

**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)**

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

*(OSDW1)*

Geneva, Switzerland, 12-14 November 2013

**FINAL REPORT**



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**CONTENTS**

<a href="#">Agenda</a>		p. 5
<a href="#">Executive Summary</a>		p. 6
<a href="#">General Summary</a>		p. 7 - p. 25
<a href="#">Annex I</a>	List of Participants	p. 26
<a href="#">Annex II</a>	Action sheet from OSDW1	p. 28
<a href="#">Annex III</a>	Guidance from the IPET-OSDE Chair on observing system network design (OSND)	p. 29
<a href="#">Annex IV</a>	Regional observation network re-design study over Europe based OSEs performed with the ALADIN LAM	p. 31
<a href="#">Annex V</a>	Marine observations: a value for money index	p. 34
<a href="#">Annex VI</a>	Classes of CryoNet observing sites	p. 42
<a href="#">Annex VII</a>	Writing Group 1 outcome: OSND principles derived from relevant OSND activities, including impact studies	p. 43
<a href="#">Annex VIII</a>	Writing Group 2 outcome: Overarching OSDN design principles in keeping with GCOS priorities	p. 44
<a href="#">Annex IX</a>	Writing Group 2 outcome: OSND principles derived from the GCOS Climate Monitoring Principles	p. 46
<a href="#">Annex X</a>	Writing Group 2 outcome: OSND principles derived from Weather radar network design activities	p. 50
<a href="#">Annex XI</a>	Writing Group 2 outcome: OSND principles proposed by the Chair of ICT-IOS	p. 52
<a href="#">Annex XII</a>	Writing Group 2 outcome: Draft OSND principles derived from the review of existing regulatory material	p. 53
<a href="#">Annex XIII</a>	Roadmap for the development of OSND principles and guidance	p. 56
<a href="#">Acronyms</a>		p. 58

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## **AGENDA**

### **1. ORGANIZATION OF THE SESSION**

- 1.1 Opening of the meeting
- 1.2 Adoption of the agenda
- 1.3 Working arrangements

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

- 2.1 Report of the Chairperson
- 2.2 Role of the workshop in the context of the IPET-OSDE work plan for CBS

### **3. ROLE OF OBSERVING SYSTEM DESIGN WITHIN WIGOS**

- 3.1 Introduction to the WIGOS Framework Implementation Plan (WIP)
- 3.2 Role of IPET-OSDE regarding observing system design as part of WIP

### **4. REVIEW OF SPECIFIC REGIONAL ACTIVITIES RELATED TO OBSERVING SYSTEM DESIGN**

- 4.1 Regional Association II
- 4.2 Regional Association IV
- 4.3 Regional Association V
- 4.4 Regional Association VI and EUMETNET
  - 4.4.1 Regional Association VI
  - 4.4.2 EUMETNET

### **5. REVIEW OF SPECIFIC OBSERVING SYSTEMS ACTIVITIES RELATED TO OBSERVING SYSTEM DESIGN**

- 5.1 Surface-based observing systems
- 5.2 Surface Marine Observations
- 5.3 WMO Space Programme, focusing on design activities of CGMS
- 5.4 Global Climate Observing System (GCOS)
- 5.5 Update on the Global Framework for Climate Services (GFCS)
- 5.6 Global Cryosphere Watch (GCW)

### **6. REVIEW OF IMPACT STUDIES RELEVANT TO OBSERVING SYSTEM DESIGN**

- 6.1 Update on recent OSEs/OSSEs relevant to observing system design
- 6.2 Next OSE/OSSE workshop
- 6.3 Recommendations on observing system design

### **7. PREPARING WMO GUIDANCE ON OBSERVING SYSTEM DESIGN**

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

- 8.1 Recommendations for consideration by IPET-OSDE and ICT-IOS-8

### **9. ANY OTHER BUSINESS**

### **10. CLOSURE OF THE SESSION**

## EXECUTIVE SUMMARY

The *ad hoc* Workshop on Observing System Design 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 12 to 14 November 2013 and was chaired by the Chair of the IPET-OSDE, Dr John Eyre (United Kingdom).

The workshop's goal was to respond to Implementation Key Activity Area No. 3 (KAA#3) of the WMO Integrated Global Observing System (WIGOS) on design, planning and optimized evolution of WIGOS and its regional, sub-regional and national component observing systems. The workshop particularly reviewed specific past, present and planned regional activities related to observing system design, elaborated some observing system design principles, and explored the different aspects of observing system design in which the World Meteorological Organization (WMO) may wish to propose guidance, including (i) design principles for single technology observing systems; (ii) design principles for composite observing systems; (iii) capacity development issues.

The workshop reviewed specific past, present and planned observing system activities related to observing system design with particular focus on (i) surface-based observing systems; (ii) surface marine observations ; (iii) design activities under the WMO Space Programme, in particular undertaken by the Coordination Group for Meteorological Satellites (CGMS), and with some additional information provided on the Architecture for Climate Monitoring from Space; (iv) the WMO-IOC-UNEP-ICSU Global Climate Observing System (GCOS) network design; (v) an update on the development of the Global Framework for Climate Services (GFCS) with focus on observational issues; and (vi) plans for observations within the Global Cryosphere Watch (GCW).

The workshop reviewed the status of relevant observing system network design (OSND) activities within WMO Programmes, WMO Regions and relevant international organizations and groupings (such as ECMWF and EIG EUMETNET<sup>1</sup>), including impact studies relevant to OSND. It developed material from which OSND principles could be extracted (annexes **VII**, **VIII**, **IX**, **X**, **XI**, and **XII**), to be taken into account in the WIGOS Framework Implementation Plan (WIP) and WIGOS implementation by Regions and Members.

