World Meteorological Organization

Working together in weather, climate and water

Workshop on Quality Management in Surface, Climate and Upper-Air Observations

(Tokyo, 27-30 July 2010)

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WMO Convention
(Part II, Article 2, Purposes)

(a) 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, and…;

(c) To promote standardization of meteorological and related observations and to ensure the uniform publication of observations and statistics;

General Regulation of WMO
(Annex III, Structure and TOR of TCs)

I. Basic Commissions

- **CBS – (A)**
- **CIMO – (A)**
- CHy – (A)
- CAS – (B)

II. Applications Commissions

- CAeM – (C)
- CAgM - (C)
- JCOMM - (C)
- CCl - (C)

(A) Basic operations and facilities
(B) Research in Atmospheric sciences
(C) Applications to economic and social activities

Develop, for consideration by the Executive Council and Congress, proposed international standards for methods, procedures, techniques and practices in meteorology and operational hydrology including, in particular, the relevant parts of the Technical Regulations, guides and manuals.

Standardization (WMO Regulatory Material)

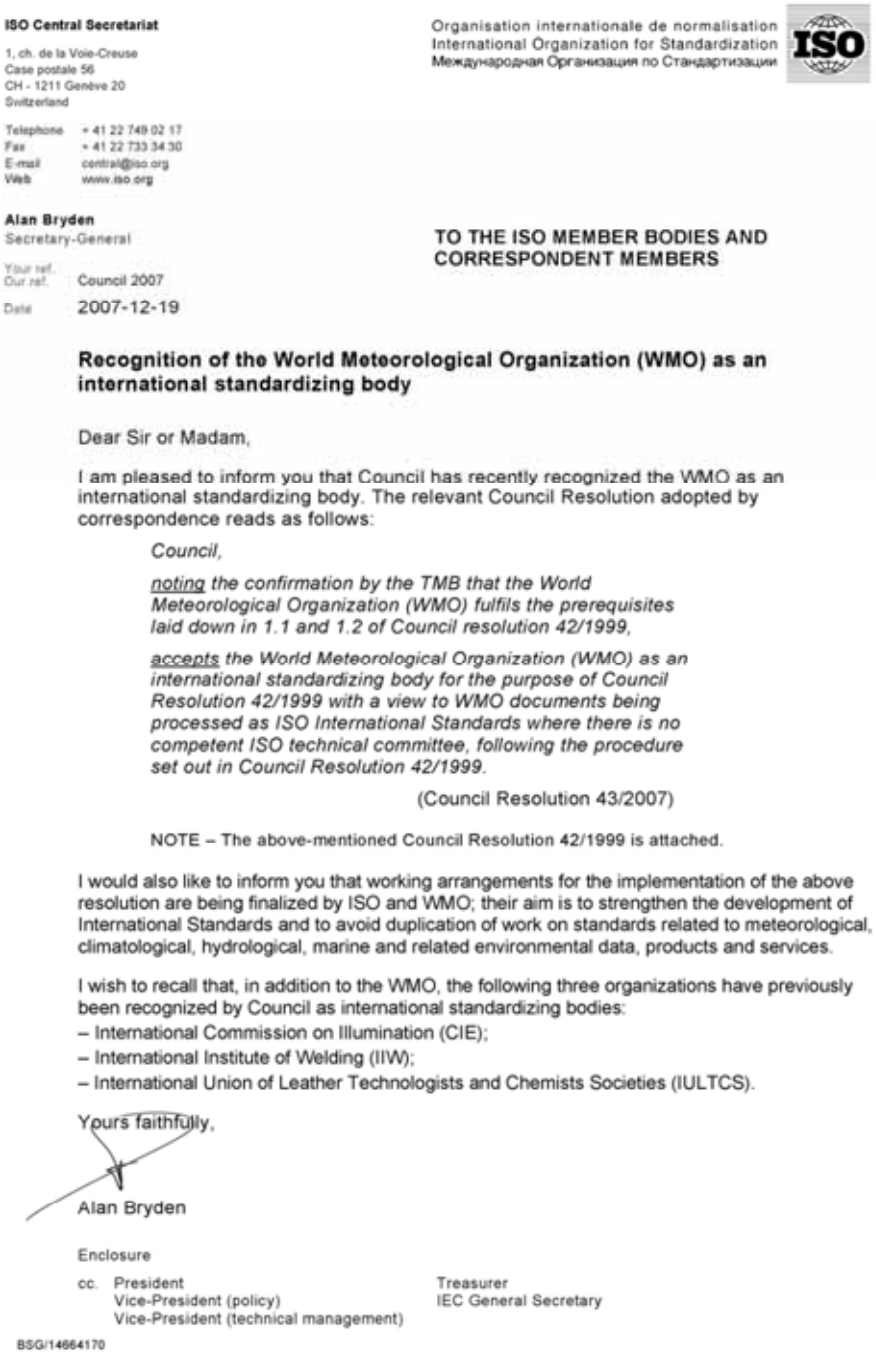
Cg and EC adopt Regulatory Material that define meteorological practices and procedures to be followed by Members

1. **Standard practices and procedures - Manuals**
2. **Recommended practices and procedures - Guides**

Partnership in Standardization

- Working agreements with other UN bodies and international Organizations:
  - **ISO:** Working Agreement on joint Standards
  - **ICAO:** Issuing Standards and Recommended Practices for Aviation
  - **CIPM&BIPM**: Working Agreement on cooperation and collaboration & MRA

Partnership in Standardization (ISO)



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Organisation internationale de normalisation
International Organization for Standardization
Международная Организация по Стандартизации

Alan Bryden
Secretary-General

Your ref.
Our ref. Council 2007

Date 2007-12-19

TO THE ISO MEMBER BODIES AND CORRESPONDENT MEMBERS

Recognition of the World Meteorological Organization (WMO) as an international standardizing body

Dear Sir or Madam,

I am pleased to inform you that Council has recently recognized the WMO as an international standardizing body. The relevant Council Resolution adopted by correspondence reads as follows:

Council,

noting the confirmation by the TMB that the World Meteorological Organization (WMO) fulfils the prerequisites laid down in 1.1 and 1.2 of Council resolution 42/1999,

accepts the World Meteorological Organization (WMO) as an international standardizing body for the purpose of Council Resolution 42/1999 with a view to WMO documents being processed as ISO International Standards where there is no competent ISO technical committee, following the procedure set out in Council Resolution 42/1999.

(Council Resolution 43/2007)

NOTE – The above-mentioned Council Resolution 42/1999 is attached.

