

**WORLD METEOROLOGICAL ORGANIZATION**

**COMMISSION FOR BASIC SYSTEMS**

**OPAG ON INTEGRATED OBSERVING SYSTEMS**

**INTER-PROGRAMME EXPERT TEAM ON THE OBSERVING  
SYSTEM DESIGN AND EVOLUTION (IPET-OSDE)**

**SECOND *AD HOC* WORKSHOP ON  
OBSERVING SYSTEM DESIGN**

*(OSDW2)*

Geneva, Switzerland, 2-4 February 2015

**FINAL REPORT**



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### **Regulation 42**

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In the case of a recommendation made by a working group between sessions of the responsible constituent body, either in a session of a working group or by correspondence, the president of the body may, as an exceptional measure, approve the recommendation on behalf of the constituent body when the matter is, in his opinion, urgent, and does not appear to imply new obligations for Members. He may then submit this recommendation for adoption by the Executive Council or to the President of the Organization for action in accordance with Regulation 9(5).

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*[Group picture]*

## **AGENDA**

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## EXECUTIVE SUMMARY

The second *ad hoc* Workshop on Observing System Design, OSDW2, of the Commission for Basic Systems (CBS) Open Programme Area Group (OPAG) on Integrated Observing Systems (OPAG-IOS) Inter-Programme Expert Team on the Observing System Design and Evolution (IPET-OSDE) was held at the WMO Headquarters in Geneva, Switzerland from 2 to 4 February 2015 and was chaired by the Chair of the IPET-OSDE, Dr John Eyre (United Kingdom).

The workshop's goal was to respond to the WIGOS Implementation Key Activity Area No. 3 (KAA#3) on design, planning and optimized evolution of WIGOS and its regional, sub-regional and national component observing systems. It particularly followed up from the first workshop, and follow-up activities by the IPET-OSDE, which had proposed Observing System Network Design (OSND) principles to be included in the Manual on WIGOS (reviewed by all WMO technical commissions, then endorsed by CBS Ext.(2014), consequently reviewed by WMO Members, and now submitted for approval to Cg-17).

According to the CBS Ext.(2014) guidance and input from the participants and other groups (e.g. GRUAN WG, GAW, GCW), the workshop further developed draft high-level OSND guidance materials, based on the OSND principles. Such guidance material is provided in annexes of this report, and it will be used during follow-up activities by OSDW2 participants to prepare the draft high-level guidance on Observing Network Design eventually to be proposed for inclusion in the future Guide to WIGOS. It is planned to distribute the draft guidance more widely to other contributors for their review and comments with the goal of submitting draft guidance to the fifth Session of the Inter-Commission Coordination Group on the WMO Integrated Global Observing System (ICG-WIGOS) for its consideration.

The workshop agreed on a revised workplan and roadmap for the further development of guidance for OSND (**Annex III**). The roadmap provides details on the role of this workshop's participants and other stakeholders in this regard.

The Fourth session of the ICG-WIGOS, Geneva, 17-20 February 2015, will be invited to review the progress and recommendations of the workshop and to provide further advice to the IPET-OSDE.

The second session of the IPET-OSDE (tentatively scheduled in Geneva in April 2016) will review and, if necessary, revise the draft OSND guidance and roadmap.

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## GENERAL SUMMARY

### 1. ORGANIZATION OF THE SESSION

#### 1.1 *Opening of the meeting*

1.1.1 The second *ad hoc* Workshop on Observing System Design, OSDW2, of the CBS<sup>1</sup> OPAG-IOS<sup>2</sup> Inter-Programme Expert Team on the Observing System Design and Evolution (IPET-OSDE) opened at 10.00 hours on Monday 2 February 2015, at the WMO Headquarters in Geneva, Switzerland.

1.1.2 Dr Miroslav Ondras, Chief, Observing Systems Division of the WMO Observing and Information Systems Department, opened the workshop on behalf of the WMO. He recalled that much has been achieved with regard to the WIGOS Framework Implementation and its ten Key Activity Areas (KAA) since the first workshop in November 2013. Substantial progress was particularly made with regard to (i) WIGOS metadata, (ii) development of WIGOS Regulatory Materials, and (ii) WIGOS Quality Management. Indeed WIGOS Metadata Standard has been proposed for inclusion in the WIGOS Manual, and the Observing System Capability Analysis and Review Tool (OSCAR) is being developed on the basis of that standard. Much work has also been undertaken with regard to Regulatory Materials, resulting in the WIGOS Technical Regulations and WIGOS Manual being submitted to Congress this year. Efforts continue to be made in the field of quality management for WIGOS, and a quality monitoring workshop was held in December 2014 in Geneva that helped to take forward a number of useful recommendations in this regard.

1.1.3 Dr Ondras also recalled that most of the work needed to complete KAA#3<sup>3</sup> falls under the responsibility of the IPET-OSDE, and this workshop is tasked to follow up from the first workshop on the development of Observing System Network Design (OSND) principles and guidance. Dr Ondras was pleased to report that the Observing System Network (OSND) Design Principles initially drafted by the first workshop and further elaborated by the first meeting of the IPET-OSDE (Geneva, 31 March – 3 April 2014) have been incorporated into the Manual on WIGOS, that was endorsed by the 2014 Extraordinary Session of the CBS (Asunción, Paraguay, 8 to 12 September 2014), and now submitted to the Seventeenth Session of the WMO Congress in mid-2015.

1.1.4 Taking into account the CBS Ext.(2014) guidance, Dr Ondras invited the workshop to discuss elaboration of OSND guidance based on the agreed OSND principles, and to discuss possible recommendation(s) to be made to the fourth Session of the ICG-WIGOS (Geneva, 17-20 February 2015), and to the CBS through the IPET-OSDE and ICT-IOS regarding OSND.

1.1.5 In closing, Dr Ondras invited the workshop to grasp this opportunity to help guide WMO into the future, when, during this week, the participants will deliberate and make recommendations regarding observing system design guidance to the CBS through the IPET-OSDE, which will have its second meeting in 2016. He wished participants a successful and productive workshop and an agreeable stay in Geneva.

1.1.6 Dr John Eyre (United Kingdom), Chair of IPET-OSDE, also greeted the participants and expressed his confidence that the workshop would work hard to fulfil its obligations.

1.1.7 The participants introduced themselves. The list of participants is provided in ***Annex I***.

#### 1.2 *Adoption of the agenda*

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1 Commission for Basic Systems

2 Open Programme Area Group on Integrated Observing Systems

3 KAA#3: Design, planning and optimized evolution of WIGOS and its regional, sub-regional and national component observing systems

1.2.1 The Chair presented and explained the provisional agenda, and the workshop adopted it. The adopted **Agenda** is reproduced at the beginning of this report.

### **1.3 Working arrangements**

1.3.1 The workshop agreed on its working hours and adopted a tentative timetable for consideration of the various agenda items.

1.3.2 The workshop established the following writing groups for the duration of this event (writing group leads are underlined):

- **Group 1:**  
Member: Jay Lawrimore (USA)  
Objective: to review GCOS and other climate related materials and identify generic OSND guidance  
Outcome of Group 1 discussions, is summarized in **Annex VII**, Part C.
- **Group 2:**  
Member: John Eyre (UK)  
Objective: to review input from the GRUAN Working Group and from Li Bai (China) for developing generic OSND guidance  
Outcome of Group 2 discussions is summarized in **Annex XII**.
- **Group 3:**  
Member: Stefan Klink (EUMETNET)  
Objective: to review EUMETNET materials and identify generic OSND guidance  
Outcome of Group 3 discussions is summarized in **Annex X**, Part B.
- **Group 4:**  
Members: Elena Saltikoff (Finland), Islam Maher (Egypt) and Jochen Dibbern (Germany)  
Secretariat: Miroslav Ondras  
Objective: to review the current Guide to the GOS and extract the generic OSND guidance  
Outcome of Group 4 discussions is summarized in **Annex VI**.
- **Group 5:**  
Members: Yoshiaki Sato (Japan), and Erik Andersson (ECMWF)  
Secretariat: Etienne Charpentier  
Objective: to review IPET-OSDE materials (i.e. appendix B of OSDW2 doc. No. 3), to make it consistent with the OSND principles, and prepare improved and new generic OSND guidance  
Outcome of Group 5 discussions is summarized in **Annex XI**.

## **2. GUIDANCE FROM THE CHAIRPERSON**

### **2.1 Report of the Chairperson**

2.1.1 The IPET-OSDE Chairperson recalled the activities undertaken so far under the IPET-OSDE and other bodies for the development of OSND principles and guidance materials (see item 3 for details):

- Outcome of the *ad hoc* workshop on Observing System Design (OSDW1), which was held, under the auspices of the IPET-OSDE, in Geneva, Switzerland from 12 to 14 November 2013 (see final report on the web<sup>4</sup>);
- Follow up activities according to the roadmap agreed at OSDW1; and particularly the

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4 <http://www.wmo.int/pages/prog/www/OSY/Reports/OSDW1-Final-Report.pdf>



development and review of OSND principles by the IPET-OSDE1 (Geneva, 31 March – 3 April 2014) and the third session of the ICG-WIGOS (Geneva, 10-14 February 2014);

- Submission of the revised version of the draft OSND Principles to the ICG-WIGOS Task Team on WIGOS Regulatory Material for submission to the Presidents of Technical Commissions and WMO Members as part of their review of the WIGOS Manual. The latest version of the OSND principles is being submitted to the WMO Seventeenth Congress for approval, and is provided in **Annex IV**.

## **2.2 Role of the workshop in the context of the IPET-OSDE work plan for CBS**

2.2.1 The Chair provided an overview of the role of the workshop in the context of the IPET-OSDE workplan for CBS and of guidance received from the CBS 2014 Extraordinary Session (Asunción, Paraguay, 8 -12 September 2014) (CBS Ext. (2014)). He recalled that this Workshop has been organized under the auspices of the CBS IPET-OSDE, and referred to the Terms of Reference of that Expert Team. In particular, he recalled that one of the responsibilities of IPET-OSDE is to propose guidance regarding observing system network design (OSND) principles, and this Workshop presents one activity in this regard. In particular, the proposed objectives and tasks for this workshop are:

- Consider the OSND Principles – their review status and any comments received. Propose any changes needed. (Agenda item 3)
- Recall the OSND draft guidance material developed at and following OSDW1. (Agenda item 3)
- Consider the status and plans for WIGOS documentation as a whole and the proposed role of the OSND Principles and OSND guidance material within the overall WIGOS framework. (Agenda items 4 and 5)
- Consider other available material relevant to the development of OSND guidance material, which might be available from a diverse range of sources. (Agenda item 6)
- Continue work on the development of OSND guidance material, improving and extending existing material, as allowed by the time constraints of the meeting. (Agenda item 7)
- Develop a plan and timetable for further development of OSND guidance material, with the aim of having a complete draft ready for IPET-OSDE2 (early 2016). (Agenda items 8 and 9)
- Prepare text to summarise the status and plans for these activities for presentation at ICG-WIGOS-4, 16-20 February 2015. (Agenda item 9)

2.2.2 The Chair also explained that it is possible that the scoping of OSND guidance material may prove difficult because of uncertainties in the plans for development of other strands and layers of WIGOS documentation. If this is found by the meeting to be a major issue, then it may be more productive for the meeting to spend some of its time of drafting proposals for the structure of relevant parts of WIGOS documentation, for consideration by ICG-WIGOS-4.

## **3. REVIEW THE STATUS OF THE OBSERVING SYSTEM NETWORK DESIGN (OSND) PRINCIPLES**

3.1. The workshop recalled the activities under the OPAG IOS for the development of observing systems network design (OSND) principles and guidance through the IPET-OSDE. In particular, following OSDW1, work on developing OSND Principles and associated guidance material has proceeded according to the plan, and draft OSND Principles were presented to ICG-WIGOS-3

(Geneva, 10-14 February 2014). ICG-WIGOS noted the progress on the draft OSND Principles and agreed that draft OSND Principles ought to be submitted to the WIGOS Regulatory Material. Further review and revision of the draft OSND Principles was made by the IPET-OSDE-1 (31 March – 3 April 2014), and submitted to the Task Team on WIGOS Regulatory Materials. It formed part of the draft WIGOS Manual that was reviewed by the WMO technical commissions.

3.2. The workshop also recalled that the ICT-IOS-8 (Geneva, 7-10 April 2014) noted the draft OSND Principles with appreciation, concurred with the Principles proposed, and agreed that they should be presented to the 2014 Extraordinary Session of the CBS (CBS-Ext.(14), Asunción, Paraguay, 8 to 12 September 2014) for its information. CBS Ext. (2014) appreciated the work of the IPET-OSDE on OSND principles and guidance. It recommended that these principles, listed in the Annex to paragraph of the CBS Ext.(2014) report (and reproduced in **Annex IV**), be included in the first edition of the Manual on WIGOS.

3.3 CBS Ext.(2014) recommended through its Recommendation 3.1(1)/1 (CBS-Ext.(2014)) that the Volume I, PART I – WIGOS and Manual on WIGOS as given in the Annex 1 and Annex 2, respectively to this recommendation, be adopted by the Cg-17 with effect from 1 January 2016. Both drafts were available for the review (from 1 October until 31 December 2014) by WMO Members at the WMO web page<sup>5</sup>. The review process was in accordance with the General Provisions of the WMO Technical Regulations (WMO-No. 49), Volume I, that any amendments to the Technical Regulations submitted by Members or by constituent bodies should be communicated to all Members at least three months before they are submitted to Congress.

3.4 The workshop also noted that, during the review process of the WIGOS Regulatory Materials whereby all Technical Commissions and Members were consulted, the Secretariat has received no comment regarding the proposed OSND principles (**Annex IV**).

3.5 The workshop noted that some of the guidance material under development may conflict with other existing regulatory material or Resolution(s). Efforts will need to be made after the adoption of the OSND principles to resolve such conflicts.

3.6 The workshop agreed that there was no more work required prior to Cg-17 with regard to the OSND principles.

#### **4. REVIEW THE VISION FOR WIGOS GUIDANCE AND DOCUMENTATION AS A WHOLE**

4.1 The workshop reviewed the purpose and scope of the WIGOS regulatory material together with brief information about the WMO Technical Regulations (WMO-No. 49). It reviewed information about the “thin layer” of the Guide to WIGOS that should be taken into account when developing OSND guidance materials. The Chair introduced his perspective on WIGOS documentation: its horizontal structure (layers) and vertical structure (strands) as summarized in figure 1 below.

4.2 The workshop recalled that, following the decision of the Sixteenth World Meteorological Congress to proceed with the implementation of WIGOS, the drafts of the WMO Technical Regulations (WMO-No. 49), Volume I, Part I - WIGOS, and the Manual on WIGOS (a future Annex to the Volume I) were developed by the TT on WIGOS Regulatory Material (TT-WRM) of the ICG-WIGOS. This marks a very important milestone on the way toward establishing the WIGOS Framework.

4.3 Information on WMO regulatory and non-regulatory material can be found on the WMO website<sup>6</sup>. Such information was taken into account for the development of the WIGOS regulatory

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5 <http://www.wmo.int/pages/prog/www/wigos/WRM.html>

6 <http://www.wmo.int/pages/prog/www/wigos/TT-WRM.html>

material, and mainly consists of (i) *Technical Regulations, Basic Documents No. 2*<sup>7</sup>, and (ii) Guidelines on the Preparation and Promulgation of WMO Technical Regulations<sup>8</sup>.

4.4 The workshop noted that, in accordance with the *Basic Documents No. 1* (WMO-No. 15), 2012 edition, decisions concerning changes in the Technical Regulations, together with relevant documents, shall be sent to Members in sufficient time to allow a period of at least nine months between the receipt of these documents and the date of implementation. In no case shall this period be less than two months (Regulation 127).

4.5 The workshop further noted that, in addition to the Technical Regulations, appropriate guides are published by the Organization. The guides describe practices, procedures and specifications which Members are **invited** to follow or implement. The WMO technical commissions are responsible for the selection of material to be included in the guides. Recommendations for amendments made by an appropriate technical commission are subject to the approval of the Executive Council.

4.6 The workshop acknowledged that the Observing System Network Design (OSND) Principles were incorporated into the Manual on WIGOS; the implementation guidance on the OSND Principles must be developed, incorporated into the Draft Guide to WIGOS and submitted to ICG-WIGOS-5 for the review and to EC-68 (2016) for approval.

4.7 Some high-level guidance on OSND Principles was already discussed and produced at IPET-OSDE1. The workshop agreed that such non-regulatory material should be further developed to provide more detailed guidance (best practices, guidelines) on how the OSND Principles (i.e. provisions 2.2.2.1 and 2.2.2.2 of the draft WIGOS Manual) should be implemented, i.e. applied by NMHS managers responsible for planning, implementation and evolution of national observing systems and networks.

4.8 The workshop noted, and concurred with the proposed change (included with the principles to be submitted to Cg-17) regarding the naming of the OSND principles, i.e. *Principles for Observing ~~System~~ Network Design*.

Note: While the old terminology OSND is still being used in this report for consistency with the current reporting and input to the workshop, it is planned to use the terminology Observing Network Design (OND) in the future.

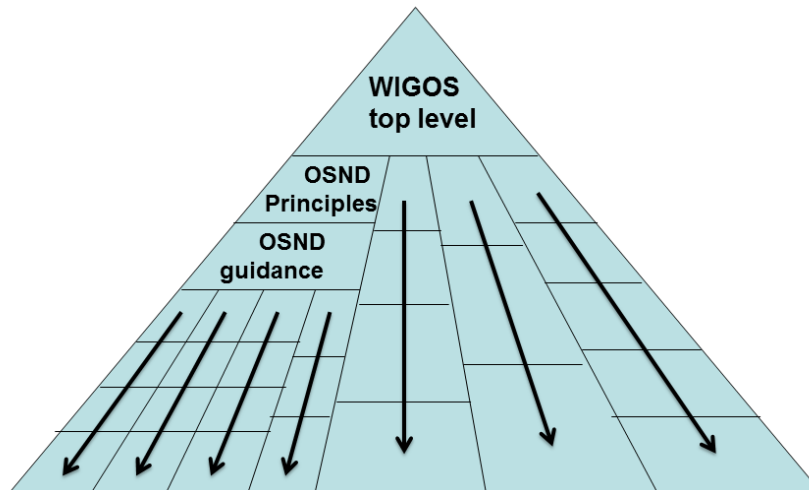
4.9 The meeting reviewed the structure of the WIGOS Manual, and recalled that the OSND principles are part of section 2, "*Common attributes of WIGOS component observing systems*".