The workshop finally agreed on a roadmap for the development of guidance for OSND (**Annex XIII**). The roadmap provides details on the role of this workshop's participants and of the IPET-OSDE in this regard. In particular the first session of the IPET-OSDE (tentatively scheduled in Geneva from 31 March to 4 April 2014) will review and revise OSND principles, draft a more complete plan for preparing OSND guidance, and task IPET-OSDE members to draft specific materials in close coordination with their respective Teams and groups. The IPET-OSDE recommendations will then be submitted to the eighth session of CBS OPAG on Integrated Observing Systems' Implementation and Coordination Team (ICT-IOS) (tentatively scheduled in Geneva from 7 to 11 April 2014) in preparation for CBS Extraordinary Session in late 2014.

The workshop acknowledged that there will be a CBS focus on regulatory materials in the WIGOS framework. IPET-OSDE will therefore have to look into these aspects as far as the RRR and Observing Network System Design is concerned. The status of the development of OSND principles and guidance will be also reported to the third session of the Inter-Commission Coordination Group on WIGOS (ICG-WIGOS) Task Team on Regulatory Material (Geneva, 25-29 November 2013), and to the third session of the ICG-WIGOS (Geneva, 10-14 February 2014).

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<sup>1</sup> A 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

## GENERAL SUMMARY

Note: The text highlighted in blue in the general summary of the meeting below corresponds to ideas of the workshop that relate to observing system network design principles.

### 1. ORGANIZATION OF THE SESSION

#### 1.1 *Opening of the meeting*

1.1.1 The *ad hoc* Workshop on Observing System Design of the CBS<sup>2</sup> OPAG-IO<sup>3</sup> Inter-Programme Expert Team on the Observing System Design and Evolution (IPET-OSDE) opened at 10.00 hours on Tuesday, 12 November 2013, 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 welcomed the participants and explained the significant developments relevant to the WMO Integrated Global Observing System (WIGOS), the CBS and its OPAG-IO since the seventh meeting of the former Expert Team on the Evolution of Global Observing Systems (ET-EGOS) in May 2012. He recalled that WIGOS and the Global Framework for Climate Services (GFCS) are two of the five priority-funded activities, and invited the workshop to address GFCS and WIGOS requirements as a matter of priority.

1.1.3 Dr Ondras recalled that the sixty-fourth Session of the Executive Council (EC-64) in 2012 has adopted the WIGOS Implementation Plan (WIP), and reshaped the CBS working structure better to focus the CBS activities towards WIGOS implementation needs. EC-64 also approved the new Implementation Plan for the Evolution of Global Observing Systems (EGOS-IP) per recommendation from CBS-XV. The EGOS-IP has now been published and is available on the WMO website in four languages.

1.1.4 Dr Ondras explained that the WIP, which has been drafted by the Inter-Commission Coordination Group on WIGOS (ICG-WIGOS), and further updated by EC-65 includes ten Key Activity Areas (KAAs), one of which, i.e. KAA#3 is the for the “design, planning and optimized evolution of WIGOS and its regional, sub-regional and national component observing systems”. Most of the work needed to complete this KAA#3 falls under the responsibility of the IPET-OSDE, which is replacing the ET-EGOS, and this workshop is tasked to address the observing system design part of this activity, and propose new WMO guidelines in this regard. Indeed, “*proposing guidance regarding observing system network design principles*” is one of the Terms of Reference of the new IPET-OSDE.

1.1.5 In closing, Dr Ondras invited the workshop to grasp this opportunity to help guide WMO into the future by making substantial recommendations regarding observing system design principles to the forthcoming CBS Extraordinary Session next year through the IPET-OSDE, which first meeting is planned in Geneva in April 2014. He wished for 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.

#### 1.2 *Adoption of the agenda*

1.2.1 The workshop adopted its Agenda, which 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.

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<sup>2</sup> Commission for Basic Systems

<sup>3</sup> Open Programme Area Group on Integrated Observing Systems

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

- **Group 1:** Based on the results of impact studies, extract issues that are relevant to OSND in order to be able to derive OSND principles. Discuss how those principles can be made generic.  
Members: E. Andersson, Y. Sato, S. Klink,  
Secretariat: L. Nunes, R. Atkinson  
Outcome of Group 1 discussions, is summarized in **Annex VII**.

- **Group 2:** Drafting OSND principles. There is some useful material and examples to be used e.g. (i) the current Manual (Volumes I & II) and Guide to the GOS; (ii) document 5.4 on GCOS for this workshop; (iii) the GCOS Climate Monitoring Principles; and (iv) the BALTRAD<sup>4</sup> Cooperation Agreement. One can start from a generic perspective, and then try to identify some more specific principles. The Vision for the GOS can help to structure OSND principles.  
Members: J. Eyre, J. Lawrimore, S. Goldstraw, L.P. Riishojgaard  
Secretariat: J. Lafeuille, E. Charpentier  
Outcome of Group 2 discussions is summarized in the following Annexes:

**Annex VIII:** Overarching OSDN design principles in keeping with GCOS priorities

**Annex IX:** OSND principles derived from the GCOS Climate Monitoring Principles

**Annex X:** OSND principles derived from weather radar network design activities

**Annex XI:** OSND principles proposed by the Chair of ICT-IOS

**Annex XII:** Draft OSND Principles derived from the review of existing regulatory material

- **Group 3:** Drafting plan and roadmap for the development of guidance for OSND, which is addressing the principles proposed. Also to draft a template of the report to be submitted to the IPET-OSDE-1 in March/April 2014.  
Members: L.P. Riishojgaard, J. Eyre, S. Goldstraw  
Secretariat: M. Ondras, E. Charpentier

Outcome of Group 3 discussions is summarized in **Annex XIII**.