I would also like to inform you that working arrangements for the implementation of the above resolution are being finalized by ISO and WMO; their aim is to strengthen the development of International Standards and to avoid duplication of work on standards related to meteorological, climatological, hydrological, marine and related environmental data, products and services.

I wish to recall that, in addition to the WMO, the following three organizations have previously been recognized by Council as international standardizing bodies:
– International Commission on Illumination (CIE);
– International Institute of Welding (IIW);
– International Union of Leather Technologists and Chemists Societies (IULTCS).

Yours faithfully,

Alan Bryden

Enclosure

cc. President
Vice-President (policy)
Vice-President (technical management)
Treasurer
IEC General Secretary

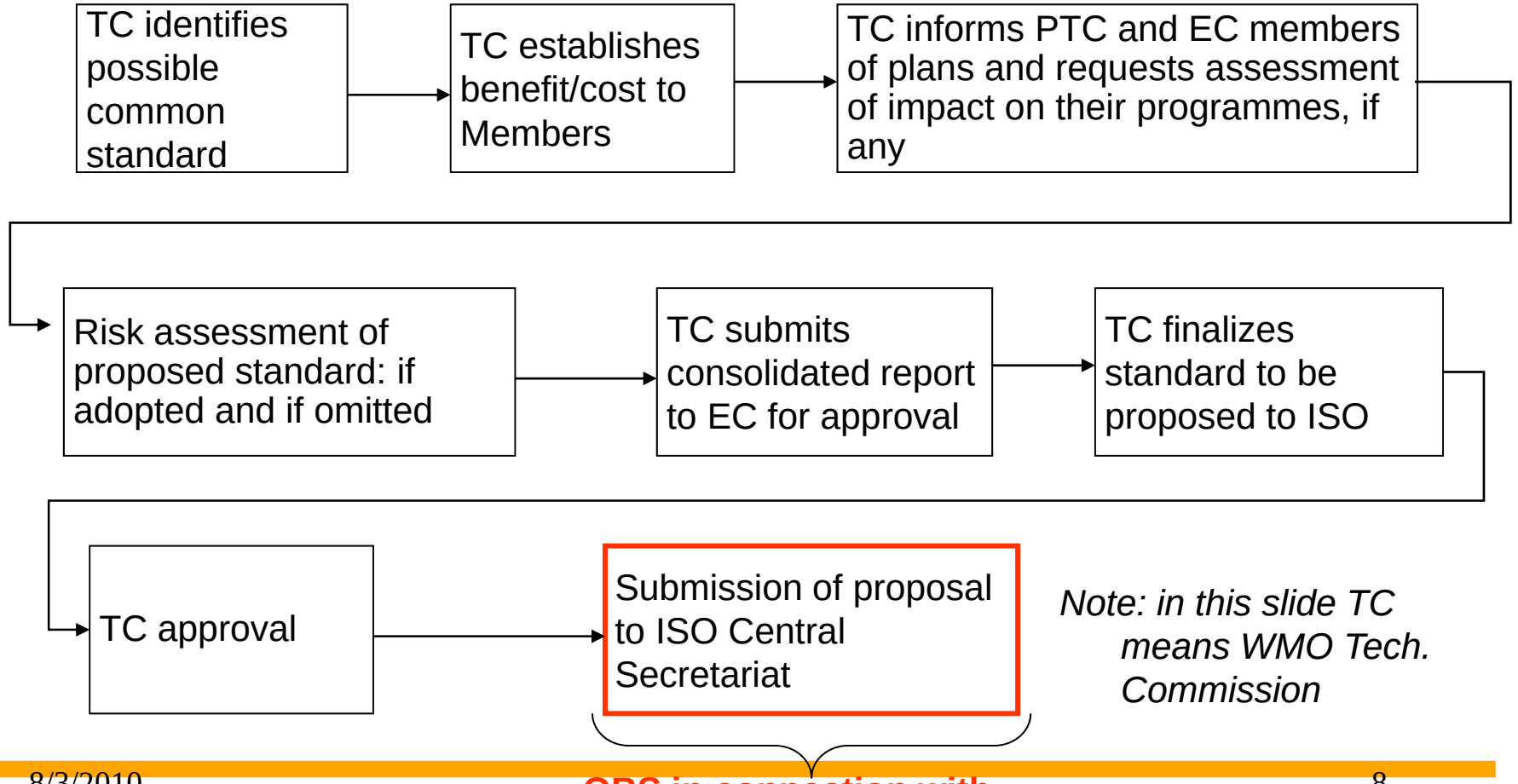
BSG/14664170

Partnership in Standardization

Cooperation Agreement with ISO:

1. Aimed at development of **joint** ISO/WMO tech standards
2. WMO to retain primary **control** of own standards
3. WMO could retain WMO specific standards (TCs decide which standard to propose)
4. Benefits
   - Underlines **authority** of WMO documents
   - Enhances international **recognition** and dissemination of WMO standards
5. Costs:
   - Standards need to be updated every 5 years (current revision cycle of WMO Technical Regulations variable)
   - Publication strategy – free access for Members

Partnership in Standardization



Note: in this slide TC means WMO Tech. Commission

Partnership in Standardization (CIPM&BIPM)

ANNEX

AGREEMENT BETWEEN THE WORLD METEOROLOGICAL ORGANIZATION AND THE INTERNATIONAL COMMITTEE FOR WEIGHTS AND MEASURES

Text approved by the CIPM on 10 October 2001

ARTICLE I

Cooperation and collaboration

1. The World Meteorological Organization (WMO), referred hereinafer as "the Organization", and the International Committee for Weights and Measures, referred hereinafter as "the Committee", agree that with a view to facilitating the implementation of their objectives, set respectively in the Convention of WMO, and in the Metre Convention, they will act in close cooperation with each other and consult each other regularly in regard to matters of common interest.

2. The Committee recognizes the responsibilities of the Organization in the field of meteorology, hydrology and other related geophysical sciences as set forth in the Convention of the Organization and recognized in the Agreement between the United Nations and the Organization and in particular that the Organization has a mandate to ensure that data obtained in the course of its work is standardized, accurate and reliable.

3. The Organization recognizes the responsibilities of the Committee as set forth in the Metre Convention and in particular the recommendation of the Member States set out in Resolution 4 of the 21st General Conference of Weights and Measures (1999) related to the need to use SI* units in studies of Earth resources, the environment, human well being and related issues.

4. Accordingly, the Organization and the Committee will consult together to ensure that data, related in particular to measurements of state and composition of atmosphere and water resources, coming from. the programmes organized under the auspices of the Organization are properly based on units traceable to the SI through the procedures of the Mutual Recognition Arrangement for National Measurement Standards drawn up by the Committee and those of the Technical Regulations of the Organization.