## 5. METHODOLOGY FOR DEVELOPING THE REQUIRED OSND GUIDANCE MATERIALS

5.1 Recalling the objectives of the workshop as detailed in paragraph 2.2.1, the workshop discussed and agreed on a methodology to be used for developing OSND guidance materials. The workshop discussed the scope of the guidance material to be developed. It also discussed what strands (see figure 1) to address OSND guidance within the WIGOS Guide, e.g. by observing network, application area, technology, region, etc. A list could be proposed to ICG-WIGOS.

7 (WMO-No. 49), Volume I – General Meteorological Standards and Recommended Practices, 2011 edition, updated in 2012 – [http://library.wmo.int/opac/index.php?lvl=notice\\_display&id=14073](http://library.wmo.int/opac/index.php?lvl=notice_display&id=14073)

8 [http://library.wmo.int/opac/index.php?lvl=notice\\_display&id=15872](http://library.wmo.int/opac/index.php?lvl=notice_display&id=15872)



**Figure 1:** OSND Principles and guidance: WIGOS documentation

## 5.2 The workshop agreed on the following:

- OSND guidance to be developed for the WIGOS Guide should be generic, and so some generic materials will have to be developed, and existing draft materials will have to be made generic;
- The task of this workshop should be to look “upwards” (referring to figure 1) when drafting the OSND guidance, i.e. address the guidance to be provided to Members regarding the OSND principles, without having necessarily to consider the lower levels of guidance materials in the various strands (figure 1).
- The workshop should start with the guidance materials developed by IPET-OSDE (Appendix B, doc. No. 3 of OSDW2), and try to identify what is generic, to be retained within this layer of OSND guidance;
- Additional materials provided by the participants at this workshop (i.e. some sections of Annexes **VI, VII, VIII, IX, X, XI, and XII**) also need to be considered;
- Part of the draft OSND guidance provided as input to this workshop is not targeted directly to Members but is advice to WMO Programmes, Technical Commissions. Such advice will have to be considered by the ICG-WIGOS;
- OSDW2 participants in developing the draft guidance will identify a list of words with proposed definitions (e.g. network, tiered network, sustainable, ...) (**action; OSDW2 participants; mid-Oct. 2015**). This list will then be submitted to ICG-WIGOS-5 for review.

5.3 The workshop noted that the final detailed structure of the WIGOS Guide is not known yet. However, the structure of Guide should mirror the structure of the Manual. This situation should not prevent the Workshop and the IPET-OSDE making progress regarding the development of OSND guidance to be included in the Guide. There may be material for which it is unclear whether it is sufficiently generic for this layer of guidance or more specific (i.e. to particular observing programmes, observing systems or applications), and so more appropriate to lower layers of guidance. It was agreed that, if in doubt, the material should be retained for the time being within the generic guidance; it could be moved to other sections of the WIGOS Guide later, if necessary.

## 6. REVIEW OF AVAILABLE INPUTS TO OSND GUIDANCE MATERIAL

6.1 The workshop reviewed available materials and information that could be used to produce OSND guidance. These included in particular comments from GRUAN WG members, and other materials from GOS, GCOS, GAW, GCW and EUMETNET. These materials contribute to the intermediate layer of general guidance that lies between the WIGOS OSND Principles and the lower layers of guidance/documentation that apply / will apply to the individual observing system components of WIGOS.

### ***Input received by the IPET-OSDE Chair***

6.2 The Workshop noted the comments from IPET-OSDE member, Li Bai (China), made to the IPET-OSDE Chair after IPET-OSDE1 meeting, and agreed that they could be considered as material for developing OSND guidance. These comments together with the related workshop's feedback and recommendations are provided in **Annex XII**, part B.

### ***GRUAN Working Group members***

6.3 John Eyre reported on the specific expertise of the GCOS Reference Upper Air Network (GRUAN) community with regard to observing system design. He explained that following the GRUAN-GSICS-GNSSRO WIGOS Workshop on "Upper Air Observing System Integration and Application", Geneva, 6-8 May 2014, and to ensure that the GRUAN community was given an explicit invitation to comment on the draft OSND Principles, the latest available draft was forwarded to leaders of the GRUAN community for comment on 30 May 2014. On 6 June 2014, general collated comments were received from leaders of the GRUAN community, and also their detailed comments on the draft OSND Principles. On 19 June 2014, some responses to these comments were sent.

6.4 It was noted that some of the comments received from GRUAN leaders derived from the fact that, initially, they were only invited to comment on the draft OSND Principles themselves and they did not see the associated draft guidance material developed at OSDW1. The associated draft guidance material was also made available to GRUAN leaders on 19 June 2014. This prompted some further dialogue but no more substantive issues emerged.

6.5 The workshop agreed that the comments received from GRUAN contain some very good points, but that they are best addressed not by modifying or expanding the OSND Principles themselves; they represent valuable input material to help improve and extend the next layer of guidance material. Specifically, they highlight the use in the OSND Principles of the word "sustainable" and point out a possible ambiguity.

6.6 The workshop's feedback and recommendations regarding the GRUAN Working Group comments are provided in **Annex XII**, part A.

6.7 The workshop requested the Secretariat to check status of the review of WIGOS Regulatory Materials by GCOS, and to invite GCOS to review such materials in case it had not done it at this point (**action; Secretariat; ASAP**).

### ***Global Observing System (GOS)***

6.8 Islam Maher (Egypt) reported on ET-SBO efforts to compile materials that could be used for developing OSND Guidance Materials. The ET-SBO proposed some input aligned with the 12 OSND principles for consideration by the workshop, some of which relating to materials from WMO no. 488, WMO Guide to the GOS, and possible update of relevant paragraphs. This input is provided in **Annex VI**. The workshop considered this input, and took it into account for further discussion.

6.9 The meeting also noted the Final report<sup>9</sup> of the Expert Team on Surface Based Observations Sub-Group on WIGOS Regulatory Materials (Geneva, Switzerland, 24-28 Nov. 2014), which includes in its Annexes I and II some statements related to network design.

6.10 The workshop recalled that weather systems are cross-boundary in nature, and this together with local meteorology should be taken into account when designing observing network systems. The workshop therefore noted the possibility for designing observing systems outside of

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9 [http://www.wmo.int/pages/prog/www/OSY/Reports/ET-SBO\\_SG-RM\\_Nov\\_2014\\_Final\\_Report.pdf](http://www.wmo.int/pages/prog/www/OSY/Reports/ET-SBO_SG-RM_Nov_2014_Final_Report.pdf)

a country's territory in order to increase the impact of the observations to end user applications in the country, and beyond.

### ***Global Climate Observing System (GCOS)***

6.11 Jay Lawrimore (USA) provided an overview of several reports, correspondence and related papers written over the past decade that provide information that could be helpful in developing OSND guidance that lies between the WIGOS OSND Principles and the lower layers of guidance/documentation that apply or will apply to the individual observing system components of WIGOS. A list of pertinent documents is included below and notes of interest from each are presented to the workshop in more detail (see ***Annex VII***, part A). These include information on metadata and data management, station siting and continuity, tiered design and other associated information.

- Guidelines on Climate Observation Networks and Systems; WMO/TD No. 1185<sup>10</sup>.
- Guidelines on Climate Metadata and Homogenization; WMO/TD No. 1186<sup>11</sup>.
- Observing Weather and Climate from the Ground Up: A Nationwide Network of Networks<sup>12</sup>.
- Comments from William Wright (ICG-WIGOS) on a draft WIGOS discussion paper regarding Externally-Sourced data.
- Report from Expert Team on National Networks and Observations in Support of Climate Activities<sup>13</sup> (OPAG on Climate Data and Data Management).
- Report on Automated Versus Manual Surface Meteorological Observations – Decision Factors<sup>14</sup>.
- WMO Commission for Climatology (CCI) Guidelines on Data Management, Version 5.0<sup>15</sup>.

6.12 In addition, Dr Lawrimore presented links to documentation (see ***Annex VII***, part B) comprising a spectrum of operational networks including a reference climate network, an automated meteorological network, a national network supported by manual observations, and a network that provides externally sourced observations. This documentation for existing networks may serve as a reference for observing system network design.

6.13 The workshop noted that, in the OSND guidance to be produced, references can be made to existing documents provided that it is clear that such documents are routinely being kept updated.

6.14 The meeting noted that the next AOPC meeting (Zürich, Switzerland, 17-20 March 2015) was an opportunity to report on the outcome of this workshop.

### ***Global Atmosphere Watch (GAW)***

6.15 Oksana Tarasova (WMO Secretariat) reported on the activities of the Global Atmosphere Watch (GAW) with regard to Observing Systems Design. She recalled that GAW is a WMO Programme that addresses atmospheric chemical composition and related physical characteristics of the global atmosphere. It consists of a coordinated system of networks of observing stations, methods, techniques, facilities and arrangements encompassing the many monitoring and related

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10 [http://www.wmo.int/pages/prog/wcp/wcdmp/wcdmp\\_series/index\\_en.html](http://www.wmo.int/pages/prog/wcp/wcdmp/wcdmp_series/index_en.html)

11 [http://www.wmo.int/pages/prog/wcp/wcdmp/wcdmp\\_series/index\\_en.html](http://www.wmo.int/pages/prog/wcp/wcdmp/wcdmp_series/index_en.html)

12 <http://www.nap.edu/catalog/12540/observing-weather-and-climate-from-the-ground-up-a-nationwide>

13 <http://www.bom.gov.au/wmo/climate/ccl/opag1.shtml>

14 <http://www.bom.gov.au/wmo/climate/ccl/opag1.shtml>

15 <http://www.bom.gov.au/wmo/climate/ccl/opag1.shtml>

scientific assessment activities. The details of the presented information regarding the GAW framework with regard to Observing System Network Design are provided in **Annex VIII**. This included in particular (i) requirements to the GAW regional stations (Part B of **Annex VIII**), (ii) main principles of the GAW Quality Management Framework (Part C of **Annex VIII**), and (iii) consistency between OSND principles and GAW network management practices (Part D of **Annex VIII**).

6.16 The workshop noted that the GAW is following the GCOS monitoring principles, which are captured in the OSND principles, and meant to be captured in future OSND guidance.

6.17 The workshop agreed that while it is understood that the design of observing networks is primarily driven by national funding and priorities, Members should be encouraged also to take into account the regional and global requirements in such design.

6.18 The workshop also noted that the GAW will in principle plan to follow the higher-level OSND guidance, which the CBS is developing. Any current GAW guidance for OSND that can be made generic should be used for guidance for other observing system.

### **Global Cryosphere Watch (GCW)**

6.19 Miroslav Ondras (Secretariat) reported on behalf of Michele Citterio (Denmark) on Global Cryosphere Watch (GCW) materials that could be used for developing OSND guidance.

6.20 It was recalled that an immediate priority for GCW is to establish the core standardized surface-based observing network called CryoNet<sup>16</sup>, as well as to identify practices that will be applied by the two types of CryoNet sites (see website<sup>17</sup>). CryoNet will be comprised of sites with varying capabilities. It will build on existing cryosphere observing programmes and promote the addition of standardized cryospheric observations to existing facilities in order to create more robust environmental observatories. CryoNet observations cover all components of the cryosphere (glaciers, ice shelves, ice sheets, snow, permafrost, sea ice, river/lake ice and solid precipitation) through *in situ* observations.

6.21 Two types of sites are envisioned based on the number of “spheres” that are monitored (e.g. atmosphere, biosphere, cryosphere, hydrosphere, etc.). CryoNet Basic Sites monitor one or more components of the cryosphere and observe multiple variables of each component. Basic Sites also measure auxiliary meteorological variables, comply with GCW best practices, are actively taking measurements, have a long-term financial commitment, make data freely available, and make data available in (near) real time whenever possible. CryoNet Integrated Sites, in addition to the CryoNet Basic Sites characteristics, monitor at least one other sphere, have a broader research focus, have support staff, and have training capability. CryoNet Integrated Sites are particularly important for the study of feedbacks and complex interactions between the atmosphere, biosphere, cryosphere and ocean.

6.22 In order for a surface measurement site or station to be included in CryoNet, it must meet certain criteria. The minimum requirements are given in **Annex IX**. If a site meets these requirements, additional information (metadata) can be provided for further evaluation through the CryoNet Site Questionnaire<sup>18</sup>. Contributing sites, which are part of the wide GCW surface network but not part of CryoNet, only need to meet the data sharing requirement. The process of selecting sites and stations as part of the CryoNet network is in its initial stage. The whole process will be completed by December 2015 for consideration by EC-68.

6.23 In order to make cryospheric ground observations available in an open and timely manner to the GCW Cryosphere Observing Network and in particular its core network CryoNet, the design of the network is progressing in parallel with the establishment of the GCW Data Portal to become

16 <http://www.globalcryospherewatch.org/cryonet/>

17 [http://www.globalcryospherewatch.org/cryonet/site\\_types.html](http://www.globalcryospherewatch.org/cryonet/site_types.html)

18 <http://globalcryospherewatch.org/cryonet/questionnaire>

a WMO Information System (WIS) Data Collection and Production Centre (DCPC).

6.24 As an enabling step toward the development of the GCW best practices and the homogeneity of delivered observational data, a database of cryospheric terms as defined by existing glossaries has been compiled and is available through the GCW Website<sup>19</sup>. Further work is needed to evaluate alternative definitions and converge on the official GCW Glossary that will be formally vetted and then translated.

6.25 More detailed information is provided in **Annex IX**.

6.26 The workshop noted that GCW is planning to take into account the OSND principles and future OSND guidance, and so it is avoiding duplication of efforts in this regard.

6.27 Regarding the OSND Principle No. 3, the workshop agreed that there should be – amongst other things – some guidance developed to recommend that a site definition document should be maintained, with information on how to collect user requirements and take them into account.

### **Network of European Meteorological Services (EUMETNET)**

6.28 Stefan Klink (EUMETNET) reported on behalf of the EUMETNET on how EUMETNET decides on OSND recommendations. It was noted that at the EUMETNET level (i.e. sub-RA VI level) a mechanism has been established in order to standardize the process of designing or re-designing parts of the EUMETNET Composite Observing System (EUCOS). Details are provided in part A of **Annex X**. The EUMETNET approach relies heavily on the output of NWP impact studies, and so the workshop noted that this approach would be difficult to apply for other Application Areas. The workshop also noted that national decisions regarding the implementation of observing systems are often driven by cost rather than by observation impact on the application areas.

6.29 Mr Klink also provided information on concrete EUMETNET Observations Programme experiences and proposals aligned with the OSND Principles. These experiences are listed in part B of **Annex X** and were discussed by the workshop.

## **7. DRAFTING PART OF THE REQUIRED OSND GUIDANCE MATERIAL**

7.1 The workshop initiated the drafting of some OSND guidance materials on the basis of previous discussion. These are provided in Annexes **VI, VII, VIII, IX, X, XI** and **XII**.

## **8. FUTURE WORKPLAN**

8.1 The workshop discussed the future workplan, and the roadmap for further elaborating OSND guidance and eventually for formalizing it as part of the WIGOS Guide and possibly other publications.

8.2 The workplan and revised roadmap agreed by the workshop are provided in **Annex III**. The roadmap provides details on the role of this workshop's participants and of the IPET-OSDE in this regard. In particular the Fourth session of the Inter-Commission Coordination Group on the WMO Integrated Global Observing System (ICG-WIGOS), Geneva, 17-20 February 2015, will be invited to review the proposal of the workshop and to provide further guidance to the IPET-OSDE. The second session of the IPET-OSDE (tentatively scheduled in Geneva in 2016) will review and revise OSND guidance, and roadmap. It may task IPET-OSDE members to draft specific materials in close coordination with their respective Teams and groups, taking account of advice from ICG-WIGOS-4 and ICG-WIGOS-5 (see 9.1 below). The IPET-OSDE recommendations will then be submitted to the ninth session of CBS OPAG on Integrated Observing Systems' Implementation

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<sup>19</sup> <http://globalcryospherewatch.org/reference/glossary.php>



and Coordination Team (ICT-IOS) (tentatively scheduled in Geneva in 2016 shortly after IPET-OSDE-2) in preparation for CBS Session in late 2016.

## **9. PREPARATION FOR THE FORTHCOMING CBS MEETINGS**

### **9.1 Recommendations for consideration by IPET-OSDE-2**

9.1.1 The workshop discussed recommendations on guidance for OSND to be considered by the IPET-OSDE at its second Session, and the CBS OPAG on Integrated Observing Systems' Implementation and Coordination Team (ICT-IOS) at its ninth Session, both to be held in 2016. The workshop invited the IPET-OSDE-2 to review status of the work to develop OSND guidance, the review the compiled materials. The workshop also invited the IPET-OSDE-2 to take into consideration what the ICG-WIGOS-4 and ICG-WIGOS-5 will have invited IPET-OSDE to do.

### **9.2 Recommendations for consideration by ICG-WIGOS-4**

9.2.1 The workshop agreed to submit a report to the fourth Session of the Inter-Commission Coordination Group on the WMO Integrated Global Observing System (ICG-WIGOS, Geneva, Switzerland, 17-20 February 2015) on the outcome of the workshop, and with some recommendations. The report should consist of a short one-page document with 2 annexes: (i) the workplan for developing further the draft OSND guidance leading to its approval by the Executive Council, and (ii) a list of items extracted from the guidance, which imply additional activities of WMO (not targeted to Members but to WMO bodies). The workshop recommendations to the ICG-WIGOS are provided in **Annex V**.

9.2.2 The workshop requested the Secretariat to draft the workshop's report to ICG-WIGOS-4 to have it reviewed by the IPET-OSDE Chair, and then to submit it to the OPAG IOS Chair for his review and submission to ICG-WIGOS-4 (**action; Secretariat, J. Eyre, J. Dibbern; 11 Feb.**).

## **10. ANY OTHER BUSINESS**

10.1 The workshop did not have any other business to discuss.

## **11. CLOSURE OF THE SESSION**

11.1 Actions decided by this meeting, are recorded in **Annex II**.

11.2 The Chair thanked the participants and the Secretariat for their contributions. The workshop closed at 16:00 on Wednesday, 4 February 2015.