## 2. GUIDANCE FROM THE CHAIRPERSON

### 2.1 *Report of the Chairperson*

2.1.1 The IPET-OSDE Chairperson provided guidance on the role and scope of the workshop on the basis of guidance received from the CBS and from the CBS Inter Commission Coordination Group on the WMO Integrated Global Observing System (ICG-WIGOS) in particular with regard to observing system design activities to be developed as part of the WIP.

2.1.2 The chair recalled that this Workshop has been organized under the auspices of the new CBS IPET-OSDE, and listed the Terms of Reference of that Expert Team. In particular, he noted that one of the responsibilities of IPET-OSDE is to propose guidance regarding observing system network design (OSND) principles, and this Workshop represents the first contribution under these ToRs to work in this area.

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

2.2.1 The Chairperson elaborated on the role of the workshop in the context of the IPET-OSDE work plan for CBS. He explained that the Workshop will respond to the WIGOS Implementation Key Activity Area No.3 (KAA#3<sup>5</sup>). It will review specific past, present and planned regional activities related

4 <http://baltrad.eu/>

5 WIP Key Activity Area No. 3 (KAA#3): Design, planning and optimized evolution of WIGOS and its regional, sub-regional and national component observing systems

to observing system design, elaborate observing systems design principles, and explore the different aspects of observing system design in which WMO may wish to propose guidance. The goals of the Workshop are therefore (i) to provide a summary of the status of relevant OSND activities within WMO Programmes, WMO Regions and relevant international organizations and groupings (such as ECMWF and EIG EUMETNET), including impact studies relevant to OSND; (ii) to propose OSND principles to be taken into account in the WIP and WIGOS implementation by Regions and Members; and (iii) to propose a plan for the development of guidance for OSND.

2.2.2 The outcomes of the Workshop will be reported to the first full meeting of IPET-OSDE (31 March - 4 April 2014) and to the 8<sup>th</sup> meeting of the Implementation Coordination Team on Integrated Observing Systems (ICT-IOS-8, 7-11 April 2014), and via these groups to CBS later in 2014. The status of this development will be also reported to the Inter-Commission Coordination Group on WIGOS (ICG-WIGOS, Geneva, 10-14 February 2014).

2.2.3 In addition to the above formal guidance, Dr Eyre offered some personal thoughts on the topic of OSND (**Annex III**), and looked forward to hearing and discussing similar ideas from other participants at the workshop.

2.2.4 The workshop identified some ideas to be considered when elaborating OSND principles:

1. The concept of network design versus evolution of observing systems;
2. The atmospheric domain is a good area to start for discussing OSND principles;
3. Design principles should initially be as generic as possible;
4. There has been a lot of activity on implementation, and not so much on design;
5. One should focus on OSND rather than on Observing System Design (OSD) in general;
6. When considering a network, one should consider how many stations, of what type, and where to place them;
7. Most attention in the short term is needed on the surface-based observing system (the satellite system is more or less regarded as a given);
8. The Vision of the GOS in 2025 is the result of an OSND activity of the CBS;
9. Basic systems are here for practical reasons, to allow Members to fulfil their mandate;
10. One should investigate how to address the historical networks;
11. One must be careful about the audience targeted for OSND principles;
12. Observing system networks should serve the needs of multiple Application Areas where possible;
13. One must also be working with the partners coming with resources but are in demand of guidance on where to implement their observing stations;
14. The proliferation of AWS is a result of some lack of coordination;
15. There can be value in deriving OSND principles from the technology-free observational user requirements;
16. Developing countries with emerging economies offer the opportunity to practice OSND principles documented through Regulatory Materials;
17. Similarly, Members are facing the problem of making the legacy systems evolve in such a way to address the WIGOS requirements;
18. Definition of a Reference network/station should be proposed;
19. Observing system networks should be designed to make effective use of available resources: guidance is needed on which technologies or mix of technologies are likely to be most cost-effective; impacts and benefits should be quantified for each Application Area, and tools are needed to do this;
20. Composite networks: guidance is needed on how to approach the network design task;
21. Guidance is needed on the relationship between RRR outputs and OSND goals/limits;
22. What is a network? Number of stations, where and of which type, but also characteristics that make a collection of stations into a network.

### 3. ROLE OF OBSERVING SYSTEM DESIGN WITHIN WIGOS

### **3.1 Introduction to the WIGOS Framework Implementation Plan (WIP)**

3.1.1 The Secretariat provided a brief overview on the status the WIGOS Framework Implementation Plan (WIP), which addresses the necessary activities to establish an operational WIGOS by the end of the period 2012-2015, as per the direction of WMO Congress. The WIP includes ten Key Activity Areas (KAAs), which are meant to provide focused effort to migrate the existing observing systems<sup>6</sup> into a more integrated single system that is WIGOS. The IPET-OSDE is expected to play a key role with regard to KAA#3. Indeed, based on the WIP endorsed by EC-64, CBS-15 established the IPET-OSDE to meet WIGOS requirements for the integration and optimized evolution of WMO observing systems, and of WMO's contribution to co-sponsored systems.

