and tsunamis, coastal erosion;
- Strong winds, windstorms and squall lines (land and oceans), wind conditions (e.g. impact on wind farms, aviation and tourism);
- Winter, polar and high-mountain weather (extreme cold and cold waves, freezing rain, snow, snow depth, icing, avalanches, glacier lake outburst floods, landslides and rockfalls, thermokarst and so forth);
- Hurricanes/typhoons;
- Air quality and aeroallergens;
- Low cloud and poor visibility;
- Extreme heat (impacts on health, agriculture, wildfire and so forth);
- Severe convection (gust fronts, microbursts, severe icing/turbulence for aviation, and so forth);
- Sand and dust (suspension, deposition and sedimentation);
- Dry air;
- Space weather;
- Volcanic gases and sulfates (suspension, deposition and sedimentation);
- Climate change (in Earth systems domains);

- Changes in weather regimes in the medium range (up to 30 days) and seasonal range (multi-month);
- Marine pollution (e.g. oil spills);
- Water quality (e.g. algae blooms).

Regional associations may choose to disregard certain challenges from the list or to consider others that are not on the list.

2. EXAMPLES OF HOW TO ADDRESS CHALLENGES

The following table provides examples of how to address some key regional challenges with the goal of identifying the key gaps to be addressed through RBON data. These examples are given solely as a starting point; regional associations are invited to organize themselves and the related activities in order to fine tune their requirements, taking into account the actual gaps and capacities of the Members in the region.

| No. | Key regional challenge | Which tools or application areas are being used to address the key challenge? | What are the key variables to be observed in order to address the key challenge? | Available observing technologies ¹ | Comment |
|-----|--|---|--|---|--|
| 1 | Forecasting and management of pluvial floods (a high-impact weather event) | GNWP; HRNWP; Hydrological and hydrodynamical models; Mathematical models; Statistical models. | Precipitation intensity at surface (liquid or solid); Evaporation; Water level; Discharge; Soil moisture; Underground water. | Satellites; Weather radars; Precipitation gauges; River gauges; Flooding level monitoring stations. | Near-surface winds (convergence zones) and boundary-layer (BL) humidity would also be relevant for forecasting with high-resolution forecast models. HRNWP with cloud resolving schemes with fast assimilation cycles would be particularly useful. Updated databases of land use and soil classification would be useful. |
| 2 | Forecasting of convective events and associated hazards | GNWP; HRNWP; Nowcasting; Aeronautical meteorology. | Wind profile (BL); Temperature profile (BL); Humidity profile (BL); All basic atmospheric surface variables; Precipitation. | Automatic Weather Station (AWS) (including rain gauge); Radiosonde AMDAR/MODE-S at airport; Low latency, high temporal and spatial resolution satellites and surface-based remote-sensing stations, including lightning detection; Raman lidar (humidity, temperature); DIAL lidar (humidity); GNSS ZTD; Doppler lidar; Wind profiler; Weather radars; Lightning detection network. | This includes flood, flash flood, damaging wind, lightning storm, tornadoes |

Key: GNWP = Global numerical weather prediction; HRNWP = High-resolution numerical weather prediction; GNSS ZTD = Global navigation satellite system zenith total delay

¹ The *High-level Guidance on the Evolution of Global Observing Systems During the Period 2023–2027 in Response to the Vision for WIGOS in 2040* (WMO-No. 1334) provides in its Annex 2, "Statements of Guidance gap overview per variable", comprehensive information on existing and emerging technologies for measuring the variables where gaps have been identified for WMO application areas.

3. **EXAMPLES OF RELATED REGIONAL ACTIVITIES**

- RA-II: Implementation of the RRR in China ([pdf](#))
 - RA-VI: EUMETNET has developed a series of regional Statements of Guidance, which are available at <https://www.eumetnet.eu/activities/observations-programme/documents/>
-

ANNEX 11.3. TEMPLATE FOR THE PROPOSED UPDATED COMPOSITION AND SELECTION OF RBON STATIONS ADDRESSING THE KEY GAPS

Note: The same template is used for the national list of stations (submitted by Members to the RA/WG-I) and the full proposed updated composition of RBON for the region (developed by the RA/WG-I based on Members' input).

| <i>WSI¹</i> | <i>WMO Member²</i> | <i>Status³ (E/N)</i> | <i>Latitude⁴</i> | <i>Longitude⁴</i> | <i>Type of observing station</i> | <i>Surface observations (Y/N)</i> | <i>Upper-air observations (Y/N)</i> | <i>Commitment⁵</i> | <i>Owner⁶</i> | <i>Comment⁷</i> |
|------------------------|-------------------------------|---------------------------------|-----------------------------|------------------------------|----------------------------------|-----------------------------------|-------------------------------------|-------------------------------|--------------------------|----------------------------|
| | | | | | | | | | | |
| | | | | | | | | | | |
| | | | | | | | | | | |

Key:

1. WIGOS Station Identifier
2. Country or territory
3. Existing RBON station (E) or new proposed station (N)
4. Provide information in decimal format
5. Number of years the station is committed from the time of expected decision by the regional association
6. NMHS or name of partner organization
7. Additional information, e.g. limitations per RBON requirements, known issues, clarifications

ANNEX 11.4. TEMPLATE FOR THE DRAFT NATIONAL OR REGIONAL PLAN ON THE EVOLUTION OF RBON TO MEET REMAINING GAPS OVER THE LONGER TERM

Notes:

1. The same template is used for national plans (submitted by Members to the RA/WG-I) and regional plans (developed by the RA/WG-I based on national plans provided by Members).
2. Entries in the table below are only given as examples.

| No. | Deliverable | By whom | Expected delivery time | Comment |
|-----|---|---------------------------------|------------------------|--|
| 1 | MoU with partner organization for upgrading <N> <station type> stations in <name of region> | NMHS and <partner name> | 6/2026 | Number of stations to be upgraded will depend on negotiation with partner organization and available resources |
| 2 | MoU with partner organization for the exchange of data from <N> <station type> stations in <name of region> | NMHS and <partner name> | 3/2024 | Good chances of success; data already shared by the partner with NMHS |
| 3 | Plan for funding <N> new <station type> stations to be implemented in <name of region> using the World Bank (WB) funding in the framework of the WMO Country Support Initiative | NMHS and WB | 2028 | |
| 4 | Agreement with neighbouring country for sharing and exchanging weather radar data | NMHS and <country name> | 12/2025 | Investigating future agreement with <country name> for the exchange of data |
| 5 | Implementation of new weather radar in <name of region> | NMHS | 6/2024 | Investigating future agreement with <country name> for the exchange of data |
| 6 | Testing use of UAS technology to replace some upper-air soundings at 0000 UTC | NMHS and <research institute> | 2026 | Implementation will depend on the results |
| 7 | Impact study on the impact of AMDAR observations in the presence of upper-air radiosonde data | NMHS | 5/2024 | Could lead to decisions on optimal mix of observations based on the results |
| 8 | Upgrade of <N> GBON stations to meet RBON requirements | NMHS and hydrological institute | 3/2025 | |

Key: MOU = Memorandum of Understanding; N = number; UAS = unstaffed aerial systems

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