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**ACTION SHEET RESULTING FROM OSDW2**

<b>No.</b>	<b>Ref.</b>	<b>Action item</b>	<b>By</b>	<b>Deadline</b>
1	5.2(6)	In developing the draft guidance, to identify a list of words with proposed definitions (e.g. network, tiered network, sustainable, ...)	OSDW2 participants	mid-Oct. 2015
2	6.7	To check status of the review of WIGOS Regulatory Materials by GCOS, and to invite GCOS to review such materials in case it had not done it at this point	Secretariat	ASAP
3	9.2.2	To draft the workshop's report to ICG-WIGOS-4, have it reviewed by the IPET-OSDE Chair, and then submit it to the OPAG IOS Chair for his review and submission to ICG-WIGOS-4.	Secretariat, J. Eyre, J. Dibbern	11 Feb. 2015

**ANNEX III****WORKPLAN AND UPDATED ROADMAP FOR THE DEVELOPMENT OF OSND GUIDANCE***(Version 4 February 2015 as proposed by OSDW2 workshop, with updated status)*

<b>Time</b>	<b>Milestone (event)</b>	<b>By whom</b>	<b>Tasks</b>	<b>Status</b>
Nov. 2013	OSDW1 TT-WRM		Produce input to OSND principles Provide input on OSND principles and guidance to WIGOS RM	Done
Dec.		J. Eyre	Draft OSND principles	Done
Jan. 2014		OSDW1 participants & J. Eyre	Review by OSDW1 participants New draft of OSND principles produced based on feedback (J. Eyre by 27 Jan.)	Done
Feb.	ICG-WIGOS		Review draft OSND principles Propose framework into which OSND principles & guidance will fit	Done
Mar/Apr.	IPET-OSDE-1		Review and revise OSND principles Draft plan for preparing OSND guidance, and tasks for Team members for drafting materials	Done
4 Apr.	TT-WRM		OSND principles submitted to the TT-WRM, and the WRM review process through Technical Commissions, and WMO Executive Bodies	Done
Apr.	ICT-IOS-8		Notes the OSND principles Review/revise and approve plan for preparing OSND guidance	Done
May		IPET-OSDE members	IPET-OSDE members to review draft OSND guidance and provide feedback to the Chair	Done
Jun.	EC-66			
Jul.				
Aug.				
Sep.	CBS Ext. (2014)		Consideration by CBS of (i) the OSND principles (to be noted by CBS), and (ii) the roadmap for producing the OSND guidance, as part of WIGOS materials for approval	Done
Oct.				
Nov.		Members	Review of Cg-17 WIGOS RM by Members	Done
Dec.		Members	Review of Cg-17 WIGOS RM by Members	Done
Jan. 2015		Members	Review of Cg-17 WIGOS RM by Members	Done

OSDW2, Final report

Feb.	OSDW2 ICG-WIGOS-4		OSDW2 to review/update OSND guidance Draft OSND guidance reviewed by ICG-WIGOS	
Mid Feb.		OSDW2 participants	Review of the OSDW2 final report	
End. Feb.		Secretariat	Final report of OSDW2 published	
Mar.		J. Eyre	Compile draft OND guidance on the basis of OSDW2 materials	
Apr.				
May.	Cg-17		Approve WIGOS Regulatory Material, including OND principles	
End. May		OSDW2 participants	Review draft OND guidance and send back comments to J. Eyre	
End Jun.		J. Eyre	Update OND guidance on the basis of comments from OSWD2 participants	
Early Jul.		Secretariat	Send the draft OND guidance to IPET-OSDE members, other OPAG IOS ET Chairs, GCOS, OSDW1 & OSDW2 participants, and past contributors from GRUAN WG, GCW, GAW, requesting review by end of Sept.	
Aug.				
Sep.		Secretariat	Comments received	
End Oct.		J. Eyre	J. Eyre to compile next version of OND guidance on the basis of received comments	
Mid. Oct.		WIGOS PO	Send draft OND Guidance to ICG-WIGOS members for their review Deadline : end of Dec. 2015	
Nov.	ET-SBO			
Dec.				
Jan. 2016		J. Eyre	To compile draft OND guidance on the basis of ICG-WIGOS comments, for review by IPET-OSDE-2	
Feb.	ICG-WIGOS-5		Draft version of OSND guidance available and reviewed by ICG-WIGOS Draft OSND guidance (possibly to be refined by IPET-OSDE2 & ICT-IO9 if requested by ICG-WIGOS) submitted to EC (fast-track)	
Mar.				
Apr.	IPET-OSDE-2		Draft version of OSND guidance reviewed by IPET-OSDE if necessary	
May	ICT-IO9		Draft version of OSND guidance (possible revision) submitted to EC (fast track) Final draft version of OSND guidance available (slow track)	
Jun	EC-68		OSND guidance approved by EC (fast track)	

OSDW2, Final report

Jul.				
Aug.				
Sep.	CBS-16		OSND Principles and Guidance endorsed by CBS (slow track)	
Oct.				
Nov.				
Dec.				
Jan. 2017			Draft OSND guidance submitted to EC (slow-track)	
Feb.				
Mar.				
Apr.				
May	EC-69		OSND Guidance approved by EC (slow track)	

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## **OBSERVING SYSTEM NETWORK DESIGN (OSND) PRINCIPLES INCLUDED IN THE MANUAL ON WIGOS**

*(Annex to paragraph 3.1(1).26 of the general summary of CBS Ext. (2014))*

### **OBSERVING SYSTEMS NETWORK DESIGN PRINCIPLES**

Members should follow the following principles when designing and evolving their observing system networks:

#### **1. SERVING MANY APPLICATION AREAS**

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

#### **2. MEETING USER REQUIREMENTS**

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

#### **3. MEETING NATIONAL, REGIONAL AND GLOBAL REQUIREMENTS**

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

#### **4. DESIGNING APPROPRIATELY SPACED NETWORKS**

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

#### **5. DESIGNING COST-EFFECTIVE NETWORKS**

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

#### **6. ACHIEVING HOMOGENEITY IN OBSERVATIONAL DATA**

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

#### **7. DESIGNING THROUGH A TIERED APPROACH**

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

#### **8. DESIGNING RELIABLE AND STABLE NETWORKS**

Observing networks should be designed to be reliable and stable.

#### **9. MAKING OBSERVATIONAL DATA AVAILABLE**

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

#### **10. PROVIDING INFORMATION SO THAT THE OBSERVATIONS CAN BE INTERPRETED**

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



**11. ACHIEVING SUSTAINABLE NETWORKS**

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

**12. MANAGING CHANGE**

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

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### Workshop Recommendations to the ICG-WIGOS

The workshop agreed to submit a report to the fourth Session of the Inter-Commission Coordination Group on the WMO Integrated Global Observing System (ICG-WIGOS, Geneva, Switzerland, 17-20 February 2015) on the outcome of the workshop, and with some recommendations. The report should consist of a short one-page document with 2 annexes: (i) the work-plan for developing further the draft OSND guidance leading to its approval by the Executive Council, and (ii) a list of items extracted from the guidance, which imply additional activities of WMO (not targeted to Members but to WMO bodies).

Issues for the ICG-WIGOS to consider:

- Taking into account the OND guidance development workplan, ICG-WIGOS will be invited to seek comments from their TC and RA members on the draft OND guidance materials, when they are available in late 2015; and
- ICG-WIGOS is requested on the role of IPET-OSDE, OPAG IOS and CBS with regard to the development of OND guidance materials, approval mechanisms, and to comment on the proposed workplan.

OSND Guidance elements to be considered by the ICG-WIGOS:

- *Develop and maintain regional (for Regional Associations, and climate regions) observational user requirements in OSCAR;*
- *Develop mechanisms for sharing best practice and lessons learnt on observing network design;*
- *Develop tools to aid design of cost-effective observing systems, including assessment of actual or anticipated impact of observations. These are needed for each Application Area;*
- *Develop observing network performance targets, and indicators;*
- *Develop guidance on the transition of existing (legacy) systems to meet WIGOS requirements and standards. e.g. CIMO could be invited to make some recommendation(s);*
- *Develop guidance on how to interpret Observational User Requirement information in OSCAR for the purpose of Network Design; and*
- *Develop guidance on how to design observing systems using the most appropriate technology or combination of technologies.*

## GOS MATERIALS THAT COULD BE USED FOR DEVELOPING OSND GUIDANCE MATERIAL

(prepared by Islam Maher (Egypt), Elena Saltikoff (Finland), and Jochen Dibbern)

### INTRODUCTION:

**ADD** definitions such as

An *integrated station network* consists of multipurpose stations and/or stations of the different station types in the same geographical area, which is applying the the agreed WMO practices.

A tiered network is ...

Third parties are ...

### 4. DESIGNING APPROPRIATELY SPACED NETWORKS

This text is **moved** from B6 cost effective networks and modified:

- Observing networks should be designed taking into account measurements and gaps from other ~~networks~~ systems in the vicinity, e.g. measurements using the same technology in neighbouring countries, or measurements from networks using different technologies.
- **ADD BUT REWORD:** You should not place several upper-air instruments at the same location.
- When considering priorities for additional observations, attention should be given to: observation-poor regions and domains, poorly observed variables, and regions sensitive to change. This may lead to acquiring observations in areas outside of the territory of funding nation or group of nations (such as EUMETNET funding E ASAP).

### 5. DESIGNING COST-EFFECTIVE NETWORKS

- Partnerships with other organizations responsible for observations should be ~~exploited~~ established in order to build on potential synergies, share costs and provide more cost-effective systems.

### 6. ACHIEVING HOMOGENEITY IN OBSERVATIONAL DATA

- (Add something about assessing the stations)

### 8. DESIGNING RELIABLE AND STABLE NETWORKS

- **Modification for more general guidance** ~~A combination of AC power and renewable energy sources (e.g., solar, wind) should be used...~~ A cost-effective unbreakable power system, potentially including backup power sources, should be used whenever possible better to ensure continued operation in all weather conditions

- **ADD:** Monitoring of availability on multiple sites both locally and centrally could reveal correlated gaps and thus deficiencies e.g. in data communication or power supply.

#### 9. MAKING OBSERVATIONAL DATA AVAILABLE

- **ADD** Observational data should be archived and made available according to agreed WMO practices.
-

## **GCOS MATERIALS THAT COULD BE USED FOR DEVELOPING OSND GUIDANCE MATERIAL**

*(submitted by Jay Lawrimore (USA))*

### **CONTENT:**

#### **PART A – CLIMATE MONITORING AND DESIGN DOCUMENT SUMMARY ITEMS**

#### **PART B – OBSERVING NETWORKS DOCUMENTS**

#### **PART C – COMPILATION OF OSND GUIDANCE ACCORDING TO THE OSND PRINCIPLES**

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### **PART A - CLIMATE MONITORING AND DESIGN DOCUMENT SUMMARY ITEMS**

#### **Guidelines on Climate Observation Networks and Systems; WMO/TD No. 1185**

Network density and station distribution depend on the particular application. National climate networks should be able to provide a satisfactory representation of the climate characteristics of the country.

The rate of spatial and temporal variation for meteorological elements varies by element. For example, the network density requirement for characterizing temperature is usually much less than precipitation. WMO provides density criteria guidelines for climatological networks.

Additional approaches include various objective analysis techniques and methodologies for specific applications. The simplest approach would be to identify homogeneous climatic regions and ensure that each region is adequately sampled. More sophisticated methods would examine the particular characteristics and merits of the available stations (e.g. Peterson et al. 1997, Collins et al. 1999) or use objective analysis to aid network selection (e.g. Daley 1993, Jones and Trewin 2000).

In designing climate networks, there should be strong recognition, that to be most cost effective, these networks can and should support other applications and purposes as well. For example, in some countries, reference climate stations also provide valuable information in real time for weather forecasting and agrometeorological applications. Even Ordinary Climatological Stations, measuring daily temperature and precipitation and snow cover (if applicable), can provide low cost data for nowcasting and forecast verification if the data are reported on a timely basis.

National networks, especially those intended for detection of climate trends, variations and changes, must be equipped with standard, approved instrumentation. A process or plan should be in place to ensure that occurs in an orderly way.

First, a careful determination of stakeholder requirements must occur through consultation. These include requirements for uncertainty (accuracy), resolution and range, robustness, and suitability for the intended operating environment. For example, are they suitable for operating in cold climates? Do they retain their accuracy in extreme temperature conditions?

The process (Fig. 6.1) should include a review of performance requirements against manufacturer specifications, laboratory testing against a reference standard traceable to a national primary standard to determine uncertainty and repeatability, and engineering quality and design. The test and evaluation process should include field-testing in operational environments. This usually requires having multiple test sites and a test period of one year to capture the expected range of climatic conditions and to acquire a statistically significant dataset. The field test plan must be carefully designed to determine performance under various measurement ranges and

environmental conditions. Field-testing could include comparisons to calibrated field reference standards (when available), identical model products (functional precision) and other sensors/systems currently in operational use.

An observation site should be representative of the climatic regime for which it is intended. Sites on steep slopes, in hollows, in proximity to pronounced features such as buildings, topographical influences, for example, ridges, should be avoided. Otherwise, the site becomes representative of local features only.

Stations measuring baseline or background atmospheric composition, specifically those part of the GAW program have very stringent siting criteria – no significant change in land use practices within 30-50 km of the site and minimal effects of local and regional air pollution (WMO 2003).

Stations should be on a level piece of ground (to the extent possible) and should be well exposed, away from obstacles and obstructions that could influence the observation including instrument performance. A general rule often employed is that the distance of any obstacle from the instrument gauge should be 2 to 4 times the height of the object above the gauge. Anemometers require even more exposure, the distance of any obstruction being prescribed as at least 10 times the height of the obstruction (WMO 2003). These restrictions may sometimes require splitting of the site, example, the anemometer location being some distance from the rest of the instrumentation.

When selecting station sites, network planners and administrators should consider locations where there is a high probability that exposure is unlikely to change over the long term and that the site is secure through long-term agreements, leases or ownership.

Factors such as security, care-taking, power, protection against flooding, etc. must also be taken into account. Many NMHSs develop instrument compound guidelines that prescribe sensor location and proximity to one another, buffer zones and security fencing. Underlying surfaces could include short-cropped well-maintained grasses or gravel.

NMHSs are strongly encouraged to have network installation guidelines and procedures in effect, including those provided by manufacturers for specific equipment. It is critical that instrument pads are well seated and leveled, that trenching for power and signal cables follow prescribed directions. Under some extreme conditions, such as some arctic or sub-arctic locations, where freeze/thaw cycles can produce ground slumping or upheaval, gravel beds are prescribed for the instrument compound.

Performance Measurement: It is also important to measure performance on a program- or network basis. In effect, these are measures of the health of a program in terms of quality, effectiveness and efficiency. Measures could include frequency and character of observational errors, reporting percentages, completeness, timeliness – e.g., what is the percentage of observations received by collection centers within prescribed time frames? They could also include percentages of time that standards are attained – for example, the percentage that national radiosonde balloon releases reach prescribed heights. Life cycle management metrics could include information on how often routine station inspection and maintenance occurred within prescribed frequency of visits, the number of unscheduled maintenance trips, how often systems were replaced within prescribed timeframes, numbers of repairs, etc.

### **Guidelines on Climate Metadata and Homogenization; WMO/TD No. 1186**

Good metadata are needed to ensure that the final data user has no doubt about the conditions in which data have been recorded, gathered and transmitted, in order to extract accurate conclusions from their analysis.

Meteorological data are influenced by a wide variety of observational practices. Data depend on the instrument, its exposure, recording procedures and many other factors. There is a need to keep a record of all these metadata to make the best possible use of the data. This guide identifies

the minimum information that should be known for all types of stations.

Complete metadata describe the history of a station since its establishment to the present and hopefully onwards to the future.

A good metadata archive helps the NMHSs in asset management and other administrative procedures, as data existences and observing conditions are kept in good order. It also can be said that good metadata helps society to gain a better understanding of weather and climate related processes, as well as climate change.

Minimum metadata requirements:

Station Identifiers; Name, Aliases, WMO Code or station number, station number in other networks, opening/closing dates, type of station, station contact.

Geographical Data; Lat/Lon, Elevation above Mean Sea Level, Relocations

Local Environment; Updated mapping, Toposcale map, Radiation horizon mapping, Photos in all compass directions and updated a minimum of annually, Microscale map of instrument enclosure and updated as changes occur.

Local land use/land cover; At different scales it is recommended to keep track of several attributes. Mesoscale (1km to 30km) account in metadata for proximity and size of large water surfaces, urbanized areas, mountain ranges. Toposcale (100m to 2km) terrain slope, forests, crops, other roughness, nearby obstacles such as trees or buildings, proximity to irrigation. Sketches providing this information are often recommended.

Instrument Exposure; Obstacles, Ground Cover.

Type of instruments; e.g., Instrument manufacturer, Model of instrument, with size and identification, Output type and sensitivity, Transducer type (if applicable), Response time (if applicable).

Instrument mounting and sheltering; Height above surface, description of shelter, degree of interference from other instruments/objects such as an artificial heat source or a ventilator.

Data recording and transmission; type of recording, signal transport.

Observing practices; Observer, Observed Elements, Observing times, Routine maintenance, corrections made by observer.

Data processing; Units, Special Codes, Calculations, Quality Control, Homogeneity Adjustments, Data recovery.

General Historical Network Information; Changes in sheltering and exposure, Changes in mean calculations, observation hours and daylight saving times, Units of observed elements and data accuracy, Urbanization and land-use changes, Introduction of Automatic Weather Stations or new types of instruments, Changes in quality control, homogenization and data recovery procedures.

**Observing Weather and Climate from the Ground Up: A Nationwide Network of Networks (US National Academy of Sciences)**

Meteorological observations at the mesoscale play a vital role in promoting the health, safety, and economic well-being of our nation. Although the federal role in weather and climate information services is pivotal, a number of state and local governments, universities, and private sector interests have developed and deployed dense networks of meteorological observing systems, known as "mesonets." The advent of inexpensive digital electronics and high bandwidth

communications lowered barriers to investment and enabled literally thousands of small businesses, Fortune 500 corporations, agricultural producers, recreation providers, and many others to enter the field of mesoscale observations, driven by a wide range of missions and markets at various investment levels.

Despite this widespread participation, all is not well. National priorities demand ever more detailed meteorological observations at much finer spatial and temporal resolutions than are widely available today. These priorities include tracking atmospheric dispersion of chemical, biological, and nuclear contaminants from industrial accidents and terrorist activities, as well as smoke dispersion monitoring and prediction for wildfires, prescribed burns, and seasonal agricultural fires; more extensive air quality forecasting, high-resolution “nowcasting,” and short-range forecasting of high-impact weather; high-resolution weather information for aviation, surface transportation, and coastal waterways; and support to regional climate monitoring.

The report offers steps that can be taken to affect near-term improvements in U.S. mesoscale observations and the investments that could be made to strengthen capability over the longer term. Although many of the recommendations specify actions to be taken by the federal sponsors of the report, federal agencies alone are unlikely to satisfy the breadth of national needs for mesoscale data. Therefore, the recommendations specifically address the broader community of private, public, and academic partners.