3.1.2 The WIP also addresses a number of additional activities that would substantially improve the operational capabilities of WIGOS beyond the 2012-2015. During the implementation of WIGOS, the Rolling Review of Requirements (RRR) process, originally developed in formulating the EGOS-IP will be a major tool for observational gap analysis and observing network design.

3.1.3 The WMO has agreed on the Vision for the Global Observing Systems in 2025<sup>7</sup>, which provides high-level goals to guide the evolution of the global observing systems during the coming decades. Coordinated strategic planning at all levels will be based on the RRR process, and will be supported by the WIGOS regulatory material.

### **3.2 Role of IPET-OSDE regarding observing system design as part of WIP**

3.2.1 The workshop discussed the role of the IPET-OSDE regarding the KAA#3 of the WIP, and noted the following issues of particular relevance to this KAA:

- (a) The sustainability of the regional basic networks in some regions, and the reduced availability of data from those networks, is an issue of concern. It agreed that WIGOS and WIS have the potential to strengthen further all basic networks, especially those in developing and the least developed countries, through optimized design and evolution of WIGOS component observing systems, improved operation and maintenance and interoperability arrangements. All regional associations were requested to address the issue of availability of observations from the regional basic networks in their Regional Implementation Plans.
- (b) The Regional WIGOS Implementation Plans (R-WIP)<sup>8</sup> have been developed in all WMO Regions and already adopted by RAs II, IV and VI. R-WIPs take into account regional and sub-regional needs, requirements and priorities. In this regard, Members' commitment to, and leadership for WIGOS implementation is essential, including provision of sufficient resources.
- (c) Integration of regional observing networks and re-design of the current RBSNs is a challenge for the regional WIGOS relevant expert teams. For this purpose, all types of surface-based observing systems, such as weather radars, wind profiler systems and aircraft measurements should be taken into account in the Regional Basic Observing Network (RBON) re-design. The network re-design should also be coordinated with satellite observations and networks from partner organizations should be integrated. The EUCOS observing network was considered as a model.

3.2.2 The Team also noted the activities of the WIGOS Task Team on Regulatory Materials (TT-WRM) under the guidance of the Inter-Commission Coordination Group on the WMO Integrated Global Observing System (ICG-WIGOS). In particular, the TT-WRM has proposed a draft structure of in WMO Technical Regulations (WMO-No. 49), Vol. I., Part I. WIGOS, and is starting to fill in content. Of particular interest to the IPET-OSDE are the following sections, which include sub-sections on (i) requirements and (ii) design, planning and evolution:

- 2. Common attributes of component observing systems

<sup>6</sup> GOS, GAW, WMO Hydrological Observing System, incl. WHYCOS, and GCW, including surface-based and space-based components and all WMO contributions to GFCS, GCOS, GOOS, GTOS and GEOSS

<sup>7</sup> Available from the WMO Website at: <http://www.wmo.int/pages/prog/www/OSY/gos-vision.html>

<sup>8</sup> [www.wmo.int/pages/prog/www/wigos/documents.html](http://www.wmo.int/pages/prog/www/wigos/documents.html)

- 3. Common attributes specific to the surface-based sub-system of WIGOS
- 4. Common attributes specific to the space-based sub-system of WIGOS
- 5. Observing component of the Global Atmosphere Watch (GAW)
- 6. Observing component of the Global Cryosphere Watch (GCW)
- 7. Global Observing System (GOS) of WWWW
- 8. WMO Hydrological Observing System

3.2.3 The TT-WRM will meet in Geneva from 25 to 29 November 2013, and the workshop agreed that the outcome of this workshop will have to be provided to this Team through the Secretariat in consultation with the IPET-OSDE Chair. A report will also have to be provided to the third session of the ICG-WIGOS (Geneva, 10-14 February 2014) in order for the ICG-WIGOS to review draft OSND principles available at the time, and to be able to propose a framework into which OSND principles and guidance will fit.

3.2.4 The workshop noted that there can be a disconnection between what is regulated in the Regulatory Material and what Members are actually doing at national or regional level.

3.2.5 The workshop also noted that WIP KAA#7, i.e. the WIGOS Operational Information Resource (WIR<sup>9</sup>) also relates to the activities of the IPET-OSDE and to OSND as it includes the Database of Observational User Requirements and Observing System Capabilities through its OSCAR<sup>10</sup> tool. The WIR also includes information<sup>11</sup> on WIP KAA#3<sup>5</sup>.

#### **4. REVIEW OF SPECIFIC REGIONAL ACTIVITIES RELATED TO OBSERVING SYSTEM DESIGN**

4.0 The workshop reviewed specific past, present and planned regional activities related to observing system design with particular focus on Regional Associations II, IV, V and VI (including EIG EUMETNET<sup>1</sup>).

##### **4.1 Regional Association II**

4.1.1 The Rapporteur on Scientific Evaluation of Impact Studies (R-SEIS), Yoshiaki Sato (Japan), provided an overview of activities related to observing system design in Region Association II, such as the enhancement of observing system and observing data exchange, and related WIGOS regional activities.

4.1.2 Regarding surface based observation enhancements, the workshop noted regional plans regarding wind profilers, weather radars, surface-based Global Navigation Satellite Systems receivers, the redesign of climate observing network in China, L-band upper-air sounding stations, and the rapid growth of the AWS networks in China.