Cg-XV decisions
Res. 31 (Cg-XV) “Impl of QMS”

1. Recommended **QMS Implementation** for **NMHSs**
2. WMO **Quality Management Framework**
   - Develop overall QM **strategy** for WMO
   - Includes both the needs of Members and the implementation of WMO Programmes
   - WMO QMF aims at **ensuring** the development, use and maintenance of the **WMO technical documentation**, supporting QMS of Members

Cg-XV decisions
Res. 31 (Cg-XV)

3. Encouraged NMSs to implement QMS following appropriate **internationally recognized** standards, if possible ISO 9001
4. Encouraged NMSs to develop a QMS covering **most** of their activities
5. NMHSs may choose:
   - Whether or not to pursue certification
   - Whether to certify all or part of the activities covered by their QMS

Cg-XV decisions
Res. 32 (Cg-XV) “WMO QMF”

NMSs were requested to:

- Quality control on-site observations
- Ensure the traceability of measurements to recognized world standards approved for the use of WMO Members.

Standardization (WMO Regulatory Material)

Technical Regulations (WMO-No. 49)

(Mandatory publication):

- **Volume I**: General Meteorological Standards & Recommended Practices
- **Volume II**: Meteorological Service for International Air navigation
- **Volume III**: Hydrology
- **Volume IV**: **QM** (**Generic**, a proposal of ICTT-QMF approved by EC-LXII)

→ **Five Annexes**: **WMO Manuals**

Standardization (WMO Regulatory Material)

- **Basic Commissions (CBS, CIMO, CAS, CHy)**
  - CAS: **Manual on the observations of clouds and other meteors** (Vol. I of ICA) **(I)**, GAW Reports
  - CBS: **Manuals on Codes (II)**, **on GTS (III)**, **on GDPFS (IV)**, **on GOS (V)**
  - CBS: Guides on GOS, GDPFS, GTS
  - CIMO: Guide to Met. Instruments and Methods of Obs.
  - CHy: Guide to Hydro Practices, Technical Docs
- **App. Commissions** (CCl, CAgM, CAeM, **JCOMM**)
  - Some Manuals, e.g. **Manual on Marine Met Services (VI)** but mostly Guides to xx Practices or Services, TN and other Reports, e.g. IOM Report series

NOTE: Marked red are mandatory publications and are Annexes to WMO TR

Standardization (WMO Regulatory Material-QM)

- Manual on the **GDPFS**, Part II, Ch.2 QC of observational data and their reception at GDPFS Centres in real and non-real time (**authoritative reference** on all matters related to QC issues),
- Manual on the **GOS**, Part V, QC
- Guide to the **GOS**, Part VIII, QM
- **CIMO** Guide, Part III, QA and QM of Obs. Systems
- Manual on **Marine** Met Services, Vol. I, QC of Data

(Note: Sections on QM also in other Manual and Guides)

Manual on GDPFS, P II, CH.2

(QC of observational data and their reception at GDPFS Centres in **real** time)

- QC requires that an **operational entity** (WMC, RSMC, NMC or observing site) **has the ability** to select, edit, or otherwise **manipulate** observations according to its own set of physical or dynamical principles.
- The primary **responsibility** for QC of obs data rest with the **originating** NMS.
- NMS should **ensure** that when obs data enter GTS they are **free** from errors.
- NMS should implement **minimum standards** of real-time quality control (Appendix II-1).

Table I

GDPFS MINIMUM STANDARDS FOR QUALITY CONTROL OF INCOMING DATA (RECEIVED VIA THE GTS OR OTHER MEANS)

(1)	*Station list* (2)	*Types of report* (3)	*Times of observations** (4)	*Parameters to be quality-controlled* (5)	*Procedures for quality control* (6)	*Records to be maintained* (7)	*Minimum frequency for performing quality control* (8)
REAL TIME	WMCs, RSMCs and NMCs: Global exchange list of RBSNs in Volume A, WMO-No. 9, *Observing Stations*	SYNOP	00, 06, 12, 18	FM 12: All mandatory groups	*Checking* • Detection of mission data at centres • Adherence to prescribed coding formats • Internal consistency • Time consistency • Space consistency • Physical and climatological limits	• Information to identify source of data such as station, aircraft, ship	Preferably with each operational cycle; otherwise, with sufficient frequency to establish representative records
		SHIP	00, 06, 12, 18	FM 13: All mandatory groups			
		PILOT Parts A and B C and D	00, 06, 12, 18	FM 32: Sections 1, 2, 3, 4			
		PILOT SHIP Parts A and B C and D	00, 06, 12, 18	FM 33: Sections 1, 2, 3, 4	*Remedial Action* Before further processing, correct or flag erroneous or suspect data	• Type of deficiency (non-receipt, incomplete or incorrect reports, etc.)	
		TEMP Parts A and B C and D	00, 06, 12, 18	FM 35: Sections 1, 2, 3, 4, 5, 6			
		TEMP SHIP Parts A and B C and D	00, 06, 12, 18	FM 36: Sections 1, 2, 3, 4, 5, 6	*Notification:* Discrepancies and missing data should be made known to the appropriate centre or station	• Identification of deficient element (whole report, specific group, specific parameter, etc.)	
		PILOT MOBIL Parts A and B C and D		FM 34: Sections 1, 2, 3, 4			
		TEMP MOBIL Parts A and B C and D		FM 38: Sections 1, 2, 3, 4, 5, 6	NOTE: It is recognized that notification of not all errors or doubtful data can be done in real time by a processing centre. Thus when it becomes feasible binary data representation should be used to exchange together with observations: • Instruments • Information on data correction applied • Information on quality control	• Frequency of occurrence of data deficiencies (according to station type and element)	
		SATEM SATOB	Asynoptic	FM 86: Mean temperatures FM 88: Cloud-motion winds			
		Aircraft meteorological observations	Asynoptic	• Time and position • Wind • Temperature • Flight level			
		BUOY	Asynoptic	FM 18: Sections 1, 2			

(continued)

Manual on GDPFS, P II, CH.2

(QC of observational data and their reception at GDPFS Centres in **non-real** time)

1. Prior to storage of data they should be subject to the QC necessary to ensure a satisfactory standard of accuracy for users.
2. The primary responsibility for non-real-time QC should rest with Members which operate the centres that store the data. (Note: This apply also Members data storage.) This QC should be performed on a routine basis and should begin as soon as possible after the data have been received at the centre.
3. Prior to placing data in storage, all suspect values and proposed corrections should be appropriately marked for future users of data.