An overarching national strategy is needed to integrate disparate systems from which far greater benefit could be derived and to define the additional observations required to achieve a true multi-purpose network that is national in scope.

The Committee envisions a distributed adaptive “network of networks” (NoN) serving multiple environmental applications near the Earth’s surface. Jointly provided and used by government, industry, and the public.

A NoN cannot deliver a net benefit to users unless comprehensive metadata are supplied by all operators.

Several steps are required to evolve from the current circumstance of disparate networks to an integrated, coordinated NoN. First, it is necessary to firmly establish a consensus among providers and users that a NoN will yield benefits in proportion to or greater than the effort required to establish it.

The new elements of a NoN are twofold: (1) the provision of services and facilities that enable individually owned and operated networks to function, more or less, as one virtual network, and (2) the provision of new observing systems or facilities to enable national objectives.

A number of recommendations were made in the report.

*Stakeholders, including all levels of government, various private-sector interests, and academia should collectively develop and implement a plan for achieving and sustaining a mesoscale observing system to meet multiple national needs.*

*To ensure progress, a centralized authority should be identified to provide or to enable essential core services for the network of networks.*

Essential core services include but are not limited to

- definition of standards for observations in all major applications,
- definition of metadata requirements for all observations,
- certification of data for all appropriate applications,
- periodic “rolling review” of network requirements and user expectations,
- definition and implementation of data communication pathways and protocols,
- design and implementation of a data repository for secure real-time access and a limited period



for post-time access,

- generation of a limited set of products based upon the raw observations, most notably, graphical presentations of data fields and analyses thereof,
- pointers to more sophisticated products generated externally, such as analyses produced from a short-term model prediction and multiple observation sources,
- pointers back to data providers, where more products and services are available,
- establishment of a link to the National Oceanic and Atmospheric Administration's (NOAA's) National Climate Data Center (NCDC) for archival of selected data, as deemed appropriate by NCDC,
- development and provision of software tools and internet connectivity for data searches, information mining, and bulk data transmissions,
- development and provision of a limited set of end-user applications software, which would enable selection of default network data configurations for major applications as well as tools for creation of custom network data configurations, and
- provision of a data quality checking service with objective, statistically based error-checking for all major categories of data, including manual intervention and feedback to providers.

*The centralized authority should require metadata of every component in an integrated, multi-use observing system.*

*A national design team should develop a well-articulated architecture that integrates existing and new mesoscale networks into a national "network of networks."*

*The national network architecture should be sufficiently flexible and open to accommodate auxiliary research-motivated observations and educational needs, often for limited periods in limited regions.*

*Federal agencies and partners should employ testbeds for applied research and development to evaluate and integrate national mesoscale observing systems, networks thereof, and attendant data assimilation systems. Among other issues, testbeds should address the unique requirements of urbanized areas, mountainous terrain, and coastal zones, which currently present especially formidable deficiencies and challenges.*

*Existing surface observations and observing platforms associated with road and rail transportation, as appropriate, should be augmented to include World Meteorological Organization (WMO)-standard meteorological parameters. Conversely, existing WMO-standard meteorological observing stations near highways and railways should be augmented, as appropriate, to meet the special needs of the transportation sector.*

*The stakeholders should commission an independent team of social and physical scientists to conduct an end-user assessment for selected sectors. The assessment should quantify further the current use and value of mesoscale data in decision making and also should project future trends and the value associated with proposed new observations. Upon implementation and utilization of improved observations, periodic assessments should be conducted to quantify the change in mesoscale data use and its added societal impact and value.*

### **Comments from William Wright (ICG-WIGOS) on a draft WIGOS discussion paper regarding Externally-Sourced data**

From a climate perspective, for certain activities, most notable climate change monitoring, a very high standard of observational practice and metadata is required. However, many climate services do not need this level of exactness, although continuity and length of data is important in most cases. This brings in the concept of tiered networks – certain applications such as catchment mapping of rainfall require a high density of observations, rather than a few points with high-end gauges. For this sort of application, crowd-sourced data is ideal. A challenge for the climate program is to establish some kind of system that grades ESO's in terms of reliability (accuracy,

siting, metadata etc), and maps these to climate services.

Many amateur weather observers (e.g., members of the storm-chasing fraternity) take great pride in their observations, and arguably in some cases perform better than co-op observers. Other countries have organised systems for non-NMHS observers to contribute their observations, e.g., CoCoRAHS in the US; WoW in several countries. And the Bureau has often had requests from external people to advise on best-practice and recommended systems.

There would seem to be great potential to harness this enthusiasm – one ideal solution would be to better harness (in Australia's case) Bureau retirees and even current employees. For instance current high quality rainfall observations from a part of Victoria that represents an important catchment area, yet is poorly served by conventional observations.

This would be further enhanced if the enthusiastic amateurs were equipped with proper instrumentation and taught how to service and maintain it.

In many areas crowd-sourced observations may be the only available observations, and can still provide very useful data.

“One set of standards ...cannot meet the needs across all applications”. This is the tiered approach. For many purposes a subset of high quality stations for high-end monitoring and for reference purposes, interspersed with a denser network of ESOs, yields good results. Importance of maximising metadata, is true. If you can evaluate the reliability of an observation, you can make an informed judgement on what that observation can and can't support.

Data management. It is strongly recommended that external data are flagged as such within Data Management systems, to avoid the sorts of problems that go with possibly lower-quality data. These data also need to be linked to information on any restrictions placed on the data. Data from private providers may have immediate commercial sensitivity, but less so after a period of time. In that case, submission of data at a later, less sensitive time would be of potential value, especially to climate services that in general have a less immediate time-frame. This “sunset clause” approach is adopted by the Water program within the Bureau.

As NMHS decrease the number of manual observers, the ability to provide visual and phenomena observations declines also (albeit to some extent automated sensors may replace these, but it is not known how well these replicate the missing observations). Therefore, more crowd-sourcing of things like hail, dust, thunderstorms, strong wind bursts etc greatly assist certain climate services, incl those to the insurance industry, horticulture planning etc. And phenomena such as frost can be very localised yet significant to agriculture and other applications.

Filling in gaps. A group of rapporteurs is being set up within OPACE 1 to investigate the potential to obtain more observations from data sparse regions such as Africa. One suggestion is to equip local people with low cost raingauges and encourage submission of their data via mobile phones.

### **Report from Expert Team on National Networks and Observations in Support of Climate Activities (OPAG on Climate Data and Data Management)**

The use of automated systems is replacing traditional stations in developed countries. Network designers need to consider unanticipated maintenance problems from a technical and cost standpoint for countries in economic transition.

The presence of automated systems takes away from the local knowledge required to maintain the engagement of local observers and meteorological services.

The need for training (maintenance in addition to all other aspects) needs to be a part of network design and deployment.

Long and homogeneous climate series are in key roles in climate change studies, and special care is required when changing instrumentation or automating these series. An overlap between the old and new systems is necessary, at least one year.

### **Report on Automated Versus Manual Surface Meteorological Observations – Decision Factors**

For many applications, automated weather stations (provided they are well-maintained and life-cycle managed), offer important advantages in terms of data quality and reliability. They have also been used to increase network densities, reporting frequencies and elements observed, especially in remote and largely unpopulated regions where access is difficult. They also can augment manned stations both as observer aids and during hours when no observer is on duty. Lower labor costs may reduce or even reverse the cost payback.

Lack of adequate supporting infrastructure may pose obstacles to implementing AWSs. Simplistic cost comparisons based on one-time only capital and installation costs can be misleading. Automation initiatives must consider factors such as user requirements, operating environments and all costs associated with the life-cycle management of the autostations. AWSs can enhance systematic observing through increased sampling and reporting frequencies and additional data elements. Very high investment costs, however, may preclude some NMHSs from automating some data parameters that human observers provide. Examples include sky cover, obstructions to visibility and precipitation type identification.

Unless the NMHS has the capacity to respond effectively to outages, it can expect increased data loss (especially in remote locations).

There are many considerations for whether to retain manual observations or install an automated system. Examples include - Are the stations located in places with labour markets that can provide the necessary skills to carry out manual observations at an affordable price? What resources does the NMHS have or need to acquire to maintain automated systems? See the 9 major questions in this document.

The meteorological variables that present the largest hurdles for automated measurement are those that are directly related to human perception of a physical parameter. Because reporting protocols for parameters such as sky cover, horizontal visibility and present weather consider the characteristics and limitations of human senses, AWS often report differently than a human would under identical conditions. In cases where the aviation sector is a client, service providers must carefully consider their needs in developing an automation strategy. Replacing manual observation programs with automated observations requires a thorough change management process e.g. testing, evaluation, implementation planning, user education, and documentation.

It is extremely important that key stakeholder groups such as climatologists, regulators, forecast production managers, data managers, etc, liaise closely with observation program managers during the requirements and subsequent planning phases to ensure that their needs are thoroughly considered before implementation starts. This communication should form part of a change management process that is recommended for any NMHS planning changes to its observation programs.

The cost of implementing an autostation varies greatly. Factors include:

- Which parameters will the station report? What standards and requirements apply?
- What site preparation is needed to establish a suitable instrument compound and bring in required utilities, e.g. electrical power, telephone or satellite communications?
- Is the site in an isolated location where it is expensive to ship supplies and obtain services?

It is incumbent upon the NMHS to consider operational requirements and related budgetary costs when planning for the implementation of autostations. AWS networks, like any manned observation program, should be sustainable, life-cycle managed, operated and maintained to

defined standards and operating procedures.

Automated observations introduce many changes that affect the way data is managed for both operational and archiving purposes. For example, automation presents an opportunity to acquire data at higher temporal resolutions. While it may not cost significantly more to collect this additional data, managers will have to assess whether it adds downstream ongoing and/or development costs to activities such as telecommunications, processing and data storage and to assess such costs in relation to user requirements and competing priorities.

### **CCI Guidelines on Data Management, Version 5.0**

This document provides information on best practice climate data management with some emphasis on building knowledge and capacity, particularly in support of the transition to a modern climate database management system. It includes the skills, systems and processes needed to be in place to ensure that operations are sustained.

Database management is an integral part of network design. If done correctly it will ensure not just the long-term preservation of data but also near real-time collection and access. This is a lengthy document. Some items of interest to network design include the following.

Database needs to be designed for the appropriate purpose – near real-time meteorological work will mainly be accessed synoptically. Climate data accessed for period of record – storage will be different.

Metadata structures are more complex than data – follow standard metadata model for climate data – extension of WMO Core Metadata Standard?) The ability to support the standard model is a desirable characteristic of data management systems.

Key entered systems should validate data as they are entered – catch errors early and recommend alternate values.

Systems should be designed to decode WMO standard formats (SYNOP, CLIMAT, etc.) directly into a climate database.

### **Metadata documentation and management**

A detailed treatment of station specific metadata can be found in the report “Guidelines on Climate Metadata and Homogenization” (WMO 2003b) in the World Climate Data and Monitoring Programme series of publications.

An important general point in this context is that the innate structure of the metadata in an ideal system will be considerably more complex than the innate structure of the climate data itself.

The associated metadata, which is needed to fully interpret the data, could include such things as the:

- Reference date used by the database (GMT, time zone, others);
- Quality which has been ascribed to the observation;
- History of the values ascribed to the meteorological parameter and any associated flags;
- Instrument used to record the observation, together with more fine detail on its own maintenance programme, tolerances, internal parameters, etc;
- Name of the observer;
- Full details of the station and its history;
- Programme of observations in effect at the time and its history;
- the inventory of the elements stored in the database, their units, their boundaries; and
- Topographical and ground-cover details of the site, information on surrounding trees, buildings, etc, and how these have changed with time.

It will also require the ability to store graphics associated with stations in a network (site plans, photos, possibly images of old documents, etc). This is not conceptually complex, but has implications for, in particular, the hardware to be used in order to capture and reproduce a range of images, and the underlying software to be used as the database management system.

Data may also be the subject of homogenisation work, which is intended to remove from a data set all influences other than those from the underlying climate. Data that has been the subject of such exercises has a need for additional associated metadata, in order to accurately represent the nature of the homogenisation work. Homogenised data sets should be a product of the CDMS and

never considered as a replacement.

### Data Acquisition

The overheads associated with running a network could be reduced if the NMHS were to use the station networks of similar institutions such as universities, local utilities, and private companies. In these cases all relevant climate data should be collected and it is highly desirable that the NMHS should be granted full use of all the climate data, without restriction, as if it were its own data. Appropriate contractual, or 'Memorandum of Understandings', between the NMHS and other organisations may need to be drafted and signed at senior management level.

### Data Entry

Data collection should be as close to the source as possible. Automated stations including stations which have some manual observations, and partially automatic weather stations should collect their climate data and error messages on site and transfer these electronically to the data management system, possibly via another database system. Manually observed data should be collected and captured on-site and transferred as soon as possible to the CDMS. (e.g., daily observations transmitted daily instead of monthly).

Data quality is likely to be improved. • While the cost for data transmission will increase, the human effort for quality control will likely decrease and there will be greater opportunities from improved access to more data; and • Technical errors will be detected much faster.

For data capture, a system that checks the constraints and data type for each parameter before it ingests the values into the database is recommended.

An important job of the data manager is to estimate data storage requirements, including estimating future growth. Account must be taken of the additional information to be included in data records (e.g. QC flags, original messages, date/time of record update), metadata needs and any redundancy necessary to ensure that databases can be restored. Estimating future growth will be difficult but it is worth keeping in mind that many NMHSs are now archiving 1 and/or 10 minute AWS data and that non-traditional climate data (e.g. soil moisture, vegetation indices) are very important for climatologists. The storage requirements for remotely sensed and oceanographic data are generally very large.

### Data Exchange

There are perhaps four categories of climate data to consider from the data exchange viewpoint:

- Real-time or near-real-time data exchanged over the GTS, and for which timeliness is vital;
- Delayed-mode datasets which may be composites of the above but which are limited in terms of QC;
- Delayed-mode datasets which have had extensive QC and possibly homogeneity analysis applied; and
- Other products (e.g. Satellite imagery, metadata, climate monitoring and prediction products, climate indices, national / regional / global analyses and climatologies, outputs from global climate models).

For the first of these, WMO standard formats have been defined. CLIMAT and CLIMAT TEMP are the 'climate-specific' ones, while others - notably SYNOP, PILOT, TEMP and Marine message formats - are relevant to climate work. Details on these can be found in WMO (1995). For the others, there are formats defined for data interchange (for example, HDF and NetCDF) but these are at a higher level of generality and are not, per se, 'self-describing'.

### Data administration and monitoring

As has been emphasized in Section 3.1, data managers need to ensure that their systems and data are managed in a way that satisfies user (or business) needs. Consequently, systems and processes need to be put in place to check that the data being managed conform to the expectations of users. A useful way of doing this is to establish and monitor a carefully selected set of performance indicators that reflect the standards expected by data managers.

Data flow problems should be identified and corrected before there are any consequences for climate data users.

Any monitoring indicators developed should be associated with target values which allow for measurement of performance against user needs.

Monitoring needs to ensure databases are:

- Comply with the relevant national and international guidelines in respect of spatial density, frequency and length of record;
- Subject to appropriate quality control;
- Of acceptable quality;
- Made readily available in digital form; and
- Stored optimally in terms of security and accessibility.

The systems and processes in place should provide real-time alerts to business critical activities. This may include alerts to missing data during times where high profile climate products are produced (e.g. for government ministers) or where data are being provided to clients who are paying an urgency-fee for the service.

## **PART B – OBSERVING NETWORK DOCUMENTS**

Documentation for existing networks can serve as a reference for observing system network design. The following provides documentation for a spectrum of networks including a reference climate network, an automated meteorological network, a national network supported by manual observations, and a network that provides externally sourced observations.

**US Climate Reference Network:** A complete set of documentation for the gold standard of climate networks is available at <http://www.ncdc.noaa.gov/crn/docs.html> . This includes functional requirements, test and evaluation, demonstration phase, site information and acquisition, commissioning plan, and field maintenance plan.

**NOAA/NWS Automated Surface Observing System (ASOS) program** documentation is available at <http://www.nws.noaa.gov/asos/> . This includes a variety of technical reports on instrumentation, change management, station information and the ASOS Users Guide (<http://www.nws.noaa.gov/asos/aum-toc.pdf>) .

Functional Specifications for Automatic Weather Stations in THE STATE-OF-THE-ART OF INSTRUMENTS AND AUTOMATED SURFACE OBSERVING SYSTEMS (ASOS) - [https://www.wmo.int/pages/prog/www/IMOP/meetings/Surface/ET-STMT1\\_Geneva2004/Doc4.1%282%29REV1.pdf](https://www.wmo.int/pages/prog/www/IMOP/meetings/Surface/ET-STMT1_Geneva2004/Doc4.1%282%29REV1.pdf) .

Measurements at Automatic Weather Stations (Draft for CIMO-16 Approval); [http://www.wmo.int/pages/prog/www/IMOP/publications/CIMO-Guide/Provis2014Ed/Provisional2014Ed\\_P-II\\_Ch-1.pdf](http://www.wmo.int/pages/prog/www/IMOP/publications/CIMO-Guide/Provis2014Ed/Provisional2014Ed_P-II_Ch-1.pdf) .

**NOAA/NWS Cooperative Observer Program** documentation is available at <http://www.nws.noaa.gov/om/coop/> .

An example of an external source observing program is the **Community Collaborative Rain, Hail and Snow Network** (CoCoRaHS) at [www.cocorahs.org](http://www.cocorahs.org) .

## **PART C – COMPILATION OF OSND GUIDANCE ACCORDING TO THE OSND PRINCIPLES**

**Note:** Microsoft Word “track changes” kept in the text below on purpose.

### **B. Observing System Network Design (OSND) Principles and high-level guidance**

*(Version dated 22 January 2014)*

## 1. SERVING MANY APPLICATION AREAS

Observing networks should be designed to meet the observational needs of many application areas<sup>20</sup> within WMO and WMO co-sponsored programmes.

- When designing observing networks the needs of WMO Application Areas, as documented in WIGOS guidance should be taken into account [Link to RRR material on Applications Areas and Statements of Guidance]
- The design of observing networks implemented primarily to support operational forecasting should also take into account the needs of other applications, including climate and environmental monitoring.
- Observing systems and their networks should be designed and operated, where technically and/or economically possible, in such a way that the needs of multiple applications are satisfied.
- Partnerships with other organizations responsible for observations should be exploited, through the integration of observing systems and multi-purpose design in order to achieve synergies and better cost effectiveness.
- ... [others?]