4.1.3 Regarding space-based observation enhancements, the workshop noted the successful launch of FY-3C polar-orbiting satellite in September 2013, and China Meteorological Administration's (CMA) plans to launch geostationary satellite FY-2G and FY-2H in 2014 and 2016. The next generation geostationary R&D satellite FY-4 will be launched in 2015. CMA is considering starting the procedure for redeploying FY3 to an early morning orbit and calls on support from WMO, the Coordination Group for Meteorological Satellites (CGMS) members and satellite operators to reach this objective. The workshop also noted that JMA is planning to launch a next generation geostationary satellite "Himawari-8" in the next summer and the operations will be stated in Japanese FY2015. "Himawari-9" launch is planned in Japanese FY2016 and the satellite will be in-orbit back up.

4.1.4 The workshop noted WIGOS regional activities related to OSND, including:

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9 <http://www.wmo.int/wigos/wir>

10 OSCAR: Observing Systems Capability Analysis and Review tool: <http://www.wmo-sat.info/oscar/>

11 <http://www.wmo.int/pages/prog/www/wigos/wir/osde.html>

- The Regional Association II (RA-II) WIGOS project for observing systems integration for supporting disaster risk reduction. This project is particularly addressing (i) the integration of surface-based remote sensing data and GPS data in the East Asia for enhanced observing capabilities and better utilization in severe weather monitoring and forecasting, and (ii) capacity building in radar techniques in the Southeast Asia. Plans are underway for the exchange of surface radar data between Members of the Regional Association, and impact studies will be conducted. Sharing their technical issues and lessons learnt among countries in the Region and developing the regional strategy on development of the radar network in the Region will enable them to tackle those challenges collaboratively with help from the WMO community in an effective and efficient manner.
- The RA II WIGOS project plans to enhance the availability and quality management support for National Meteorological and Hydrological Services (NMHSs) in surface, climate and upper-air observations. One of the goals is to improve understanding of measurement traceability and related skills in RA II Member countries.

4.1.5 In terms of OSND principles, the workshop noted the following comments:

- Observing station data distribution is an important requirement, and the plan for that should be part of the design.
- Observations should be disseminated as space/time densities up to the goals of the user requirements.
- Observations gathered to meet national requirements may often be useful to neighbouring Members.
- Non-uniform network may be justified for many reasons, including representation of regional climates.
- The synchronisation of the surface-based observing systems with the satellites observation update cycles (e.g. 10 min. for surface radar data) should be considered.
- Rapid progress on the implementation of networks in East Asia – what were the design principles?

## **4.2 Regional Association IV**

4.2.1 The Chair of the ICT-IOS, Lars Peter Riishojgaard (USA) provided a short overview of various observing system design studies undertaken in the USA. A number of design studies have been done using the so-called Joint OSSE framework established by the National Aeronautics and Space Administration (NASA) and the National Oceanic and Atmospheric Administration (NOAA) based on the T-511 Nature Run provided by the European Center for Medium Range Weather Prediction. This framework makes it possible to study the consequences and impact of a wide range of possible future observing system scenarios. In addition, several impact studies for already existing data have been done using operational and research Numerical Weather Prediction (NWP) systems operated by the NOAA National Centers for Environmental Prediction (NCEP), the US Navy and NASA's Global Modeling and Assimilation Office. Among the studies carried out are (a brief summary of the rationale and the main results from each of these studies was provided in the preparatory document for this agenda item):

1. Impact experiments for a notional 3D-Wind Lidar Mission concept developed by NASA in response to the NRC Decadal Survey;
2. Support studies for the US Department of Defense (DoD) Analysis of Alternatives for the early morning sun-synchronous low-earth orbit;
3. Impact studies for two inexpensive Doppler Wind Lidar pathfinder concepts deployed on the International Space Station;
4. Observation System Simulation Experiment for Unmanned Aerial System Data Impact on Hurricane Track Forecast; and
5. General Observing System Simulation Experiments (OSSEs) in support of the WMO RRR and the Fifth WMO Impact Workshop in Sedona, May 2012.

4.2.2 The workshop noted that several impact experiments and design studies are planned for the coming years in the US, including data denial studies designed to investigate the potential impact of one or more gaps in the afternoon coverage currently provided by Suomi/NPP, to be replaced by JPSS-1 in 2016. Two possible gaps are currently under investigation; one is between Suomi/NPP and JPSS-1, the other is between JPSS-1 and JPSS-2 in the 2020-21 time frame.

4.2.3 Also, Observing System Simulation Experiments to study the impact of an operational follow-on to the very successful COSMIC Global Positioning System (GPS) Radio Occultation (GPSRO) constellation are in development, along with a series of OSSEs to assess the impact of deploying hyperspectral infrared sounders in geostationary orbit. Results from these and other impact and design studies will be reported to WMO as they become available.

4.2.4 In terms of OSND principles, the workshop noted the following comments:

- There have been recommendations for the 2016 NWP “impact” workshop to address OSND
- Repeated observations improve the forecast skills (vs. “snapshot observations”)

### 4.3 *Regional Association V*

4.3.1 The WMO Secretariat provided a brief review of Regional Association V (RA-V) activities related to observing system design, from the perspective of the WMO RA-V Working Group on Infrastructure. The workshop noted that a lot of guidance on the design of observing systems in RA-V is provided by the WMO Technical Commissions. Technical Regulations, Manuals and Guides provide guidance of a long-term slow-change nature. This includes standards, recommended practices and supporting guidance for implementation of observing systems by Member countries, including implementation at a Regional level.