GDPFS MINIMUM STANDARDS FOR QUALITY CONTROL OF INCOMING DATA (RECEIVED VIA THE GTS OR OTHER MEANS) *(contd.)*

(1)	*Station list* (2)	*Types of report* (3)	*Times of observations** (4)	*Parameters to be quality-controlled* (5)	*Procedures for quality control* (6)	*Records to be maintained* (7)	*Minimum frequency for performing quality control* (8)
		CLIMAT**	Monthly	FM 71: Section 1			
		CLIMAT SHIP**	Monthly	FM 72: Section 1			
		CLIMAT TEMP**	Monthly	FM 75			
		CLIMAT TEMP SHIP**	Monthly	FM 76			
		BUFR	As defined within the message	FM 94: Section 4			
NON REAL TIME	WMCs, RSMCs and NMCs: Global exchange list of RBSNs in Volume A, WMO-No. 9, *Observing Stations*	Same as for real time plus:	Same as for real time plus:	Same as for real time plus:	*Checking* Same as for real time and in addition: • Review of recorded data in comparison with observations taken before and after • Inter-comparison of parameters and calculations • Check of supplementary data • Check of extreme values *Remedial Action* Correct errors and flag data as appropriate *Notification* Refer discrepancies to observing stations or WWW centre as follows: • Once per month from NMCs • Once every three months from RSMCs • Once every six months from WMCs and lead centres	*Summarize records developed in real time to include:* Same as for real-time with all data deficiencies found in real time combined with additional ones found in non-real time	With sufficient frequency to establish representative records
		ROCOB	Asynoptic	FM 39: Sections 1, 2			

* Use observation time nearest to maintain synoptic hours when observation not taken at main synoptic hours.

** Monthly on receipt and prior to initial distribution or use.

NOTES: (1) Any of the observational data types, described in column (3) in terms of their alphanumeric code forms, may also be transmitted in BUFR code. If so, they should be subject to the same minimum standards of quality control as their alphanumeric counterpart. New data (in BUFR) should have quality-control standards developed as appropriate.

(2) Lead centres for data-quality monitoring are given in WMO-No. 488, *Guide on the Global Observing System*, Part VII, paragraph 7.2.2.1.

Guide on GDPFS, CH.6
(QC Procedures and Techniques)

Gross-error limit checks
(against physical or climatological limits)

Table 6.4
Limit values for surface wind speed
(The value is considered suspect when MAX 1 < *ff* < MAX 2;
the value is considered erroneous when *ff* > MAX 2)

Area	*Winter*		*Summer*	
	MAX 1	*MAX 2*	*MAX 1*	*MAX 2*
45°S – 45°N	60 m s^{-1}	125 m s^{-1}	90 m s^{-1}	150 m s^{-1}
45°N – 90°N and 45°S–90°S	50 m s^{-1}	100 m s^{-1}	40 m s^{-1}	75 m s^{-1}

Guide on GDPFS, CH.6
(QC Procedures and Techniques)

Internal consistency checks

(Different parameters are checked against each other)

The different parameters in SYNOP reports are checked against each other. In the description below, the suggested checking algorithms have been divided into areas where the physical parameters are closely connected:

(*a*) Wind *dd/ff*

The wind information is considered to be erroneous in the following cases:

$dd = 00$ and $ff \neq 00$;

$dd \neq 00$ and $ff = 00$;

$dd = 99$ and $ff = 00$ or $ff \geq 05$ m s^{-1};

(*b*) Visibility *VV* and weather *ww*

The values of visibility and weather are considered suspect when:

$42 \leq ww \leq 49$ and $\{10 \leq VV \leq 89$ or $94 \leq VV \leq 99\}$;

$ww = 10$ and $\{00 \leq VV \leq 09$ or $90 \leq VV \leq 93\}$;

$VV < 10$ and $\{ww < 04$ or $ww = 05$ or $10 \leq ww \leq 16$ or $20 \leq ww \leq 29$ or $ww = 40\}$;

$\{VV < 60$ or $90 \leq VV \leq 96\}$ and $ww \leq 03$;

$\{60 \leq VV \leq 89$ or $97 \leq VV \leq 99\}$ and $\{04 \leq ww \leq 07$ or $38 \leq ww \leq 39\}$;

$\{ww = 11$ or $ww = 12$ or $ww = 28$ or $ww = 40\}$ and $\{00 \leq VV \leq 09$ or $90 \leq VV \leq 93\}$;

Manual on GOS, Part V, QC

1. QC of observational data consists of examination of data at **stations** at **data centres** to detect errors so that data may be corrected or flagged.
2. A QC system should include procedures for **returning to the source** of data to verify them and to prevent recurrence of errors.
3. Within the framework of the GOS, QC shall be a **real-time activity** which has to be performed prior to the transmission of the observational data on GTS.
4. The **primary responsibility** for QC of all obs data shall rest with the Members (where observations originated).

Guide on GOS, Part VIII, QM
(Ref: QMF)

1. The key aim: to check the **entire process** not only the final product.
2. Res.27 (Cg-XIV) –initiated WMO QMF to develop the following elements: WMO **technical standards**; **QMS**, including QC; and **certification** procedures.
3. The structure of the QMF corresponds to the following aims of WMO:
   a) To ensure adequate uniformity and **standardization** in the practices and procedures used by NMSs;
   b) To ensure **quality** of observational data, since the effectiveness of any NMS depends on the quality of data and products exchanged through the WMO Systems;
   c) To ensure overall **availability** of observational data for all purposes, especially for the NWP.

CIMO Guide, Part III
"QA & QM of OS"

1. ISO 9000: QMS – Fundamentals and vocabulary
2. ISO 9001: QMS – Requirements
3. ISO 9004: QMS – Guidelines for performance improvements
4. 9011 : Guidelines for quality and/or environmental management systems auditing
5. ISO /IEC 1 7025: General requirements for the competence of testing and calibration laboratories
6. ISO /IEC 20000: Information technology – Service management
7. WMO QMF
8. Accreditation of Laboratories
9. Factors affecting Data Quality

CIMO Guide, Part III
"QA & QM of OS"
(Factors affecting Data Quality)

a) User requirements
b) Functional and technical specifications
c) Selection of instruments
d) Acceptance tests
e) Compatibility
f) Siting and exposure
g) Instrumental errors
h) Data acquisition
i) Data processing
j) Real-time quality control
k) Performance monitoring
l) Testing and calibration
m) Maintenance
n) Training and education
o) Metadata

Manual on Marine Met Services

Para 5.6.3 “QC of Data” & App. I.15

- All Members should make every effort to apply the **minimum quality control procedures** (Appendix I.15) before dispatching the data to the global collecting centres.
- Centres should **ensure** that this minimum quality control has been **applied before** making the data available to Members.
- Details of national QC schemes should be made **available**.