## 2. MEETING USER REQUIREMENTS

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

- User communities should be involved in observing system network design. To ensure observing system networks meet the key needs of the user communities, detailed decisions about observing system network design should include a consultation stage with appropriate application area representatives.
- When design observing networks, the user needs as documented and quantified in WIGOS guidance should be taken into account [with link to RRR details of URs and SoGs]
- [Guidance should be developed on how to interpret the UR information in the OSCAR database for the purposes of network design]
- Long-term requirements, including appropriate sampling frequencies, should be specified to network designers, operators and instrument engineers at the outset of system design and implementation.
- The domains and spacing of observing networks should be sized in order to capture severe and high impact events.
- Observing systems should be designed with temporal spacings and other performance characteristics such that extreme events of short duration are captured and climate-relevant changes (e.g. diurnal, seasonal, and long-term inter-annual) can be resolved.
- Network design should consider the need for data continuity with historical records.
- ... [others?]

## 3. MEETING NATIONAL, REGIONAL AND GLOBAL REQUIREMENTS

Observing networks designed to meet national needs should also take into account the needs of the WMO community for applications for which requirements are regional or global.

- National networks shall be established by Members to satisfy their own requirements. When implementing these national networks, Members shall take into account the needs of global and regional applications. These considerations should include data storage, availability, exchange and documentation.
- WIGOS principles should be adopted for networks that are implemented primarily to meet national needs.
- ... [others?]

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<sup>20</sup> A WMO Application Area is an activity involving primary use of observations, in a chain of activities which allow National Meteorological Services or other organizations to render services contributing to public safety, socio-economic well-being and development in their respective countries, in a specific domain related to weather, climate and water. The concept of a WMO Application Area is used in the framework of the [WMO Rolling Review of Requirements \(RRR\)](#) and describes a homogeneous activity for which it is possible to compile a consistent set of observational user requirements agreed by community experts working operationally in this area.

#### 4. MAKING OBSERVATIONAL DATA AVAILABLE

Observational data from national observing networks should be made available to other WMO Members, at space-time resolutions and with a timeliness needed to meet the needs of regional and global applications.

- Many gaps in user requirements for observations can be filled by disseminating observations that are currently made but not collected centrally in a NMHS, or made but not disseminated internationally, or made but not disseminated in a timely manner.
- Mechanisms should be established to minimise loss of observational data and to promote recovery of old data for climate applications.
- Multiple and overlapping methods of dissemination should be used whenever possible to ensure continuity of data collection.
- All data should be processed into a documented and permanent data and metadata record following common standards (e.g., GCOS-143) and archived in a World Data Center or other recognized data center. A Sustained Operational Capability to produce the archived data record throughout the life of the observing system/network is required.
- ... [others?]

#### 5. PROVIDING INFORMATION SO THAT THE OBSERVATIONS CAN BE UNDERSTOOD

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 interpretation of the observational data (i.e. metadata) are documented and treated with the same care as the data themselves.

- Appropriate metadata are essential to ensure quality, traceability and homogeneity of observations [link to appropriate WIGOS guidance]
- Metadata collection, dissemination, archive and access systems should be designed with as much attention as those for observational data.
- Station metadata should be created at the time of network installation, following WIGOS standards for metadata ~~and updated at a minimum annually~~ and updated whenever changes to the metadata occur.
- BUFR [c1] when fully utilized has the capacity for transmission of full metadata reports over the WMO Information System (WIS) and should include metadata such as instrument (sonde) model, batch number, ground check info etc, that BUFR [c2] allows.
- Station [c3] metadata should ~~to include at a minimum information such as including station identifiers, geographical location and elevation, the surrounding local environment conditions, instrument exposure, instrumentation type and calibration metrics, observing practices, and maintenance practices.~~
- Whenever possible photographic images of the station and environment should be made and archived annually.
- WIGOS metadata should be updated whenever changes occur; including changes in sheltering and exposure, changes in mean calculations, observation hours, land-use changes, new types of instruments, changes in quality control, homogenization and data recovery procedures.
- Metadata practices should adhere to international standards in use by the WMO meteorological<sup>21</sup> community.
- Advance notice of instrument/data processing changes to end users is encouraged.
- Metadata is important for understanding the quality and reliability of stations within a tiered network that includes third party (externally sourced) observations.
- ... [others?]

#### 6. DESIGNING COST-EFFECTIVE NETWORKS

Observing networks should be designed to make the most cost-effective use of available

<sup>21</sup>Editorial noted from J. Eyre 2/24/2014: Should we generalize this?



resources.

- Observing networks should be designed using the most appropriate and cost-effective technologies or combinations of technology. [Develop guidance on how to do this.]
- Developments to observing systems should normally build on existing sub-systems, capitalising on both existing and new technology, and integrating new systems into existing WIGOS capabilities.
- Designs should be sufficiently flexible to allow for expansion without the need for complete network re-design. As requirements change the design of the observing system network may need to change, and its configuration should be sufficiently flexible to allow for incremental expansion, or contraction, without the need for entire network re-design.
- Partnerships with other organizations responsible for observations should be exploited in order to build on potential synergies, share costs and provide more cost-effective systems.
- Observing network design should, where possible, be based on the results from scientific studies which assess the impact, importance and cost-effectiveness<sup>22</sup> of the observations for the applications to which they contribute.
- Tools are required to aid design of cost-effective composite observing systems. They should include assessment of actual or anticipated impact of observations. A variety of such tools are available and widely used in some application areas (e.g. GNWP)<sup>23</sup>.
- Tools are required to assess the cost-effectiveness of observations for each application and the combined value across all application. This will require consultation between observing system designers and application owners/experts.
- Spaced-based and surface-based observing networks should be designed and operated in such a way that they are complementary, with appropriate activities and cooperation between the communities responsible for these networks, to ensure that observations from each system are used to enhance the impact and effectiveness of the other.
- [Use of functioning baseline instruments that meet calibration and stability requirements should be maintained for as long as possible, even when these exist on decommissioned observing systems – originally written for satellite instruments, and should be generalized.]
- Observing networks should be designed taking into account measurements available from other networks in the vicinity, e.g. measurements using the same technology in neighbouring countries, or measurements from networks using different technologies.
- To optimize benefits within a Member's own territory, an effective observing network may require investment outside the Member's territory.
- Mechanisms should be developed for sharing best practice and lessons learnt on observing network design.
- ... [others?]

## 7. DESIGNING APPROPRIATELY SPACED NETWORKS

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

- An observation site should be representative of the climatic regime for which it is intended.  
For some applications the representativeness and effectiveness of observations may be more important design drivers than spatial and temporal homogeneity.
- Sites representative of local features only should be generally avoided (e.g., on steep slopes, in hollows, in proximity to pronounced features such as buildings, topographical influences, ridges), unless sited for a specific purpose and application.
- When considering priorities for additional observations, attention should be given to: observation-poor regions and domains, poorly observed variables, and regions sensitive to change.
- Observing capabilities should be established/maintained in the transition zone between sparsely populated and populated areas, with the extent of this transition zone being defined by the phenomenon that places populations at greatest risk.
- For the purpose of climate monitoring, special attention should be given to maintaining

<sup>22</sup>Editorial note from E. Andersson 2/24/2014: could we mention 'value' of observations, too?

<sup>23</sup> Editorial note from J. Eyre 3/24/2014: "...are required ..." "...are available ...". There is an apparent contradiction here.

stations with long, historically-uninterrupted records

- ~~Network design may need to take advantage of university and private-sector networks-third party networks~~ in order to provide adequate spatial coverage not possible from national and other networks alone.
- Third party observations can provide invaluable measurements for filling in observing gaps where national networks are not possible, and in many areas may be the only available observations, particularly for elements requiring higher density measurements such as precipitation and extremes such as hail, wind storms, etc.
- ~~Members are encouraged to follow WMO density criteria guidelines for observing networks. Additional approaches include various objective analysis techniques and methodologies for specific applications. [More sophisticated methods would examine the particular characteristics and merits of the available stations (e.g. Peterson et al. 1997, Collins et al. 1999) or use objective analysis to aid network selection (e.g. Daley 1993, Jones and Trewin 2000).]~~
- Gaps should be assessed according to WMO Rolling Review of Requirements as described in the Manual on WIGOS, EGOS IP, and the Vision for Global Observing Systems in 2025.
- ... [others?]

## 8. DESIGNING RELIABLE ~~AND~~, STABLE ~~AND SUSTAINABLE~~ NETWORKS

Observing networks should be designed to be reliable, stable and sustainable.

- Observing systems and their telecoms should be designed to be robust against exposure to severe weather.
- A combination of AC power and renewable energy sources (e.g., solar, wind) should be used whenever possible better to ensure continued operation in all weather conditions.
- On-site data storage should be designed to augment real-time telecommunication and to ensure original observations are preserved on site for a minimum of 6 months to 1 year.
- Station sites should be selected in areas least likely to be impacted by factors such as new construction that will force station relocations.
- Training for observing and maintenance procedures at the time of network deployment can increase reliability, and improve stability and sustainability.
- Reliability [c4] can be better assured using a quality system containing procedures for feeding back into the measurement and quality control process to prevent the errors from recurring i.e. quality assurance results should be returned to the observation managers for follow-up. (CIMO Guide to met instr and methods of obs)
- When possible, data should be made available to collection centres where data monitoring can be performed and feedback provided in near real-time regarding data quality, including frequency and character of observational errors, reporting percentages, completeness, and timeliness.
- [Expand on other issues of reliability, stability and sustainability – with links to guidance material]<sup>24</sup>.
- ... [others?]

## 9. DESIGNING THROUGH A TIERED APPROACH

Observing network design should use a tiered structure, through which information from reference observations of high quality can be transferred to and used to improve the quality and utility of other observations[c5],[c6]

- In addition to improving the quality and utility of observations, this approach to design will also lead to improvements in the understanding of the quality of the observations.
- Instrument redundancy should be used whenever appropriate at the higher level to ensure observational accuracy.
- The [c7]tiered approach should include at a minimum a sparse network of reference stations (e.g., USCRN, GRUAN) from which other stations can be benchmarked.

<sup>24</sup>Editorial note from S. Klink 2/24/2014: What is about robustness against other geophysical exposures such as floodings, avalanches, earthquakes, solar wind? Robustness against simple types of vandalism by humans and animals (-> fences)? Robustness against misuse? (E.g. preventing that the telecommunication connection of an observing site can be easily hacked into...)

Reference stations should be calibrated to NIST<sup>25</sup> SI traceable standards, have the highest level of robustness (e.g., have triplicate [C8] measurements 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, the highest standard of metadata collection including photo documentation, and continuous monitoring of system performance to resolve instrument and environmental issues as they arise. ~~Stations from university and public sector networks will often be necessary for filling gaps and providing the spatial density required for climate service requirements<sup>26</sup>.~~

- [C9] Stations such as the “baseline” networks of GCOS (GSN, GUAN) can form an intermediate data layer, with quality between that of Reference stations and the larger comprehensive network of observing stations. A core facet of the baseline network capability is its ability to robustly characterize global and hemispheric change.
- A network of other NMHS or third-party stations can be interspersed with a subset of high quality stations for more complete coverage high-end monitoring and for reference purposes.
- Network design may include the need for visual/manual observations and observations of phenomena not necessarily well sensed by automated systems or because manual observations are more cost effective (possibly reference back to section regarding linked technologies).
- ... [others?]

## 10. ACHIEVING HOMOGENEITY AND CONSISTENCY IN OBSERVATIONAL DATA

Observing networks should be designed to deliver observational data of the level of homogeneity and consistency required by the intended applications.

- NMHSs should give a high priority to maintaining the operations of observing stations/sites that have long data periods.
- Stations should be sited in locations that are least likely to be impacted by changes through time in the natural or man-made environment.
- Where possible, technologies with known performance characteristics should be deployed, to ensure consistent levels of observational quality.
- As part of routine operations the quality and homogeneity of data should be regularly assessed through an ongoing programme to monitor the health of the network<sup>27</sup>.
- When<sup>28</sup> station relocations or instrument upgrades are made, a minimum of one year of overlap between the old and new systems should be made.
- The collection and archive of complete metadata are essential to ensuring the homogeneity of observations..
- For many applications including climate monitoring, it is important that calibration, calibration-monitoring and cross-calibration are designed as part of observing system;
- Observations should be disseminated in a consistent way according to relevant regulatory material [links]
- Observations should be disseminated in such a way that the quality and provenance of the original measurement is retained.
- Observations should be disseminated to meet agreed availability performance targets.
- ... [others?]

## 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

<sup>25</sup>Editorial note from J. Eyre 2/24/2014: Should this be “SI”?

<sup>26</sup>— Editorial note from J. Eyre 2/24/2014: Is this a duplicate of #7?

<sup>27</sup> Editorial note from S. Klink 2/24/2014 for this bullet item, and the 2 bullet items below: As this aspect is mentioned here –which is actually also a sub-item of the “quality management” paragraph in section C-, I would like to suggest moving the entire “quality management” paragraph to this place! From my perspective homogeneity and consistency can be only achieved if comparisons are conducted, i.e. if QM is conducted.

<sup>28</sup> Editorial note from J. Lawrimore 2/24/2014: Realizing this is included in #12 should it also be included here? With a specification of a minimum period of overlap. – Yes, I think so [JE]

transition of research systems to operational status.

- When selecting sites/stations, network planners and administrators should consider locations that can be secured through long-term agreements, leases or ownership.
- Infrastructure should be designed to withstand the type of extremes of weather and climate where located; e.g., in arctic or sub-arctic locations where freeze/thaw cycles can produce ground slumping or upheaval, hurricanes, etc..
- Instruments need to be fit for purpose to measure extremes; e.g., higher-capacity raingauges in areas prone to heavy rainfall, robust anemometers in cyclone-prone areas, and instrumentation and power supplies in very cold areas able to cope with extreme cold.
- A minimum of annual calibration and maintenance of systems, including standardizing and comparing instruments should be conducted while also ensuring staff are adequately trained and comply with well-established procedures.
- A network-wide 'audit' or review of a system should occur on a regular basis (e.g., every five years) to ensure station inspections, operations, and documentation are maintained to standards.
- Some research-based systems, where mature and cost-effective, should be transferred to operational status while maintaining the quality of the observations produced.
- Make pre-operational data available to users on a best efforts basis to facilitate early update and adoption of the new data, once operational.
- Written agreement for operational collection and archive of observations should be made with a recognized archive centre.
- The transition to operations should include the design of robust and maintainable software systems associated with data collection, quality control, archive and access.
- ... [others?]

## 12. MANAGING CHANGE

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

- The conversion 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).
- ~~Significant changes to observation practices or technologies need an adequate change management process overseen by a Change Management board responsible for review, approval and documentation (including updates to metadata).~~
- The impact of new systems or changes to existing systems on products, services, and the user community should be assessed prior to implementation.
- A suitable period of overlap for new and old observing systems is required (i.e., parallel observations), to maintain the homogeneity and consistency of time-series observations.
- When period of overlap is not possible, other methods such as paired observations (co-location of original and new instrumentation) should be used
- When introducing a change aim for as many similarities as possible between the old and new system (e.g., similar site exposure, procedures, and sensors)
- To avoid gaps in the long-term record, continuity of key measurements should be ensured through appropriate deployment strategies.
- Test-beds and pilot projects are required through which new systems can be evaluated and guidelines for operational transition developed.
- Guidance is needed on the transition of existing (legacy) systems to meet WIGOS requirements and standards. [Too general? Or anything specific to say on this?]
- ... [others?]

X<sup>29</sup>

### C. Other Observing System Design issues – non-network issues

29 Editorial note from J. Eyre 2/24/2014: Have all GCOS Monitoring Principles been adequately reproduced or generalised?

#### Quality Management

- Mechanisms are required for collecting, archiving and providing access to observational metadata.
- Data management systems that facilitate access, use and interpretation of data and products should be included as essential elements in observing system design
- Instruments should be characterized and calibrated to agreed standards before operational deployment. [links to guidance]
- Instruments should be calibrated and monitored to agreed standards after operational deployment. [links to guidance]
- Random errors and time-dependent biases in observations should be quantified and documented.
- Operational production of data sets for climate monitoring should be sustained and peer-reviewed new products should be introduced as appropriate.
- Improved qc and characterisation of errors
- Improved data quality with defined standards on availability, accuracy, qc
- Adhere to WIGOS and WIS standards
- Radio frequency requirements

#### Data and dissemination

- Where possible, use redundant data dissemination pathways to enhance reliability
- Data systems to facilitate user access to climate products, metadata and raw data, including key data for delayed-mode analysis, should be established and maintained. [anything new here?]
- Telecommunications adequate for data dissemination ... bandwidth ...
- Collect and transmit in digital form (WIS guidelines)
- Improved homogeneity of data formats and dissemination via WIS

#### Other

- Interoperability
- Technical Design Principles – also needed?
- [The RAs are responsible for the establishment and management of the criteria used to select stations as part of the regional and global networks. – Do we need to retain this?]

## GLOBAL ATMOSPHERE WATCH (GAW) MATERIALS THAT COULD BE USED FOR DEVELOPING OSND GUIDANCE MATERIAL

*(submitted by Oksana Tarasova, WMO Secretariat)*

### PART A – THE GAW FRAMEWORK REGARDING OBSERVING SYSTEM DESIGN

1. The Global Atmosphere Watch (GAW) Programme is a WMO Programme that addresses atmospheric chemical composition and related physical characteristics of the global atmosphere. It consists of a coordinated system of networks of observing stations, methods, techniques, facilities and arrangements encompassing the many monitoring and related scientific assessment activities.

2. GAW addresses six groups of variables, namely stratospheric ozone and vertical ozone distribution, greenhouse gases, reactive gases, precipitation chemistry, aerosols (chemical and physical properties) and UV Radiation. The variables were included in the programme during different periods to address the environmental issues related to those variables. Hence, the maturity of supporting observational network and the spatial coverage for the different variables vary.

3. The Global Climate Observing System (GCOS) defined 50 Essential Climate Variables (ECVs) required to support the work of the UNFCCC and the IPCC. Several GAW observing networks are recognized by GCOS for atmospheric composition ECVs and follow GCOS observational principles.

4. GAW observational network consists of GAW Global and Regional stations and stations working within contributing networks. Information about stations is recorded in the GAW Station Information System (GAWSIS) operated by MeteoSwiss. GAWSIS is to be linked with the OSCAR database to provide information related to the GAW observational capacity.