4.3.2 RA-V is for example using strategic plans issued in various forms for the evolution of observing systems, providing further guidance on the implementation of observing systems at a Regional level. Such plans include the EGOS-IP, GCOS-IP, GAW Strategic Plan and its addendum, GCW Implementation Plan, and so on. These documents together represent an enormous set of guidance on the design and implementation of observing systems. It is a challenge to remain aware of and to adhere to all the relevant guidance. The challenge is eased when there is good cross-referencing, coordination and consistency between the documents.

4.3.3 The workshop noted that a major part of observing system design and implementation, then, is to interpret the technical guidance in light of Regional circumstances. This is reflected in the Regional WIGOS Implementation Plan (R-WIP) for RA-V through activities 1.2.3<sup>12</sup>, 1.2.4<sup>13</sup> and 3.2.1<sup>14</sup>.

#### *Regional requirements for observations*

4.3.4 It was noted that there is currently no all-encompassing ongoing process to gather and assess user requirements for observations at a Regional level in RA-V. A number of activities have been identified to give greater attention to this: (i) RA-V formed a Task Team on Satellite User Requirements, which has been actively developing a table of prioritized requirements for satellite data and products, and which will probably help to inform the dissemination of data and products more than the design of the observing systems; and (ii) R-WIP for RA-V activity 3.2.3<sup>15</sup>.

4.3.5 The RA V Tropical Cyclone Committee regularly considers the requirements for observations

12 R-WIP activity 1.2.3: Assess the EGOS-IP and other WMO observing system implementation plans to identify actions relevant to RA-V and Member countries; assign priorities to these actions.

13 R-WIP activity 1.2.4: Provide an effective RA-V focal point to liaise with CBS about the implementation of EGOS-IP in RA-V.

14 R-WIP activity 3.2.1: Design and plan observing systems in the Region, taking into account: (i) the technical guidance of the technical commissions as represented in the EGOS-IP and other observation system implementation plans; (ii) the Regional priorities adopted by President RA-V (see action item 1.2.3); (iii) relevant actions identified in the Technical Plan of the Tropical Cyclone Committee for the South Pacific and South-East Indian Ocean; (iv) the need for “gap filling” and restoration of silent stations; and (v) cross-regional coordination opportunities.

15 R-WIP activity 3.2.3: Validate the user requirements documented by the global RRR process against Regional user requirements; use the results to update the RRR user requirements database and to fine tune the EGOS-IP and observing system plans.

in support of effective regional monitoring and warnings for TCs. This is reflected in the relevant section of its Technical Plan 2012-2015.

4.3.6 The workshop also noted that the guidance provided by NWP impact studies tends to be derived from international studies rather than studies conducted with the Region. Australia benefits from collaboration with the UK to run the Unified Model, referred to in Australia as the ACCESS model. It is possible to run the adjoint model and collect statistics to describe forecast sensitivity to observations. This investment is currently being made for specific studies.

#### *Regional observing capabilities*

4.3.7 The workshop noted that monitoring and reporting on the current configuration and performance of WMO Regional observing systems in RA-V is not very strong at present. A number of activities by different groups is improving this, including efforts by the GCOS office. At a Regional level, the R-WIP proposes several activities including 1.2.2<sup>16</sup>, 2.2.2<sup>17</sup>, 5.2.3<sup>18</sup>, 5.2.4<sup>19</sup>. With respect to knowledge of available technologies and newly emerging technologies, and development of new technologies, RA-V depends heavily on the technical guidance developed through CIMO.

#### *WIGOS demonstration projects*

4.3.8 It was noted that a WIGOS demonstration project was completed in RA-V. It demonstrated integration by the Bureau's Composite Observing System (BCOS), taking an integrated view of user requirements and best applying resources to address them through the integrated use of observations from various systems and from various sources. In particular it demonstrated the integrated use of various technologies for upper air observations. A more detailed report is available on the WMO web site.

4.3.9 R-WIP includes activity 4.2.3<sup>20</sup>, for Capacity Building in Radar Techniques in Southeast Asia. This is a cross-Region initiative with RA-II, undertaken by countries of the ASEAN Sub-Committee on Meteorology and Geophysics.

4.3.10 The workshop also noted a report by Roger Atkinson on a design study conducted by the Bureau of Meteorology in 2006: "*Australia's Composite Observing System: Identifying Future Directions*<sup>21</sup>."

4.3.11 In terms of OSND principles, the workshop noted the following comments:

- RA-V includes many islands, and ocean areas, and the region is relying on capabilities of developing countries, and very much on space-based observations;
- Value assessment is important for convincing decision makers to invest in the observing system (value/benefits of the services, cost of the application, which allows delivering the services, and cost of the observations required to address the requirements of the application).

## **4.4 Regional Association VI and EUMETNET**

### **4.4.1 Regional Association VI**

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16 R-WIP activity 1.2.2: Compile information from Member countries, other relevant partners and WMO sources as input to a "stock-take" of existing WMO observing systems in RA-V.

17 R-WIP activity 2.2.2: Collaborate with CIMO to develop a *reliable feedback mechanism* on the performance of instruments and systems in Region V. Provide feedback regularly.

18 R-WIP activity 5.2.3: Actively review and respond to the findings of CBS' periodic data flow monitoring exercises.

19 R-WIP activity 5.2.4: Find new means of continuous monitoring of observations data quality in Region V with the support of Centres of the GDPFS (Global Data Processing and Forecasting System).