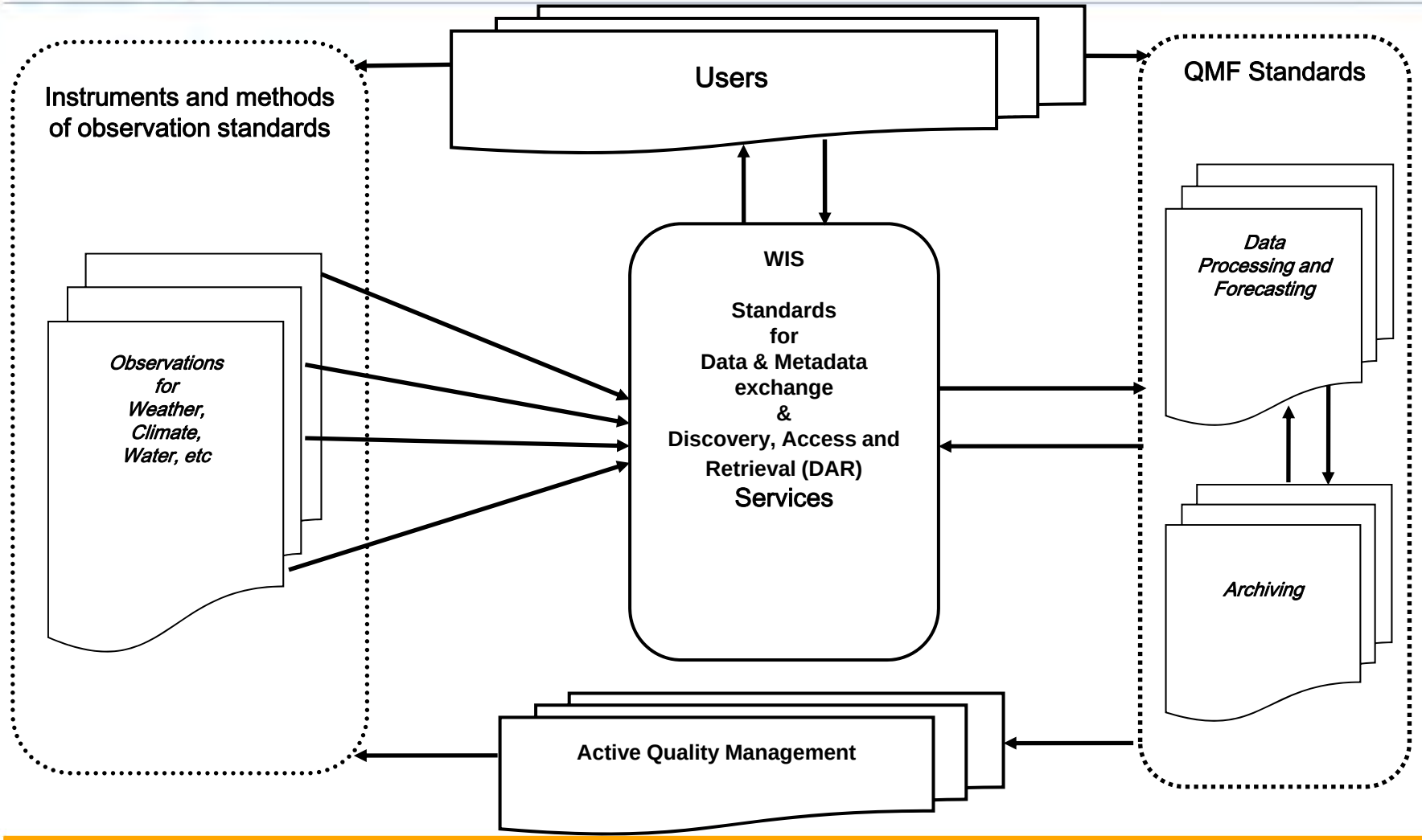
CBS

- **Responsible** for matters relating to:
  - Cooperation with Members, TCs and other bodies in the development and operation of **integrated systems for observing**, DP, TC, and DM in response to requirements;
  - **Observational systems, facilities and networks** (land, sea, air, and space) as decided by Members including, in particular, all technical aspects of the Global Observing System (GOS) of WWW.

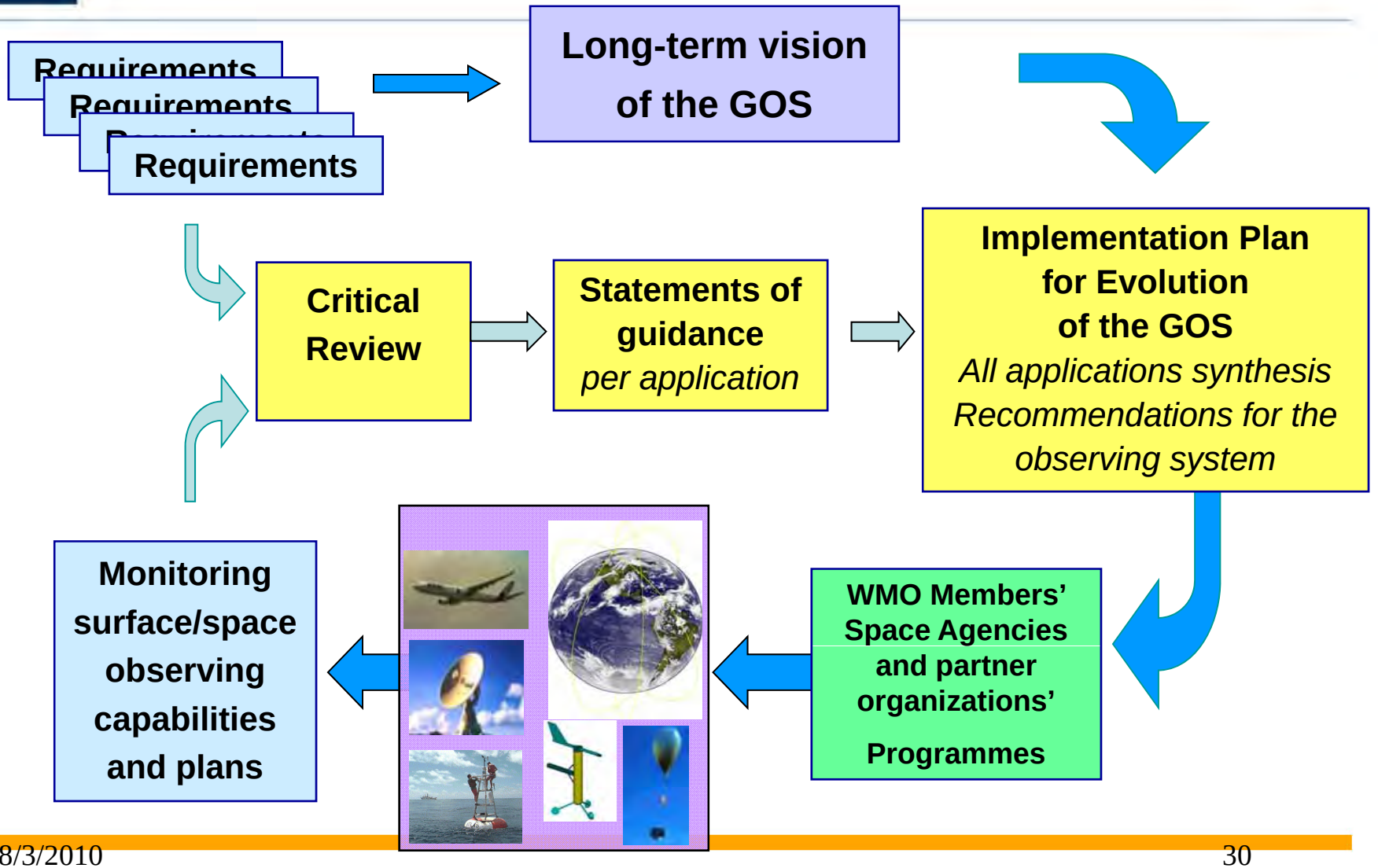
Res. 30 (Cg-XV) “WIGOS”