5. GAW Global and Regional stations are accepted in the programme after consideration of their application by respective Scientific Advisory Groups or Environmental Pollution and Atmospheric Chemistry (EPAC) Scientific Steering Committee of the Commission for Atmospheric Sciences (CAS). The requirements to GAW Regional and Global stations were presented and are included in Part B. Contributing networks are evaluated by relevant groups as individual entities to GAW. A challenge related to contributing networks is that they are designed for specific purposes which are not always completely aligned to the objectives of the GAW Programme. The networks are accepted in GAW if they have demonstrated traceability to the WMO/GAW standards, use measurement techniques comparable to the ones recommended by GAW and share their data openly (including through GAW mechanisms). Siting requirements as for GAW also apply to contributing stations. The inclusion of regional networks as contributing networks to GAW may cause spatial biases for some variables which must be accounted for.

6. Through its evolution GAW mostly focused on issues of global scale, rather than on regional priorities. This is reflected in the general requirements to GAW stations formulated in the GAW Strategic Plan for the period 2008-2015 (GAW Report No.172). A change of focus to better address user needs in specific application is foreseen in the new GAW Implementation Plan which will require the extension of the GAW observational network to include more diverse condition. Inclusion of a new category of stations (“local station”) has been discussed at the 16<sup>th</sup> session of CAS in 2013 and the requirements for such stations are currently under development.

7. GAW strives to implement “integrated” observing system including ground-based observations and satellite remote sensing though some difficulties related to this platform integration do exist. It is difficult to ensure that recommendations on vertical profile measurements using aircraft or other platforms are done with regular spatial resolution as these observations are rather done utilizing opportunities. GAW works to establish a dialogue with satellite agencies to

ensure continuity of that component of the integrated observing system and a task team has been established between GAW and WIGOS to initiate that discussion in the wider context of the Rolling Review of Requirements process.

8. GAW observational network is highly heterogeneous due to a number of factors:

- different level of understanding of diverse environmental issues (e.g interest in total ozone impact on weather initiated ozone observational network in 50s, acid precipitation and urban air pollution drove development of SO<sub>2</sub> and precipitation chemistry observational network in 70s);
- different level of maturity and complexity of measurement techniques for measurements of different parameters; and
- different level of capacity in Member countries to implement atmospheric composition measurements and different national priorities.

9. To achieve a more representative observational network, in support of environmental issues, a requirement of regional representativeness of the GAW stations is followed. GAW strives to reach more ideal spatial homogeneity by continuously promoting this requirement among Members.

10. GAW does not have in its regulations or publications clearly laid out network design principles. The general considerations formulated in the GAW Strategic plan, Congress and Executive Council documents, regional association and CAS documents and individual Measurement Guidelines related to individual variables state that regions important for particular environmental issues should address the gaps in the observational network. Requirements to horizontal and vertical resolution of the observing network are to be driven by Rolling Review of Requirements process. RRR is currently being established for applications using atmospheric composition measurements.

11. An initial step to identify relevant application areas was done at the first meeting of GAW Task Team on Observational Requirements and Satellite Measurements as regards Atmospheric Composition and Related Physical Parameters that took place in WMO on 10-13 November 2014.

12. Network design is also impacted by the GAW Quality Management Framework (QMF) principles (listed in Part C). The primary objectives of the GAW QMF are to ensure that the data in the World Data Centers, which are used in particular in support of decision making, are consistent, of known and adequate quality, supported by comprehensive metadata, and sufficiently complete to describe global atmospheric states with respect to spatial and temporal distribution. Requirements to the quality of data are formulated through Data Quality Objectives.

13. Part D summarizes the consistency between OSND principles and GAW network management practices.

## **PART B – REQUIREMENTS TO THE GAW REGIONAL STATIONS**

1. The station location is chosen such that, for the variables measured, it is regionally representative and is normally free of the influence of significant local pollution sources.
2. There are adequate power, air conditioning, communication and building facilities to sustain long term observations with greater than 90% data capture (i.e. <10% missing data).
3. The technical support provided is trained in the operation of the equipment.
4. There is a commitment by the responsible agency to long term observations of at least one of the GAW variables in the GAW focal areas (ozone, aerosols, greenhouse gases, reactive gases, UV radiation, precipitation chemistry).
5. The GAW observation made is of known quality and linked to the GAW Primary Standard.
6. The data and associated metadata are submitted to one of the GAW World Data Centres no later than one year after the observation is made. Changes of metadata including instrumentation,

traceability, observation procedures, are reported to the responsible WDC in a timely manner.

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

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

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

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

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

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

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

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

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

## **PART C – MAIN PRINCIPLES OF THE GAW QUALITY MANAGEMENT FRAMEWORK**

1. Full support of the GCOS Climate Monitoring Principles
2. Network-wide use of only one reference standard or scale (primary standard). In consequence, there is only one institution that is responsible for this standard.
3. Full traceability to the primary standard of all measurements made by Global, Regional and Contributing GAW stations.
4. The definition of data quality objectives (DQOs).
5. Establishment of guidelines on how to meet these quality targets, i.e., harmonized measurement techniques based on Measurement Guidelines (MGs) and Standard Operating Procedures (SOPs).
6. Establishment of MGs or SOPs for these measurements.
7. Use of detailed log books for each parameter containing comprehensive meta information related to the measurements, maintenance, and 'internal' calibrations.
8. Regular independent assessments (system and performance audits).
9. Timely submission of data and associated metadata to the responsible World Data Centre as a means of permitting independent review of data by a wider community.

## **PART D – OBSERVING SYSTEM NETWORK DESIGN (OSND) PRINCIPLES AS APPLIED IN THE GLOBAL ATMOSPHERE WATCH PROGRAMME**

### **1. SERVING MANY APPLICATION AREAS**

GAW observations are aimed at serving many applications. Stations are recommended to perform observations of as many parameters as possible at each individual station.

### **2. MEETING USER REQUIREMENTS**

Currently user community is being consulted and requirements to be reflected in requirements database.

### **3. MEETING NATIONAL, REGIONAL AND GLOBAL REQUIREMENTS**

GAW was created to address rather global and regional issue than national. For a number of parameters design of the network to address national requirements (e.g. in the case of the short



lived gases or aerosols) would require different network design.

#### 4. DESIGNING APPROPRIATELY SPACED NETWORKS

GAW indicates spatial gaps in the network in the Congress, EC and Regional Association documents and encourages the Members to address these gaps.

#### 5. DESIGNING COST-EFFECTIVE NETWORKS

This is not implemented in GAW as we rely on the capacity of Members. Though GAW uses opportunities provided by contributing networks and encourages regional and national networks to join GAW if they are compatible with GAW protocols.

#### 6. ACHIEVING HOMOGENEITY IN OBSERVATIONAL DATA

GAW implements Quality Management System with harmonized measurement techniques, regular comparison campaigns and checks in the Data Centres to achieve homogeneity of observational data.

#### 7. DESIGNING THROUGH A TIERED APPROACH

This principle is embedded in the GAW Quality Assurance System.

#### 8. DESIGNING RELIABLE AND STABLE NETWORKS

GAW station requirement include the request for continues long-term uninterrupted operation of stations.

#### 9. MAKING OBSERVATIONAL DATA AVAILABLE

GAW practises open data policy. Observational data are submitted by Members to the dedicated data centres and are made freely available.

#### 10. PROVIDING INFORMATION SO THAT THE OBSERVATIONS CAN BE INTERPRETED

Observational data submitted to the data centres require accompanying metadata and flagging that can be used to interpreted observational data. Stations are required to have detailed log book to support their observations. The synchronization of the flagging between different data centres is on-going work.

#### 11. ACHIEVING SUSTAINABLE NETWORKS

GAW is a research programme. Unfortunately recent attempts to move atmospheric composition measurements to operational mode led to loss of quality of observations and data gaps are due to limited capacity and experience within the operational community. Research support is still needed to support atmospheric composition observations at the required quality level.

#### 12. MANAGING CHANGE

Individual measurement guidelines and standard operating procedures contain information on required overlap period between different systems to ensure consistency of the data sets from the same station.

## GLOBAL CRYOSPHERE WATCH (GCW) MATERIALS THAT COULD BE USED FOR DEVELOPING OSND GUIDANCE MATERIAL

*(Submitted by Michele Citterio (Denmark) and the WMO Secretariat)*

1. Following decisions made by the Sixteenth World Meteorological Organization Congress in 2011, WMO is now developing the Global Cryosphere Watch (GCW) as an IPY legacy with a view towards achieving an operational GCW. This initiative is an international mechanism for supporting all key cryospheric in situ and remote sensing observations. Intrinsically GCW is a cross-cutting activity with interests extending globally. Its activities relate to several Technical Commissions (TCs), all Regional Associations (RAs) and virtually all WMO Programmes. GCW will provide authoritative, clear, and useable data, information, and analyses on the past, current, and future state of the cryosphere. The observing component of GCW is a component of the WMO Integrated Global Observing System (WIGOS).
2. As defined in the Manual on WIGOS, GCW shall be a coordinated system of networks of observing stations, methods, techniques, facilities and arrangements encompassing monitoring and related scientific assessment activities devoted to the investigation of the changing cryosphere. The Cryosphere Observing Network shall build on existing cryosphere observing programmes and promote the addition of standardized cryospheric observations to existing facilities. The purpose and long-term goal of the Global Cryosphere Watch shall be to provide data and other information on the global cryosphere to improve understanding of its behaviour, interactions with other components of the climate system, and impacts on society. In designing the GCW Cryospheric Observing Network, the recommendations laid out in the IPET-OSDE OSND Principles have been taken into account.
3. An immediate priority for GCW is to establish the core standardized surface-based observing network called CryoNet, see more details on: <http://www.globalcryospherewatch.org/cryonet/>, as well as to identify practices that will be applied by the two types of CryoNet sites, see: [http://www.globalcryospherewatch.org/cryonet/site\\_types.html](http://www.globalcryospherewatch.org/cryonet/site_types.html).
4. Recognizing that existing communities, practices and needs for ground based cryospheric observations may partly have a regional character, the GCW CryoNet Team has organized a CryoNet Asia and CryoNet South America workshops which proved to be very successful at bringing together the relevant communities. This will ensure that existing observing networks designed to meet national needs also take into account the needs of GCW and the WMO at the regional and global levels, as recommended by OSDE.
5. CryoNet will be comprised of sites with varying capabilities. It will build on existing cryosphere observing programmes and promote the addition of standardized cryospheric observations to existing facilities in order to create more robust environmental observatories. CryoNet observations cover all components of the cryosphere (glaciers, ice shelves, ice sheets, snow, permafrost, sea ice, river/lake ice and solid precipitation) through in situ observations.
6. Two types of sites are envisioned based on the number of “spheres” that are monitored (e.g. atmosphere, biosphere, cryosphere, hydrosphere, etc.). See Figure 1. CryoNet Basic Sites monitor one or more components of the cryosphere and observe multiple variables of each component. Basic Sites also measure auxiliary meteorological variables, comply with GCW best practices, are actively taking measurements, have a long-term financial commitment, make data freely available, and make data available in (near) real time whenever possible. CryoNet Integrated Sites, in addition to the CryoNet Basic Sites characteristics, monitor at least one other sphere, have a broader research focus, have support staff, and have training capability. CryoNet Integrated Sites are particularly important for the study of feedbacks and complex interactions between the atmosphere, biosphere, cryosphere, and ocean.

7. CryoNet Sites contain one or more CryoNet Stations. Primary Stations have a target (intent) of long-term operation and have at least a 4-year initial commitment. Baseline Stations have a long-term operational commitment and long-term (more than 10 years) data records.

<b>CryoNet Sites</b>	
<b>Basic Sites (Cryosphere only)</b>	<b>Integrated Sites (Multiple spheres)</b>
<ul style="list-style-type: none"> <li>• Monitor single or multiple components of the cryosphere</li> <li>• Observe multiple variables of each component</li> <li>• Measure auxiliary meteorological variables</li> <li>• Comply with GCW best practices</li> <li>• Be currently active</li> <li>• Commit to long-term operation</li> <li>• Make data freely available, whenever possible in (near) real time</li> </ul>	<p>In addition to CryoNet Basic Site characteristics:</p> <ul style="list-style-type: none"> <li>• Monitor at least one other sphere (e.g., hydrosphere, biosphere, atmosphere)</li> <li>• Have a broader research focus</li> <li>• Have supporting staff</li> <li>• Have training capability</li> </ul>
<b>CryoNet Stations (Sites contain one or more stations)</b>	
<b>Primary Stations</b>	<b>Baseline Stations</b>
<ul style="list-style-type: none"> <li>• Have target of long-term operation</li> <li>• Have a 4 year initial commitment</li> </ul>	<ul style="list-style-type: none"> <li>• Have long-term operational commitment</li> <li>• Have a long-term record (10+ years)</li> </ul>

Figure 1: The structure of CryoNet

8. It is envisioned that a number of currently active ground monitoring sites producing valuable cryospheric observations may not satisfy all the requirements to become CryoNet sites. These sites can apply for inclusion in the wide GCW Cryosphere Observing Network as Contributing Sites.

9. In order for a surface measurement site or station to be included in CryoNet, it must meet certain criteria. The minimum requirements are given below. If a site meets these requirements, additional information (metadata) can be provided for further evaluation through the [CryoNet Site Questionnaire](#) (a preview is available here). Contributing sites, which are part of the wide GCW surface network but not part of CryoNet, only need to meet the data sharing requirement.

- i. The site location is chosen such that, for the cryospheric components measured, it is representative of the surrounding region.
- ii. User needs have been considered in the observation design process.
- iii. CryoNet sites have to be active and perform sustained observations according to CryoNet best practices. There shall be a commitment to continue measurements for a minimum of four (4) years.
- iv. Personnel are trained in the operation and maintenance of the site.
- v. The responsible agencies are committed, to the extent reasonable, to sustaining long-term observations of at least one cryosphere component, including auxiliary meteorological variables.

- vi. The relevant CryoNet observations are of documented quality. The measurements are made and quality controlled according to CryoNet best practices.
  - vii. Associated standard meteorological in situ observations, when necessary for the accurate determination and interpretation of the GCW variables, are made with documented quality.
  - viii. A logbook for observations and activities that may affect observations is maintained and used in the data validation process.
  - ix. The data and metadata, including changes in instrumentation, traceability, observation procedures, are submitted in a timely manner to a data centre that is interoperable with the GCW portal.
  - x. The site characteristics and observational programme information are kept up-to-date in the GCW station information database. Station metadata are also provided to the WIGOS Information Resource (WIR) and maintained regularly.
10. The process of selecting sites and stations as part of the CryoNet network is in its initial stage (see <http://globalcryospherewatch.org/cryonet/stations.php>). An online site application form has been made available and several sites were identified for the preoperational testing phase, see: (<http://globalcryospherewatch.org/cryonet/sites.php?category=core>). The whole process will be completed by December 2015 for consideration by EC-68.
11. Acknowledging the importance of historical time series at sites not currently active, the GCW Cryosphere Observing Network will accept such historical time series and encourage efforts aimed at rescuing data from existing archives, their digitalization, and their opening for public access.
12. In order to make cryospheric ground observations available in an open and timely manner to the GCW Cryosphere Observing Network and in particular its core network CryoNet, the design of the network is progressing in parallel with the establishment of the GCW Data Portal. The online data portal collects and maintains metadata records and pointers to the data repositories physically holding the data. The GCW Data Portal implements machine interfaces to the data providers operating the ground observation sites, allowing timely metadata updates when new measurements are added, current time series are interrupted or other relevant changes occur at sites belonging to the GCW Cryosphere Observing Network. This further implements the OSDE recommendations for 'providing information so that the observations can be interpreted' and for 'managing change'
13. As an enabling step toward the development of the GCW best practices and the homogeneity of delivered observational data, a database of cryospheric terms as defined by existing glossaries has been compiled and is available through the GCW Website at <http://globalcryospherewatch.org/reference/glossary.php>. Further work is needed to evaluate alternative definitions and converge on the official GCW Glossary that will be formally vetted and then translated.
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## **EUMETNET MATERIALS THAT COULD BE USED FOR DEVELOPING OSND GUIDANCE MATERIAL**

*(Submitted by Stefan Klink (EUMETNET))*

### **CONTENT:**

**PART A – GENERAL CONSIDERATIONS – HOW DOES EUMETNET DECIDE ON OSND RECOMMENDATIONS?**

**PART B – CONCRETE EUMETNET OBSERVATIONS PROGRAMME EXPERIENCES AND PROPOSALS FOR ITEMS TO BE DISCUSSED UNDER THE VARIOUS DESIGN PRINCIPLES**

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### **PART A – GENERAL CONSIDERATIONS – HOW DOES EUMETNET DECIDE ON OSND RECOMMENDATIONS?**

Different drivers (external and internal) can force NMHSs to reconsidering the design of their different observing networks from time to time. Data users may have interest in getting observations of variables which haven't been monitored so far or users may ask for more (higher density in space and time) observations of a certain variable/element. A typical driver for such requests is the ongoing improvement of data assimilation algorithms which can make use of more and more data.

On EUMETNET level (i.e. sub-RA VI level) a mechanism has been established in order to standardize the process of designing or re-designing parts of the EUMETNET Composite Observing System (EUCOS).

First observation data users make a proposal for more or 'new' observations. In a second step the EUMETNET Observations Scientific Expert Team (Obs-SET; comprising of data assimilation experts) and sometimes also the Observations Programme Advisory Group (OPAG; comprising of national observations managers) consider such proposals and make a decision whether the Observations Programme Management shall coordinate data impact studies which can demonstrate the expected benefit of these new observations. Such data impact studies are considered to be 'objective' tools for the assessment of the impact or benefit of observations. When the advising bodies are in favour of conducting data impact studies the Obs Programme Management Team drafts a study specification and coordinates this with the Obs-SET. This is the third step. After identification of a suitable 'contractor' for the study (e.g. a NWP/ data assimilation section of a Member) the fourth step is the approval of the study proposal by the EUMETNET Science and Technology Advisory Committee (STAC) and Policy and Finance Advisory Committee (PFAC). Step five is the realisation of the study which can take between half a year and two years. Typical durations are between one and two years. E.g. classical Observing System Experiments take longer (usually at least one year) than new 'forecast sensitivity to observations' analyses (can be conducted in a few months in some cases). When final study results are available the sixth step is to analyse these and to agree on relevant OSND recommendations. The analysis of results and the drafting of recommendations are done by Obs-SET. Afterwards the recommendations are presented to STAC for their consideration (step seven). Finally, after a positive STAC decision for following such a recommendation and a corresponding PFAC decision for making available funding (if required) the Observations Programme Management can take measures to start step eight: the coordination and/or procurement of 'new' or more observations. The entire process starting with first ideas up to operational provision with new observations takes on average three years.