20 R-WIP activity 4.2.3: Capacity Building in Radar Techniques in Southeast Asia, supported by appropriate technical missions to countries, through: (i) all the ASEAN developing countries will prepare a national report on their arrangements for the operational use of weather radar data; and (ii) a sub/cross-region (for the ASEAN developing countries) strategic plan for addressing technical issues and necessary actions identified in the national reports.

21 [http://www.knmi.nl/samenw/geoss/wmo/TECO2006/ppt/session\\_5/5\(1\)\\_Atkinson.PPT](http://www.knmi.nl/samenw/geoss/wmo/TECO2006/ppt/session_5/5(1)_Atkinson.PPT)

4.4.1.1 The workshop reviewed a written report from Gergely Bölöni (Hungary) on a regional observation network re-design study over Europe, based on Observing System Experiments (OSEs) performed with the ALADIN limited area model (LAM). The OSE study aimed at measuring the relative impact of aircraft and radiosonde observations as well as the impact of spatial thinning of these observation networks. The details of this study are provided in **Annex IV**.

#### 4.4.2 EUMETNET

4.4.2.1 Mr Stefan Klink (Germany) recalled that the EIG EUMETNET<sup>1</sup> Observations Programme's main objective is a central management of surface-based operational observations on a European-wide scale serving the needs of general forecasting, specifically those of numerical weather prediction, and those of climate monitoring. The work content of the Observations Programme (former EUCOS Programme) includes the management of the operational observing networks, through the following services and projects: (i) E-AMDAR (aircraft observations from commercial airlines); (ii) E-ASAP (radiosonde observations predominantly from merchant ships); (iii) E-GVAP (humidity measurements derived from global navigational satellite systems data); (iv) E-PROFILE (wind profiler and Lidar/Ceilometer measurements); (v) E-SURFMAR (buoy and voluntary observing ship measurements); and (vi) OPERA (weather radar composite production and single site data re-distribution). The coordination of NMHS owned territorial networks (e.g. radiosonde stations and synoptic stations), data quality monitoring, fault reporting and recovery, a studies programme for the evolution of the observing networks and liaison with other organizations like WMO are among the tasks of the programme.

4.4.2.2 Mr Klink reported on the rationale and methods used by the EIG EUMETNET<sup>1</sup> to undertake observing system network design studies for its Observations Programme. He elaborated on the data impact studies initiated from time to time, and summarized the results of three completed OSE or adjoint-based data impact studies:

1. Upper-air network redesign study
2. Second Space-Terrestrial study
3. E-ASAP impact study

4.4.2.3 He then outlined the future needs for OSND recommendations in the EIG EUMETNET<sup>1</sup> Observations Programme.

4.4.2.4 In particular, the workshop noted that within many European NMHSs the budget for non-satellite observations is much under pressure. Efficiency savings or even real reductions in the operational observing networks have to be considered by several Members. On the other hand new observing technologies and new observing networks operated by third parties become available. Examples are aircraft-based observations transmitted to ground via air traffic control radars and radio communications (Mode-S, ADS-B) or an improved usage of ground-based Global Navigation Satellite System (GNSS) data.

4.4.2.5 In the framework of the EIG EUMETNET<sup>1</sup> Observations Programme OSND recommendations have to be derived during the next few years concerning the following observing networks and technologies:

- In-situ upper-air profiles: composite observing system comprising of radiosondes, Aircraft Meteorological Data Relay (AMDAR) data, potentially other aircraft based observations, Mode-S/ ADS-B data, GNSS profile data, wind profiler;
- In-situ surface marine observations: composite observing system comprising of conventional and automated voluntary observing ships, drifting and moored buoys;
- Weather radar derived observations: besides reflectivity and Doppler-velocity measurements, is there a need for dual-polarization data?

4.4.2.6 Mr Klink then described current and planned observation data impact studies which are coordinated by the EIG EUMETNET<sup>1</sup> Observations Programme, including (i) AMDAR q/ TAMDAR

impact study, and (ii) General FSO<sup>22</sup>/FEC<sup>23</sup> study.

4.4.3 In terms of OSND principles, the workshop noted the following comments:

- There can be value in looking at the observation times where the observations have the most impact.

## 5. REVIEW OF SPECIFIC OBSERVING SYSTEMS ACTIVITIES RELATED TO OBSERVING SYSTEM DESIGN

5.0 The workshop reviewed specific past, present and planned observing system activities related to observing system design with particular focus on:

- (i) surface-based observing systems;
- (ii) surface marine observations (e.g. the Met Office (UK) design study of 2003);
- (iii) design activities under the WMO Space Programme, in particular undertaken by the CGMS, and with some additional information provided on the Architecture for Climate Monitoring from Space;
- (iv) the Global Climate Observing System (GCOS) network design;
- (v) an update on the development of the Global Framework for Climate Services (GFCS) with focus on observational issues; and
- (vi) plans for observations within the Global Cryosphere Watch (GCW).

### 5.1 Surface-based observing systems

5.1.1 The Chair of the Expert Team on Surface Based Observations (ET-SBO), Stuart Goldstraw (United Kingdom) introduced the current status of the work of the ET-SBO, which was established by the Commission for Basic Systems (CBS) at its 15<sup>th</sup> session in Jakarta during September 2012. It held its first meeting during July 2013 where the Work plan was developed and tasks assigned to ET Members. The focus of this work plan is to improve the quality of regulatory and guidance material, provide mechanisms to improve the Members understanding of existing and emerging observing systems and encourage a greater exchange of observation data from existing observing systems. It was noted that within this improved guidance material there will be reference to the technological aspects of network design principles and examples, particularly within the context of Weather Radars, Wind Profiling Radars and AWSs. However at this time there is no plan to consider the integrated design of all surface based observing systems.