- One of the WMO’s **high** priorities;
- **Framework** enabling the integration and optimized evolution of WMO observing systems, and WMO’s contribution to co-sponsored systems;
- Focus on single management, governance, interoperability, **standardization**, ...

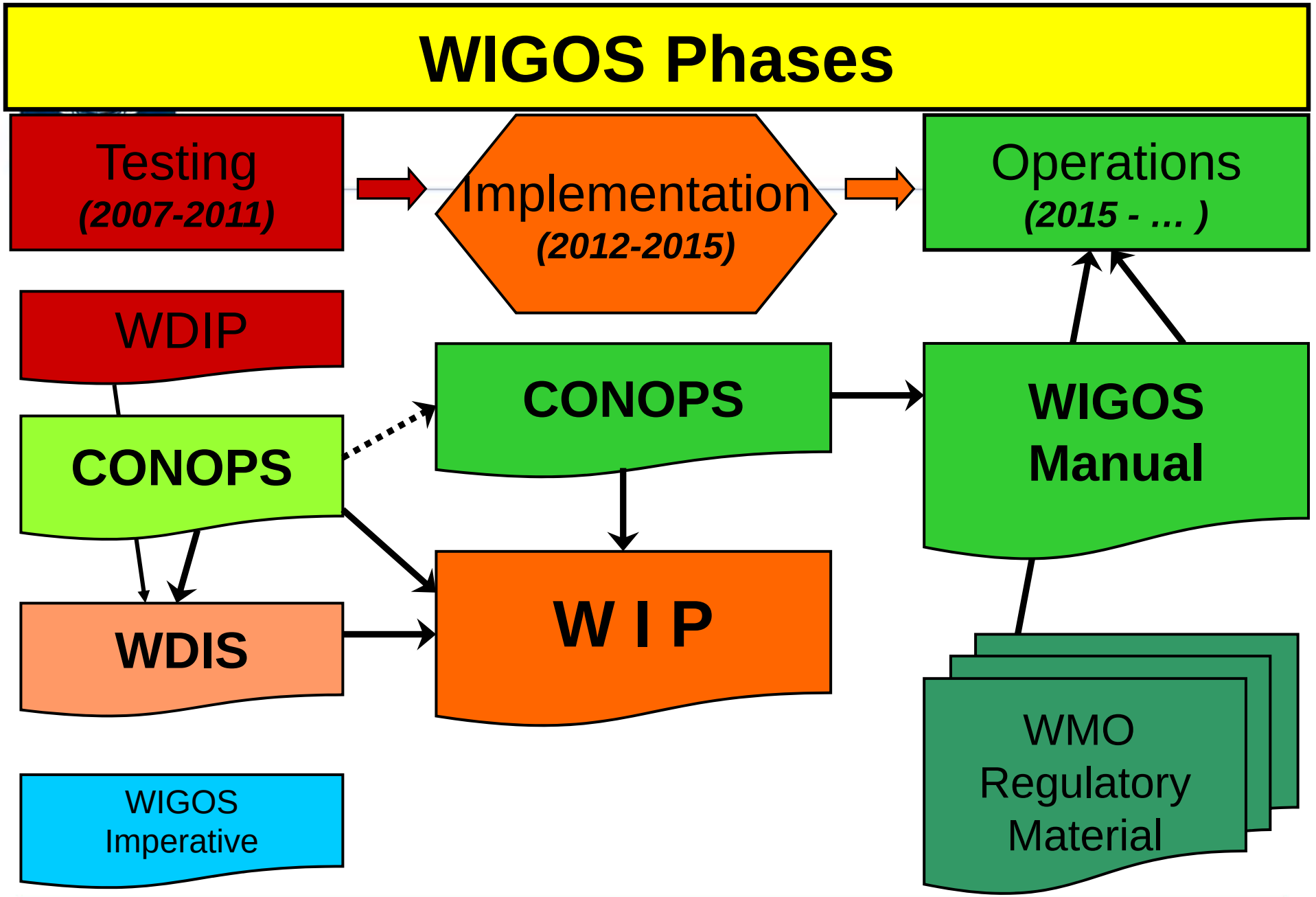
Key areas of standardization



WIGOS evolution process - RRR



WIGOS Phases



CIMO

- **Responsible** for matters relating to international standardization and compatibility of instruments and methods of observation of meteorological, related geophysical, and environmental variables:
  - Advice (types, characteristics, accuracies, performance),
  - Instrument comparisons and tests,
  - Recommendations (methods, calibration, …),
  - Reference instruments.

WMO Regulatory Material

- Process for standard development defined by TC
- TR > > **Cg**
- Manuals and Guides:
  - CBS > > **EC** > > Manual and Guide on GOS;
  - CIMO > > **EC** > > CIMO Guide.
- Technical Reports > > **TCs**:
  - CBS WWW Reports;
  - CIMO IOM Report series – 99 reports on WWW web.
- **Future**: (a) WIGOS Manual; (b) CIMO Manual; (c) Joint standards with ISO.