On EUMETNET level OSND recommendations are typically formulated in a rather concrete way. Usually Obs-SET aims for agreeing on OSND recommendations which demand for observation of a certain variable but do not prescribe the observing technology for obtaining such measurements.

Example from the EUCOS Upper-Air Network Redesign Study:

“Humidity information in the lower troposphere should not be degraded. It is therefore recommended to improve the coverage of lower tropospheric moisture observations.”

Sometimes even the suggested/desired observing technology is specified.

Example from the 2<sup>nd</sup> EUCOS Space-Terrestrial Study:

“Use drifting buoys to fill gaps where VOS observations are not regularly available.”

Further examples of data impact studies coordinated by the EUMETNET Observations Programme Management/ “EUCOS” and some basic description of studies’ purposes, contents and their results and derived OSND recommendations can be found in the document “REVIEW OF SPECIFIC REGIONAL ACTIVITIES RELATED TO OBSERVING SYSTEM DESIGN - EIG EUMETNET” (CBS/OPAG-IOS/OSDW1 / Doc. 4.4.2) and its annexes.

## **PART B – CONCRETE EUMETNET OBSERVATIONS PROGRAMME EXPERIENCES AND PROPOSALS FOR ITEMS TO BE DISCUSSED UNDER THE VARIOUS DESIGN PRINCIPLES**

**Note:** Microsoft Word “track changes” kept in the text below on purpose.

### **1. SERVING MANY APPLICATION AREAS**

Observing networks should be designed to meet the observational needs of many application areas<sup>30</sup> within WMO and WMO co-sponsored programmes.

- When designing observing networks the needs of WMO Application Areas, as documented in WIGOS guidance should be taken into account [Link to RRR material on Applications Areas and Statements of Guidance]
- The design of observing networks implemented primarily to support operational forecasting should also take into account the needs of other applications, including climate and environmental monitoring.
- Observing systems and their networks should be designed and operated, where technically and/or economically possible, in such a way that the needs of multiple applications are satisfied.
- Observing network management should implement a user consultation procedure which guarantees that the requirements of different application areas can be considered and analysed simultaneously.
- Partnerships with other organizations responsible for observations should be exploited, through the integration of observing systems and multi-purpose design in order to achieve synergies and better cost effectiveness.
- ... [others?]

### **2. MEETING USER REQUIREMENTS**

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

- User communities should be involved in observing system network design. To ensure

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<sup>30</sup> A WMO Application Area is an activity involving primary use of observations, in a chain of activities which allow National Meteorological Services or other organizations to render services contributing to public safety, socio-economic well-being and development in their respective countries, in a specific domain related to weather, climate and water. The concept of a WMO Application Area is used in the framework of the [WMO Rolling Review of Requirements \(RRR\)](#) and describes a homogeneous activity for which it is possible to compile a consistent set of observational user requirements agreed by community experts working operationally in this area.

observing system networks meet the key needs of the user communities, detailed decisions about observing system network design should include a consultation stage with appropriate application area representatives. A procedure should be implemented which allows a documented collection and synthesis of user requirements. (In addition an objective tool is required which informs about the potential impact and benefit of the different observations.)

- When design observing networks, the user needs as documented and quantified in WIGOS guidance should be taken into account [with link to RRR details of URs and SoGs]
- [Guidance should be developed on how to interpret the UR information in the OSCAR database for the purposes of network design]
- Long-term requirements, including appropriate sampling frequencies, should be specified to network designers, operators and instrument engineers at the outset of system design and implementation.
- The domains and spacing of observing networks should be sized in order to capture severe and high impact events.
- Observing systems should be designed with temporal spacings and other performance characteristics such that extreme events of short duration are captured and climate-relevant changes (e.g. diurnal, seasonal, and long-term inter-annual) can be resolved.
- ... [others?]

### 3. MEETING NATIONAL, REGIONAL AND GLOBAL REQUIREMENTS

Observing networks designed to meet national needs should also take into account the needs of the WMO community for applications for which requirements are regional or global.

- National networks shall be established by Members to satisfy their own requirements. When implementing these national networks, Members shall take into account the needs of global and regional applications. These considerations should include data storage, availability, exchange and documentation.
- WIGOS principles should be adopted for networks that are implemented primarily to meet national needs.
- The procedure allowing a documented collection and synthesis of user requirements (see principle no. 2 – Meeting User Requirements) should be designed in a way so that regional and global requirements can be handled simultaneously.
- ... [others?]

### 4. MAKING OBSERVATIONAL DATA AVAILABLE

Observational data from national observing networks should be made available to other WMO Members, at space-time resolutions and with a timeliness needed to meet the needs of regional and global applications.

- Many gaps in user requirements for observations can be filled by disseminating observations that are currently made but not collected centrally in a NMHS, or made but not disseminated internationally, or made but not disseminated in a timely manner.
- Mechanisms should be established to minimise loss of observational data and to promote recovery of old data for climate applications.
- Multiple and overlapping methods of dissemination should be used whenever possible to ensure continuity of data collection.
- (Third party data of sufficient quality should be made available for global exchange.)
- [A practical means for facilitating data availability is to specify standardized data formats for data exchange, to demand for the implementation of such standards and to monitor the conformity with standards. A current example is the migration from TAC to TDCF. A detailed monitoring of observation reports allows detection of coding errors and is the prerequisite for any corrective actions.
- ... [others?]

### 5. PROVIDING INFORMATION SO THAT THE OBSERVATIONS CAN BE UNDERSTOOD

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 interpretation of the observational data (i.e. metadata) are documented and treated with the same care as the data themselves.

- Appropriate metadata are essential to ensure quality, traceability and homogeneity of observations [link to appropriate WIGOS guidance]
- Metadata collection, dissemination, archive and access systems should be designed with as much attention as those for observational data.
- Station metadata should be created at the time of network installation and updated at a minimum annually 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.
- Metadata practices should adhere to international standards in use by the meteorological<sup>31</sup> community.
- ... [others?]

## 6. DESIGNING COST-EFFECTIVE NETWORKS

Observing networks should be designed to make the most cost-effective use of available resources.

- Observing networks should be designed using the most appropriate and cost-effective technologies or combinations of technology. [Develop guidance on how to do this.]
- Developments to observing systems should normally build on existing sub-systems, capitalising on both existing and new technology, and integrating new systems into existing WIGOS capabilities.
- Designs should be sufficiently flexible to allow for expansion without the need for complete network re-design. As requirements change the design of the observing system network may need to change, and its configuration should be sufficiently flexible to allow for incremental expansion, or contraction, without the need for entire network re-design.
- Partnerships with other organizations responsible for observations should be exploited in order to build on potential synergies, share costs and provide more cost-effective systems.
- Observing network design should, where possible, be based on the results from scientific studies which assess the impact, importance and cost-effectiveness<sup>32</sup> of the observations for the applications to which they contribute.
- Tools are required to aid design of cost-effective composite observing systems. They should include assessment of actual or anticipated impact of observations. A variety of such tools are available and widely used in some application areas (e.g. GNWP)<sup>33</sup>.
- Tools are required to assess the cost-effectiveness of observations for each application and the combined value across all application. This will require consultation between observing system designers and application owners/experts.
- Spaced-based and surface-based observing networks should be designed and operated in such a way that they are complementary, with appropriate activities and cooperation between the communities responsible for these networks, to ensure that observations from each system are used to enhance the impact and effectiveness of the other.
- [Use of functioning baseline instruments that meet calibration and stability requirements should be maintained for as long as possible, even when these exist on decommissioned observing systems – originally written for satellite instruments, and should be generalized.]
- Observing networks should be designed taking into account measurements available from other networks in the vicinity, e.g. measurements using the same technology in neighbouring countries, or measurements from networks using different technologies.
- To optimize benefits within a Member's own territory, an effective observing network may require investment outside the Member's territory.
- Mechanisms should be developed for sharing best practice and lessons learnt on observing network design.
- ... [others?]

<sup>31</sup>Editorial noted from J. Eyre 2/24/2014: Should we generalize this?

<sup>32</sup>Editorial note from E. Andersson 2/24/2014: could we mention 'value' of observations, too?

<sup>33</sup> Editorial note from J. Eyre 3/24/2014: "...are required ..." "...are available ...". There is an apparent contradiction here.



## 7. DESIGNING APPROPRIATELY SPACED NETWORKS

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

- Objective tools should be employed which demonstrate the impact and benefit of observations for certain application areas. Additionally such tools must be suited for demonstrating the impact of observation density in the various application areas. (Such tools exist in NWP/ data assimilation and are well-proven. There are different kinds of data impact studies (e.g. OSEs, OSSEs, Forecast Sensitivity to Observations Analyses).)
- For some applications the representativeness and effectiveness of observations may be more important design drivers than spatial and temporal homogeneity.
- When considering priorities for additional observations, attention should be given to: observation-poor regions and domains, poorly observed variables, and regions sensitive to change.
- Observing capabilities should be established/maintained in the transition zone between sparsely populated and populated areas, with the extent of this transition zone being defined by the phenomenon that places populations at greatest risk.
- For the purpose of climate monitoring, special attention should be given to maintaining stations with long, historically-uninterrupted records
- Network design may need to take advantage of university and private-sector networks in order to provide adequate spatial coverage not possible from national and other networks alone.
- ... [others?]

## 8. DESIGNING RELIABLE, STABLE AND SUSTAINABLE NETWORKS

Observing networks should be designed to be reliable, stable and sustainable.

- Observing systems and their telecoms should be designed to be robust against exposure to severe weather.
- A combination of AC power and renewable energy sources (e.g., solar, wind) should be used whenever possible better to ensure continued operation in all weather conditions.
- On-site data storage should be designed to augment real-time telecommunication and to ensure original observations are preserved on site for a minimum of 6 months to 1 year.
- Station sites should be selected in areas least likely to be impacted by factors such as new construction that will force station relocations.
- Monitoring procedures described under OND Principle no. 6[SK101] – Achieving Homogeneity In Observational Data – are also helpful for assessing the current and long-term reliability and stability of networks.
- [Expand on other issues of reliability, stability and sustainability – with links to guidance material]<sup>34</sup>.
- ... [others?]

## 9. DESIGNING THROUGH A TIERED APPROACH

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

- In addition to improving the quality and utility of observations, this approach to design will also lead to improvements in the understanding of the quality of the observations.
- The tiered approach should include at a minimum a sparse network of reference stations from which other stations can be benchmarked. Reference stations should be calibrated to NIST<sup>35</sup> traceable standards, have triplicate measurements of key variables such as temperature and precipitation, be well sited in locations least affected by urbanization and

<sup>34</sup>Editorial note from S. Klink 2/24/2014: What is about robustness against other geophysical exposures such as floodings, avalanches, earthquakes, solar wind? Robustness against simple types of vandalism by humans and animals (-> fences)? Robustness against misuse? (E.g. preventing that the telecommunication connection of an observing site can be easily hacked into...)

<sup>35</sup>Editorial note from J. Eyre 2/24/2014: Should this be "SI"?

other non-climatic influences, have regular maintenance and replacement cycling of instruments, the highest standard of metadata collection including photo documentation, and continuous monitoring of system performance to resolve instrument and environmental issues as they arise. Stations from university and public-sector networks will often be necessary for filling gaps and providing the spatial density required for climate service requirements<sup>36</sup>.

- ... [others?]

## 10. ACHIEVING HOMOGENEITY AND CONSISTENCY IN OBSERVATIONAL DATA

Observing networks should be designed to deliver observational data of the level of homogeneity and consistency required by the intended applications.

- Stations should be sited in locations that are least likely to be impacted by changes through time in the natural or man-made environment.
- Instruments and observing practices fulfilling the commonly agreed user requirements should be used. Where possible, technologies with known performance characteristics should be deployed, to ensure consistent levels of observational quality.
- As part of routine operations the quality and homogeneity of data should be regularly assessed through an ongoing programme to monitor the health of the network<sup>37</sup>. A comprehensive monitoring of data availability, timeliness and accuracy – the latter through a comparison against short-term model forecasts – can help detecting various types of errors, e.g. non-timely or missing data, improperly coded observations, erroneous measurements. Monitoring results can be made available in different ways, e.g. via web portals, regular reports (visualisation of overall performance statistics) or fault reports (focus on detected errors at specific sites).
- When<sup>38</sup> station relocations or instrument upgrades are made, a minimum of one year of overlap between the old and new systems should be made.
- The collection and archive of complete metadata are essential to ensuring the homogeneity of observations..
- For many applications including climate monitoring, it is important that calibration, calibration-monitoring and cross-calibration are designed as part of observing system;
- Observations should be disseminated in a consistent way according to relevant regulatory material [links]
- Observations should be disseminated in such a way that the quality and provenance of the original measurement is retained.
- Observations should be disseminated to meet agreed availability performance targets.
- ... [others?]

## 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.

- Some research-based systems, where mature and cost-effective, should be transferred to operational status while maintaining the quality of the observations produced.
- Make pre-operational data available to users on a best efforts basis to facilitate early update and adoption of the new data, once operational.
- Written agreement for operational collection and archive of observations should be made with a recognized archive centre.
- The transition to operations should include the design of robust and maintainable software systems associated with data collection, quality control, archive and access.
- Data providers have to inform about the error characteristics of their data and data users

<sup>36</sup> Editorial note from J. Eyre 2/24/2014: Is this a duplicate of #7?

<sup>37</sup> Editorial note from S. Klink 2/24/2014 for this bullet item, and the 2 bullet items below: As this aspect is mentioned here –which is actually also a sub-item of the “quality management” paragraph in section C-, I would like to suggest moving the entire “quality management” paragraph to this place! From my perspective homogeneity and consistency can be only achieved if comparisons are conducted, i.e. if QM is conducted.

<sup>38</sup> Editorial note from J. Lawrimore 2/24/2014: Realizing this is included in #12 should it also be included here? With a specification of a minimum period of overlap. – Yes, I think so [JE]

have to explain to data providers how they intend to make use of the different data types. Finally, data providers together with data users should develop a common understanding of usability or non-usability of a certain observation type for a certain application.

- ... [others?]

## 12. MANAGING CHANGE

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

- The conversion 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).
- The impact of new systems or changes to existing systems should be assessed prior to implementation. The objective tools demonstrating the impact and benefit of observations for certain application areas, mentioned under OND Principle no. 4 – Designing Appropriately Spaced Networks - , can also support the change management.
- A suitable period of overlap for new and old observing systems is required, to maintain the homogeneity and consistency of time-series observations.
- To avoid gaps in the long-term record, continuity of key measurements should be ensured through appropriate deployment strategies.
- Test-beds and pilot projects are required through which new systems can be evaluated and guidelines for operational transition developed.
- Guidance is needed on the transition of existing (legacy) systems to meet WIGOS requirements and standards. [Too general? Or anything specific to say on this?]
- ... [others?]

## REVIEW OF OSND GUIDANCE MATERIALS DEVELOPED BY OSDW1

(3 Feb. 2015, Y. Sato, E. Andersson)

**Note:** Microsoft Word "track changes" kept in the text below on purpose.**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.

Observing networks should be designed to meet the observational needs of many WMO Rolling Review of Requirements (RRR) application Areas<sup>1</sup> within WMO and WMO co-sponsored programmes. For each Application Area the Rolling Review of Requirements (RRR) documents quantitatively the observational user requirements ~~are documented quantitatively~~ for the Atmosphere, Oceans, Terrestrial, and Outer Space domains.

- When designing observing networks the needs of WMO Application Areas, as documented in WIGOS guidance should be taken into account [Link to RRR material on Applications Areas and Statements of Guidance]
- For example, the design of observing networks implemented primarily in support of Application Areas that are primarily relying on operational forecasting should also take into account the needs of other Applications Areas, including climate and environmental monitoring such as climate monitoring.
- Where practicable, observing systems and their networks should be designed and operated, where technically and/or economically possible, in such a way that the needs of multiple applications are satisfied.
- Partnerships with the co-sponsored programmes responsible of observations should be taken into account in observing network design.
- Partnerships with other organizations (e.g. involved in road transportation, electric power generation, etc.), including partner organizations responsible for observations should be exploited, through the integration of observing system networks and multi-purpose design in order to achieve synergies between networks or domains and better cost effectiveness.
- ~~... [others?]~~

**2. MEETING USER REQUIREMENTS**

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

Such requirements are documented in the Observing System Capability Analysis and Review tool (OSCAR).

- User communities should be involved in observing system network design. To ensure observing system networks meet the key needs of the user communities, detailed decisions about observing system network design should include a consultation stage with appropriate application area representatives.
- Members should take into account the actions from the Implementation Plan for the Evolution of Global Observing Systems (EGOS-IP), as well as the gap analysis from the RRR Statements of Guidance (SoG) for all Application Areas when designing their

<sup>1</sup> A WMO Application Area is an activity involving primary use of observations, in a chain of activities which allow National Meteorological Services or other organizations to render services contributing to public safety, socio-economic well-being and development in their respective countries, in a specific domain related to weather, climate and water. The concept of a WMO Application Area is used in the framework of the WMO Rolling Review of Requirements (RRR) and describes a homogeneous activity for which it is possible to compile a consistent set of observational user requirements agreed by community experts working operationally in this area.

observing networks.

~~1. When design observing networks, the user needs as documented and quantified in WIGOS guidance should be taken into account [with link to RRR details of URs and SoGs]~~

~~2. [Guidance should be developed on how to interpret the UR information in the OSCAR database for the purposes of network design]~~

- Long-term requirements, including appropriate sampling frequencies, should be specified to network designers, operators and instrument engineers at the outset of ~~system~~ network design and implementation.
- The domains and ~~three-dimensional~~ 3D spacing of observing networks should be ~~sized~~ dimensioned in order to capture severe and high impact events (see also principle No. 4).
- Observing ~~system~~ networks should be designed with temporal spacings and other performance characteristics such that extreme events of short duration are captured and climate-relevant changes (e.g. diurnal, seasonal, and long-term inter-annual) can be resolved.
- Taking into account observational user requirements specified in OSCAR, together with additional regional that may not be specified in OSCAR, and national requirements, Members should conduct further studies to assess feasibility of addressing them with existing technology, taking resources, and cost effectiveness into account (e.g. see OND principles No. 5).

~~3. ... [others?]~~

For ICG-WIGOS to consider:

- Decide on the opportunity/need to develop separate guidance materials with OSCAR on [Guidance should be developed on how to interpret the UR User Requirements information in the OSCAR database for the purposes of network design.]