WMO Regulatory Material and other guidance

- Resolution 6 (EC-LIX):
  - **Vision for the Global Observing System in 2025;**
  - Functional **specifications** for AWSs (GOS Guide);
  - Basic **set of variables** for a standard AWS for multiple users (GOS Guide).

- Resolution 7 (EC-LIX):
  - **Measurements in severe icing conditions**;
  - **Standardized procedure for laboratory calibration of catchment type RI gauges**;
  - ToR of RRCs, **RICs** (CIMO Guide)**;**
  - **Procedure and reference instruments for field rainfall intensity intercomparisons.**

WMO TCs and the Region

- **RA II RICs**:
  - Beijing, China
  - Tsukuba, Japan

- Recommendations 11 and 12 (CIMO-XIV):
  - **Full** and basic **capabilities** and corresponding **functions of RICs**;
  - RICs must be regularly (≤5 years) evaluated to verify their capabilities by a recognized authority.

WMO TCs and the Region

- Capabilities (must):
  - have the necessary facilities and lab EQ;
  - maintain a set of meteorological standard instruments;
  - Apply international standards for cal labs (ISO 17025).
- **Functions** (must):
  - assist M in calibrating their national meteorological standards and related instruments (how?);
  - advise M on enquiries regarding instrument performance, maintenance and the availability of relevant guidance materials;
  - actively participate, or assist, in the organization of regional workshops on instruments;
  - inform M on an annual basis on the services provided and activities carried out.

WMO TCs and the Region

- **CIMO ET on RIC** (Casablanca, 4-5 Dec.09)
  - **Evaluation** scheme for RICs (or CAL labs of M)
  - **Status** on instrument traceability;
  - **Recommended** instruments for CAL Labs;
  - Guidance on **inter-labs comparisons.**
- **WIGOS PP** (GE, 8/9 Oct.09)
  - Siting classification of surface Oss;
  - Maintained performance classification of surface Oss.

CIMO Guide

Part I. Measurement of meteorological Variables:

- CHAPTER 1. General
- CHAPTER 2. Measurement of temperature
- CHAPTER 3. Measurement of atmospheric pressure
- CHAPTER 4. Measurement of humidity
- CHAPTER 5. Measurement of surface wind
- CHAPTER 6. Measurement of precipitation
- CHAPTER 7. Measurement of radiation
- CHAPTER 8. Measurement of sunshine duration
- CHAPTER 9. Measurement of visibility
- CHAPTER 10. Measurement of evaporation
- CHAPTER 11. Measurement of soil moisture
- CHAPTER 12. Measurement of UA pressure, temperature and humidity
- CHAPTER 13. Measurement of upper wind
- CHAPTER 14. Present and past weather; state of the ground
- CHAPTER 15. Observation of clouds
- CHAPTER 16. Measurement of ozone
- CHAPTER 17. Measurement of atmospheric composition

CIMO Guide

Part II. Observing Systems:

- CHAPTER 1. Measurements at automatic weather stations
- CHAPTER 2. Measurements and observations at aeronautical met stations
- CHAPTER 3. Aircraft observations
- CHAPTER 4. Marine observations
- CHAPTER 5. Special profiling techniques for the BL and the troposphere
- CHAPTER 6. Rocket measurements in the stratosphere and mesosphere
- CHAPTER 7. Locating the sources of atmospherics
- CHAPTER 8. Satellite observations
- CHAPTER 9. Radar measurements
- CHAPTER 10. Balloon techniques
- CHAPTER 11. Urban observations
- CHAPTER 12. Road Meteorological Measurements

Part III. QA and Management of Observing Systems:

- CHAPTER 1. Quality management
- CHAPTER 2. Sampling meteorological variables
- CHAPTER 3. Data reduction
- CHAPTER 4. Testing, calibration and intercomparison
- CHAPTER 5. Training of instrument specialists

ANNEX 1.B

OPERATIONAL MEASUREMENT UNCERTAINTY REQUIREMENTS AND INSTRUMENT PERFORMANCE

	(1) Variable	(2) Range	(3) Reported resolution	(4) Mode of measurement/ observation	(5) Required measurement uncertainty	(6) Sensor time constant	(7) Output averaging time	(8) Achievable measurement uncertainty	(9) Remarks
1.	**Temperature**								
1.1	Air temperature	–80 – +60°C	0.1 K	I	0.3 K for ≤ –40°C 0.1 K for > –40°C and ≤ +40°C 0.3 K for > +40°C	20 s	1 min	0.2 K	Achievable uncertainty and effective time-constant may be affected by the design of the thermometer solar radiation screen Time-constant depends on the air-flow over the sensor
1.2	Extremes of air temperature	–80 – +60°C	0.1 K	I	0.5 K for ≤ –40°C 0.3 K for > –40°C and ≤ +40°C 0.5 K for > +40°C	20 s	1 min	0.2 K	
1.3	Sea surface temperature	–2 – +40°C	0.1 K	I	0.1 K	20 s	1 min	0.2 K	
2.	**Humidity**								
2.1	Dewpoint temperature	–80 – +35°C	0.1 K	I	0.1 K	20 s	1 min	0.5 K	
						Wet-bulb temperature (psychrometer)			
2.2	Relative humidity	0 – 100%	1%	I	1%	20 s	1 min	0.2 K	If measured directly and in combination with air temperature (dry bulb) Large errors are possible due to aspiration and cleanliness problems (see also note 11)
						Solid state and others			
						40 s	1 min	3%	Solid state sensors may show significant temperature and humidity dependence

	(1) Variable	(2) Range	(3) Reported resolution	(4) Mode of measurement/ observation	(5) Required measurement uncertainty	(6) Sensor time constant	(7) Output averaging time	(8) Achievable measurement uncertainty	(9) Remarks
3.	**Atmospheric pressure**								
3.1	Pressure	500 – 1 080 hPa	0.1 hPa	I	0.1 hPa	20 s	1 min	0.3 hPa	Both station pressure and MSL pressure Measurement uncertainty is seriously affected by dynamic pressure due to wind if no precautions are taken Inadequate temperature compensation of the transducer may affect the measurement uncertainty significantly
3.2	Tendency	Not specified	0.1 hPa	I	0.2 hPa			0.2 hPa	Difference between instantaneous values
4.	**Clouds**								
4.1	Cloud amount	0/8 – 8/8	1/8	I	1/8	n/a		2/8	Period (30 s) clustering algorithms may be used to estimate low cloud amount automatically
4.2	Height of cloud base	0 m – 30 km	10 m	I	10 m for ≤ 100 m 10% for > 100 m	n/a		~10 m	Achievable measurement uncertainty is undetermined because no clear definition exists for instrumentally measured cloud-base height (e.g. based on penetration depth or significant discontinuity in the extinction profile) Significant bias during precipitation
4.3	Height of cloud top	Not available							

	(1) Variable	(2) Range	(3) Reported resolution	(4) Mode of measurement/ observation	(5) Required measurement uncertainty	(6) Sensor time constant	(7) Output averaging time	(8) Achievable measurement uncertainty	(9) Remarks
5.	**Wind**								
5.1	Speed	0 – 75 m s^{-1}	0.5 m s^{-1}	A	0.5 m s^{-1} for ≤ 5 m s^{-1} 10% for > 5 m s^{-1}	Distance constant 2 – 5 m	2 and/or 10 min	0.5 m s^{-1} for ≤ 5 m s^{-1} 10% for > 5 m s^{-1}	Average over 2 and/or 10 min Non-linear devices. Care needed in design of averaging process
5.2	Direction	0 – 360°	1°	A	5°	1 s	2 and/or 10 min	5°	Distance constant is usually expressed as response length Averages computed over Cartesian components (see Part III, Chapter 3, section 3.6 of this Guide)
5.3	Gusts	0.1 – 150 m s^{-1}	0.1 m s^{-1}	A	10%		3 s	0.5 m s^{-1} for ≤ 5 m s^{-1} 10% for > 5 m s^{-1}	Highest 3 s average should be recorded
6.	**Precipitation**								
6.1	Amount (daily)	0 – 500 mm	0.1 mm	T	0.1 mm for ≤ 5 mm 2% for > 5 mm	n/a	n/a	The larger of 5% or 0.1 mm	Quantity based on daily amounts Measurement uncertainty depends on aerodynamic collection efficiency of gauges and evaporation losses in heated gauges
6.2	Depth of snow	0 – 25 m	1 cm	A	1 cm for ≤ 20 cm 5% for > 20 cm				Average depth over an area representative of the observing site
6.3	Thickness of ice accretion on ships	Not specified	1 cm	I	1 cm for ≤ 10 cm 10% for > 10 cm				

	(1) Variable	(2) Range	(3) Reported resolution	(4) Mode of measurement/ observation	(5) Required measurement uncertainty	(6) Sensor time constant	(7) Output averaging time	(8) Achievable measurement uncertainty	(9) Remarks
6.4	Precipitation intensity	0.02 mm h^{-1} – 2 000 mm h^{-1}	0.1 mm h^{-1}	I	(trace): n/a for 0.02 – 0.2 mm h^{-1} 0.1 mm h^{-1} for 0.2 – 2 mm h^{-1} 5% for > 2 mm h^{-1}	< 30 s	1 min		Uncertainty values for liquid precipitation only Uncertainty is seriously affected by wind Sensors may show significant non-linear behaviour For < 0.2 mm h^{-1}: detection only (yes/no) sensor time constant is significantly affected during solid precipitation using catchment type of gauges
7.	**Radiation**								
7.1	Sunshine duration (daily)	0 – 24 h	60 s	T	0.1 h	20 s	n/a	The larger of 0.1 h or 2%	
7.2	Net radiation, radiant exposure (daily)	Not specified	1 J m^{-2}	T	0.4 MJ m^{-2} for ≤ 8 MJ m^{-2} 5% for > 8 MJ m^{-2}	20 s	n/a	0.4 MJ m^{-2} for ≤ 8 MJ m^{-2} 5% for > 8 MJ m^{-2}	Radiant exposure expressed as daily sums (amount) of (net) radiation
8.	**Visibility**								
8.1	Meteorological optical range (MOR)	10 m – 100 km	1 m	I	50 m for ≤ 600 m 10% for > 600 m – ≤ 1 600 m 20% for > 1500 m	< 30 s	1 and 10 min	The larger of 20 m or 20%	Achievable measurement uncertainty may depend on the cause of obscuration Quantity to be averaged: extinction coefficient (see Part III, Chapter 3, section 3.6, of this Guide). Preference for averaging logarithmic values

	(1) Variable	(2) Range	(3) Reported resolution	(4) Mode of measurement/ observation	(5) Required measurement uncertainty	(6) Sensor time constant	(7) Output averaging time	(8) Achievable measurement uncertainty	(9) Remarks
8.2	Runway visual range (RVR)	10 m – 1 500 m	1 m	A	10 m for ≤ 400 m 25 m for > 400 m – ≤ 800 m 10% for > 800 m	< 30 s	1 and 10 min	The larger of 20 m or 20%	In accordance with WMO-No. 49, Volume II, Attachment A (2004 ed.) and ICAO Doc 9328-AN/908 (second ed., 2000)
9	**Waves**								
9.1	Significant wave height	0 – 50 m	0.1 m	A	0.5 m for ≤ 5 m 10% for > 5 m	0.5 s	20 min	0.5 m for ≤ 5 m 10% for > 5 m	Average over 20 min for instrumental measurements
9.2	Wave period	0 – 100 s	1 s	A	0.5 s	0.5 s	20 min	0.5 s	Average over 20 min for instrumental measurements
9.3	Wave direction	0 – 360°	1°	A	10°	0.5 s	20 min	20°	Average over 20 min for instrumental measurements
10.	**Evaporation**								
10.1	Amount of pan evaporation	0 – 100 mm	0.1 mm	T	0.1 mm for ≤ 5 mm 2% for > 5 mm	n/a			

Notes:

1. Column 1 gives the basic variable.
2. Column 2 gives the common range for most variables; limits depend on local climatological conditions.
3. Column 3 gives the most stringent resolution as determined by the *Manual on Codes* (WMO-No. 306).
4. In column 4:
   I = Instantaneous: In order to exclude the natural small-scale variability and the noise, an average value over a period of 1 min is considered as a minimum and most suitable; averages over periods of up to 10 min are acceptable.
   A: = Averaging: Average values over a fixed period, as specified by the coding requirements.
   T: = Totals: Totals over a fixed period, as specified by coding requirements.

WMO Regulatory Material

2010 updates:

- 2010 updated of the Guide on the GOS (July 2010)
- 1st Supplement to the 7th Edition of CIMO Guide (CIMO-XV, September 2010)
- 2010 updated of the Manual on the GOS (November 2010)

QM in Surface, Climate and Upper-air Observations

1. **Traceability**
   - **Accuracy**
   - **Compatibility**

2. **Responsibility**
   - **QFCS, DRR, WIGOS,**
   - **CB, Aviation Met**

Training Workshop on Calibration

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