**3. MEETING NATIONAL, REGIONAL AND GLOBAL REQUIREMENTS**

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

- National networks shall be established by Members primarily to satisfy their own requirements. When implementing these national networks, Members shall take into account the needs of global and regional applications.
- For example, Members could consider how the national networks could be also useful also to global and regional applications outside of the country? What small additional commitments or adjustments (e.g. in terms of data storage, data policy, availability, exchange and documentation) could be proposed? These considerations should include data storage, availability, exchange and documentation.
- WIGOS ~~principles~~ regulations should be adopted for networks that are implemented primarily to meet national needs.
- ... [others?]

**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.

- The composite network should deliver basic observation information that are quasi uniform in space for observed variables, and resulting from an analysis of the 3D resolution requirements (threshold) provided in OSCAR.
- For some application areas the representativeness and ~~effectiveness~~ potential impact of observations may be more important design drivers than spatial and temporal

homogeneity. For example, the density of an observing network could be adjusted according to variability of the observed phenomena in a given region.

- When considering priorities for additional observations, attention should be given to: observation-poor regions and domains, poorly observed variables, and regions sensitive to change, which are not necessarily located in the primary region of interest of a country.
- ~~Observing capabilities should be established/maintained in the transition zone between sparsely populated and populated areas, with the extent of this transition zone being defined by the phenomenon that places populations at greatest risk.~~
- ~~For the purpose of climate monitoring, special attention should be given to maintaining stations with long, historically uninterrupted records~~
- Members should investigate potential synergies with other organizations within the Country, and how to complement existing networks and share resources in order to address gaps. For example ~~Network-network~~ design may need to take advantage of ~~university and private sector~~ third party networks in order to provide adequate spatial coverage not possible from national and other networks alone.
- ~~... [others?]~~

For ICG-WIGOS to consider:

- Need mechanism(s) to develop and maintain regional (for Regional Associations, and climate regions) observational user requirements in OSCAR.

## 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.

- Observing networks should be designed using the most appropriate and cost-effective technologies or combinations of technology (e.g. measurement technologies, data collection mechanisms, power sources). For example, existing materials from CIMO and other Technical Commissions on existing technology, and impact studies could be consulted. [Develop guidance on how to do this.]
- Developments to observing ~~system~~ networks should normally build on existing sub-~~system~~ networks, capitalising on both existing and new technology, and integrating new ~~system~~ networks into existing WIGOS capabilities.
- Designs should be sufficiently flexible to allow for expansion without the need for complete network re-design. As requirements change the design of the observing ~~system~~ network may need to change, and its configuration should be sufficiently flexible to allow for incremental expansion, or contraction, without the need for entire network re-design.
- Partnerships with other organizations responsible for observations should be exploited in order to build on potential synergies, share costs and provide more cost-effective ~~system~~ multi-purpose networks.
- Observing network design should, where possible, be based on the results from scientific studies which assess the impact, importance and ~~cost-effectiveness~~ value<sup>2</sup> 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 observing systems when designing networks.
- Tools are required to aid design of cost-effective composite observing systems. They should include assessment of actual or anticipated impact of observations. A variety of such tools are available and widely used in some application areas (e.g. GNWP)<sup>3</sup>.
- Tools are required to assess the cost-effectiveness of observations for each application and the combined value across all application. This will require consultation between observing ~~system~~ network designers and application owners/experts.
- Spaced-based and surface-based observing networks should be designed and operated in

<sup>2</sup> Editorial note from E. Andersson 2/24/2014: could we mention 'value' of observations, too?

<sup>3</sup> Editorial note from J. Eyre 3/24/2014: "...are required ..." "...are available ...". There is an apparent contradiction here.

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 system network are used to enhance the impact and effectiveness of the other.

- Considering that space-based observing systems that continue to meet calibration and stability requirements may remain cost-effective for longer than their expected/designed life-time, operators should consider to continue operating such systems at a lower level of maintenance after the designed life-time;
- ~~[Use of functioning baseline instruments that meet calibration and stability requirements should be maintained for as long as possible, even when these exist on decommissioned observing systems—originally written for satellite instruments, and should be generalized.]~~
- Observing networks should be designed taking into account measurements available from other networks in the vicinity, e.g. measurements using the same technology in neighbouring countries, or measurements from networks using different technologies.
- To optimize benefits within a Member's own territory, an effective observing network may require investment outside the Member's territory.
- ~~Mechanisms should be developed for sharing best practice and lessons learnt on observing network design.~~
- ~~... [others?]~~

For ICG-WIGOS to consider:

- Mechanisms should be developed for sharing best practice and lessons learnt on observing network design.
- Additional tools should be developed by WMO to assist Members in designing their observing networks (e.g. impact study tools, impact/cost tool).

## 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.

- Stations should be sited in locations that are least likely to be impacted by changes through time in the natural or man-made environment.
- ~~Where possible,~~ Only observing technologies with known performance characteristics should be deployed, to ensure consistent levels of observational quality.
- As part of routine operations, the quality and homogeneity of data should be regularly assessed through an ongoing programme to monitor ~~the health~~ performance of the network<sup>4</sup>.
- When<sup>5</sup> station relocations or instrument upgrades are made, ~~a minimum of one year~~ a sufficient period of overlap ~~– considering the targeted application areas (refer to specific guidance materials) –~~ between the old and new systems should be made whenever practicable.
- The ~~collection and archive~~ availability of complete metadata ~~are is~~ essential to ensuring assess the homogeneity of observations.
- For many applications including climate monitoring, it is important that calibration, calibration-monitoring and cross-calibration are designed as part of observing system network;
- Inter-comparisons and validation of observations made using different technologies should be undertaken in order to characterize the observations uncertainty or relative

<sup>4</sup> Editorial note from S. Klink 2/24/2014 for this bullet item, and the 2 bullet items below: As this aspect is mentioned here –which is actually also a sub-item of the “quality management” paragraph in section C-, I would like to suggest moving the entire “quality management” paragraph to this place! From my perspective homogeneity and consistency can be only achieved if comparisons are conducted, i.e. if QM is conducted.

<sup>5</sup> Editorial note from J. Lawrimore 2/24/2014: Realizing this is included in #12 should it also be included here? With a specification of a minimum period of overlap. – Yes, I think so [JE]

- performances (bias, standard deviation, gross errors), and allow homogenous use of the observations;
- While some observations from third parties could be collected using ~~non-standard~~ non-standard formats, all ~~Observations~~ observations should always be disseminated ~~in a consistent way~~ using standard formats and according to standard procedures ~~according to relevant regulatory material~~ ~~[links]~~
- Observations should be disseminated in such a way that the quality and provenance of the original measurement is retained.
- ~~Observations~~ Observing networks should be ~~disseminated~~ operated to meet agreed ~~availability~~ performance targets.
- ~~...~~ ~~[others?]~~

#### For ICG-WIGOS to consider:

- To consider developing observing network performance targets, and indicators

### 7. DESIGNING THROUGH A TIERED APPROACH

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

- In addition to improving the quality and utility of observations, this approach to design will also lead to improvements in the understanding of the quality of the observations.
- ~~The~~ tiered approach should include at a minimum a sparse network of reference stations from which other stations can be benchmarked. Reference stations should be calibrated to NIST<sup>6</sup> traceable standards, have triplicate measurements 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, the highest standard of metadata collection including photo documentation, and continuous monitoring of system network performance to resolve instrument and environmental issues as they arise. Stations from university and public-sector networks will often be necessary for filling gaps and providing the spatial density required for climate service requirements<sup>7</sup>.
- ~~...~~ ~~[others?]~~

### 8. DESIGNING RELIABLE AND STABLE NETWORKS

Observing networks should be designed to be reliable and stable.

- For the purpose of climate monitoring, special attention should be given to maintaining stations with long, historically-uninterrupted records
- Observing system networks and their telecoms should be designed to be robust against exposure to severe weather weather, hydrological, climate, and other environment conditions.
- A combination of standard and backup energy sources ~~AC power and renewable energy sources~~ (e.g. renewable such as, solar, ~~and~~ wind) should be used whenever possible better to ensure continued-uninterrupted operation of observing platforms in all weather environment conditions.
- On-site Parallel long term (e.g. on site) data storage should be designed to augment real-time telecommunication and to ensure original observations are preserved (e.g. on site) for a minimum of 6 months to 1 year sufficient time period to be used by the application areas, which require delayed mode data.
- Station sites should be selected in areas least likely to be impacted by factors such as new construction that will force station relocations.

<sup>6</sup> Editorial note from J. Eyre 2/24/2014: Should this be "SI"?

<sup>7</sup> Editorial note from J. Eyre 2/24/2014: Is this a duplicate of #7?



- [Expand on other issues of reliability, stability and sustainability – with links to guidance material]<sup>8</sup>.
- Appropriate maintenance and calibration procedures must be followed.
- ~~... [others?]~~

## 9. MAKING OBSERVATIONAL DATA AVAILABLE

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

- ~~Observational data from national observing networks should be made available to other WMO Members, at space-time resolutions and with a timeliness needed to meet the needs of regional and global applications.~~
- 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; and (iii) improve data timeliness.~~Many gaps in user requirements for observations can be filled by disseminating observations that are currently made but not collected centrally in a NMHS,~~
- ~~or made but not disseminated internationally, or made but not disseminated in a timely manner.~~
- Mechanisms should be established to minimise the loss of existing observational data and to promote the recovery of ~~old data~~historical records for climate applications~~;~~
- Multiple and overlapping methods of dissemination (e.g. through multiple routes) that comply with the Technical Regulations ~~should~~could be used ~~whenever possible~~ to ensure improve continuity of data delivery to users~~collection~~.
- ~~... [others?]~~

## 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.

- Members should follow standard procedures to collect, check, share, and distribute the WIGOS metadata that are required for international exchange.~~Appropriate metadata are essential~~ to ensure appropriate homogeneous use of the observational data, and knowledge about their quality, and traceability and homogeneity of observations ~~[link to appropriate WIGOS guidance];~~additional WIGOS metadata should be recorded by Members and to be made available on request;
- Metadata collection, dissemination, archive and access system networks should be designed with as much attention as those for observational data.
- Station metadata should be created at the time of network installation and updated ~~at a minimum annually~~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.
- Metadata practices should adhere to international standards in use by the ~~meteorological~~<sup>9</sup>WMO community programmes and co-sponsored programmes.
- ... [others?]

<sup>8</sup> Editorial note from S. Klink 2/24/2014: What is about robustness against other geophysical exposures such as floodings, avalanches, earthquakes, solar wind? Robustness against simple types of vandalism by humans and animals (-> fences)? Robustness against misuse? (E.g. preventing that the telecommunication connection of an observing site can be easily hacked into...)

<sup>9</sup> Editorial noted from J. Eyre 2/24/2014: Should we generalize this?

## 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.

- Some research-based systems, where appropriate, mature and cost-effective, should ~~be transferred~~ evolve to operational status secured long-term funding status while maintaining or improving the availability, and quality of the observations and WIGOS metadata produced.
- In case of transition to operations, it should include the design of robust and maintainable systems that is assuring appropriate data collection, quality control, archive and access.
- Members should take steps to make ~~Make~~ pre-operational data available to users on a best efforts basis to facilitate early ~~update~~ uptake and adoption of the new data, once operational.
- Written agreement for operational collection and archive of observations should be made with a recognized archive centre.
- Members should ensure that their funding to the sustained networks remains sufficient in the longer term taking into the required evolutions and changes (e.g. technology) (see principle no. 12);
- The conversion 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).
- ~~—~~
- ~~The transition to operations should include the design of robust and maintainable software systems associated with data collection, quality control, archive and access.~~
- ~~... [others?]~~

## 12. MANAGING CHANGE

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

- ~~The conversion 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).~~
- 4. The impact of new systems or changes to existing systems should be assessed prior to implementation taking into account observational user requirements of all application areas.
- A suitable period of overlap for new and old observing systems is required, to maintain the homogeneity and consistency of time-series observations.
- To avoid gaps in the long-term record, continuity of key measurements should be ensured through appropriate deployment strategies.
- Test-beds and pilot projects are required through which new systems can be evaluated and guidelines for operational transition developed.
- ~~Guidance is needed on the transition of existing (legacy) systems to meet WIGOS requirements and standards. [Too general? Or anything specific to say on this?]~~
- ~~... [others?]~~

For ICG-WIGOS to consider:

- Guidance is needed on the transition of existing (legacy) systems to meet WIGOS requirements and standards. [Too general? Or anything specific to say on this?] e.g. CIMO could be invited to make some recommendation(s)

~~5.~~

**REVIEW OF INPUT FROM THE GRUAN WORKING GROUP AND FROM LI BAI (CHINA) FOR DEVELOPING GENERIC OSND GUIDANCE**

*(John Eyre, 3 February 2015)*

**PART A ANALYSIS OF THE INPUT FROM GRUAN, 6-6-2014**

1. “Tiered network” Principle should be developed further.  
This has already been done to some extent in draft guidance – 2 bullets at present. Is this sufficient? (More below). Review by GRUAN would be useful.
2. Meeting user requirements. Different applications have different and sometimes conflicting requirements.  
This should be acknowledged in an additional guidance item, which recognizes that compromises are needed.
3. Meeting national, regional and global requirements. Members should consider supporting observing systems outside their national borders in order better to meet the needs of regional and global applications.
4. Designing appropriately spaced networks. Networks should be designed based on scientific analysis of optimal impact and cost-effectiveness.
5. Designing through a tiered approach  
New guidance offered, complementary to current guidance #2.  
Does “information” include skills, expertise, experience? Where should we capture this aspect? Sustainability?
6. Designing reliable and stable networks. Some metrics are needed here to define “reliable” and “stable”.
7. Making observational data available.  
Provision should be made for submission of data on timescales and in formats to meet different user needs.
8. Providing information so that observations can be interpreted.
  - Repositories of all data and metadata.
  - Resources for reprocessing.
9. Achieving sustainable networks  
Define sustainability – not all observational records need to be sustained → “managing change” and “achieving homogeneity”.
10. Replace local operating procedures with international standard operating procedures.
11. Site assessment and certification?

**PART B LETTER FROM LI BAI, 6-4-2014**

1. In observing system design, give priority to (improved) vertical resolution.
2. In observing system design, give priority to real-time calibration, in order to improve the quality of observations.
3. In observing system design, metadata standards are important.
4. In observing system design, consideration should be given to “data fusion”, i.e. to how data from different observing systems will be combined to deliver products to users for some applications, e.g. nowcasting.

Responses

1. This is a response to the Principle “Meeting user requirements”. In general, current observing capabilities do not have adequate vertical resolution to meet stated user requirements of NWP and NWC. No new item of guidance needed.
2. This comes under the Principle “Achieving homogeneity and consistency of observations” and specifically the guidance “For many applications, ..., it is important that calibration ...(etc)... are designed as part of the observing system”. Perhaps the importance of real-time calibration could be strengthened with an additional item of guidance.
3. This is well covered by the Principle “Meeting user requirements”.
4. This fits under the Principle “Meeting user requirements”. It merits a new item of guidance: “Observations should be processed to a level to be established in consultation with users. 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”.

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## ACRONYMS

AMDAR	Aircraft Meteorological Data Relay
AOPC	Atmospheric Observation Panel for Climate
CBS	Commission for Basic Systems
CEOS	Committee on Earth Observation Satellites
CGMS	Coordination Group for Meteorological Satellites
CMA	China Meteorological Administration
DoD	US Department of Defense
E-AMDAR	EIG EUMETNET AMDAR programme
E-ASAP	EIG EUMETNET Automated Shipboard Aerological Programme
EC	Executive Council
ECMWF	European Centre for Medium-Range Weather Forecast
EC-PORS	Executive Council Panel of Experts on Polar Observations, Research and Services
ECV	Essential Climate Variable
EGOS-IP	Implementation Plan for the Evolution of Global Observing Systems
E-GVAP	EIG EUMETNET GNSS water vapour programme
EIG	Economical Interest Group
E-PROFILE	EIG EUMETNET Radar Wind Profilers and Backscatter Lidars programme
E-SURFMAR	EIG EUMETNET Surface Marine observation programme
ET-EGOS	Former CBS Expert Team on the Evolution of Global Observing Systems
ET-SAT	CBS Expert-Team on Satellite Systems
ET-SUP	CBS Expert Team on Satellite Utilization and Products
EUCOS	EIG EUMETNET Composite Observing System
EUMETNET	An EIG consortium of currently 30 national meteorological and hydrological services (NMHS) in Europe that provides a framework for different operational and developmental co-operative programmes between the services
FCDR	Fundamental Climate Data Record
FSO	Forecast Sensitivity to Observation
GAW	Global Atmosphere Watch
GCW	Global Cryosphere Watch
GCOS	WMO-IOC-UNEP-ICSU Global Climate Observing System
GCW	Global Cryosphere Watch
GEO	Group on Earth Observations
GFCS	Global Framework for Climate Services
GNSS	Global Navigation Satellite System
GOS	Global Observing System
GPS	Global Positioning System
GPSRO	GPS Radio Occultation
GRUAN	Global Reference Upper Air Network
GSN	GCOS Surface Network
GUAN	Global Upper Air Network
IBCS	Intergovernmental Board on Climate Services
ICG-WIGOS	Inter-Commission Coordination Group on WIGOS
ICT-IOS	CBS Implementation Coordination Team on Integrated Observing Systems
IPET-OSDE	CBS OPAG-IOS Inter-Programme Expert Team on the Observing System Design and Evolution
IPO	International Project Office
KAA	Key Activity Area
LAM	Limited Area Model
NASA	National Aeronautics and Space Administration
NCEP	NOAA National Centers for Environmental Prediction
NOAA	US National Oceanic and Atmospheric Administration
NMHSs	National Meteorological and Hydrological Services
NWP	Numerical Weather Prediction
OOPC	Ocean Observations Panel for Climate
OPAG	Open Programme Area Group

OPAG-IOS	OPAG on Integrated Observing Systems
OPERA	Operational Programme for the Exchange of Weather Radar Information
OSCAR	Observing System Capability Analysis and Review tool
OSE	Observing System Experiment
OSSE	Observing System Simulation Experiment
OSND	Observing system network design
RA	Regional Association
RBON	Regional Basic Observing Networks
RRR	Rolling Review of Requirements
R-SEIS	CBS Rapporteur on Scientific Evaluation of Impact Studies
R-WIP	Regional WIGOS Implementation Plan
USA	United States of America
WIGOS	WMO Integrated Global Observing System
WIP	WIGOS Framework Implementation Plan
WIS	WMO Information System
WRF	Weather Research and Forecasting

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