5.1.2 A general review of WMO NO.544, the Manual on the GOS was undertaken and it was suggested that a number of clauses within Section II were network design principles, or at least could form the framework of more general network design principles taking into account the WIGOS multi-disciplinary framework. These clauses were discussed and at **Annex XII** of this report some have been highlighted as suitable for consideration for inclusion in a general network design principles document.

5.1.3 In addition a range of technical design principles were briefly discussed. Whilst not Network Design Principles, some further work on these Technical Design Principles may be of value to the general work of ET-SBO when developing the detailed guidance that will sit behind the Network Design Principles for those technologies ET-SBO is responsible for improving. The workshop noted the following topics to be considered:

- The workshop advised not to recommend the widespread use of a technology until it has been proven;
- Pilot projects should be promoted to test new technology (progressive introduction of new or emerging technology);

22 FSO: Forecast Sensitivity to Observation

23 FEC: Forecast Error Contribution

- An observing system shall provide a net economical benefit to the Application Area(s). However, guidance needs to be provided on how to realize this in practice.

## **5.2 Surface Marine Observations**

5.2.1 Dr John Eyre presented a report (**Annex V**) on a cost-benefit (value-for-money) study for surface marine observations conducted by the Met Office (UK). Although this study was completed 10 years ago, the approach is still relevant to general questions of how to design cost-effective observing systems.

5.2.2 In terms of OSND principles, the workshop noted the following comments:

- The value of the study is that it shows that such a study is relatively easy to do, and it provides useful information;
- Guidance material should include information on cost/benefit analysis.
- The methodology could be adjusted to take into account new tools such as FSO;
- The methodology can be used for Application Areas other than NWP;
- Applying a monetary value to the benefits is a difficult exercise;
- There can be value to assessing the impact of observations vs. their cost for each Application Area;
- Consideration should be given to the problem of how to combine “value” of observations (e.g. impact per cost) over several Application Areas.

## **5.3 WMO Space Programme, focusing on design activities of CGMS**

5.3.1 The Secretariat reported recent progress made in terms of space-based observing system design and implementation within the Space Programme, in particular through the CGMS and the Expert-Team on Satellite Systems (ET-SAT).

5.3.2 The workshop noted that the 65<sup>th</sup> WMO Executive Council adopted a Resolution on “Avoiding gaps in Essential Space-based Observations” inviting the CGMS to monitor the plans and coordinate efforts, in view of the risks of gaps in the following missions: (i) early morning orbit imagery and sounding, (ii) afternoon orbit continuity between Suomi-NPP and JPSS-1, (iii) geostationary coverage of South America, (iv) geostationary hyperspectral sounding, (v) operational follow-on of the R&D GPM mission, (vi) earth Radiation Budget measurement, (vii) limb sounding observations of atmospheric composition, and (viii) space weather.

### ***CGMS Baseline for operational missions contributing to the space-based GOS***

5.3.3 In 2011, the Coordination Group for Meteorological Satellites (CGMS) adopted a “Baseline for operational missions contributing to the space-based GOS”. The CGMS “baseline” reflects the plans that CGMS Members could agree to at this point of time (2011), as an intermediate step towards the implementation of the WMO Vision in 2025. On this basis, an amendment to the Manual on the GOS was developed by ET-SAT, recommended by CBS-XV, and approved by EC-65. The baseline involves a diversity of constellations of satellites, which are not all independent from each other.

### ***Optimization of Low-Earth Orbit missions through the redeployment of the FY-3 morning satellite series to the early-morning orbit***

5.3.4 In accordance with the WMO Vision of the GOS in 2025 and the CGMS baseline, discussions were held among CGMS operators on the optimization of Low Earth Orbit satellites with a view to maintain satellites on three orbital planes: mid-morning, afternoon and “early morning”, the latter being in the dawn-dusk zone.

5.3.5 In order to support such an optimization, a Tiger Team was set up with several NWP centres conducting Observing System Experiments (OSEs) to document the benefit of early morning

observation for global or regional NWP. Other applications of early morning observations have been reviewed (such as e.g. typhoon, fog, or air quality monitoring). A “Tiger Team seminar” was held in Beijing in April 2013 and reported at CGMS-41 (See website<sup>24</sup>).

5.3.6 The China Meteorological Administration (CMA) is prepared to take responsibility for the early morning orbit, through redeploying the FY-3-E and FY-3G satellites initially planned for mid-morning orbit. In doing so, if this plan is confirmed, CMA will enable a major step forward for the space-based observing system. This is also a remarkable example of international coordination by WMO and CGMS.

### ***Radio-occultation constellation assessment by the IROWG and subsequent implementation issues***

5.3.7 The workshop recalled that, thanks to high vertical resolution, excellent accuracy and the limited investment it requires in comparison to the amount of information delivered, GNSS Radio-Occultation (RO) has become a major component of the global observing systems for weather forecasting, climate monitoring and ionosphere monitoring. A related action (S21<sup>25</sup>) is included in the Implementation Plan for Evolution of Global Observing systems (EGOS-IP)<sup>26</sup>

5.3.8 The status of the global RO constellation was assessed in September 2013 by the IROWG (see document on the web<sup>27</sup>). Current plans to address the EGOS-IP action S21 objective of at least 10,000 occultations per day rely mainly on COSMIC-2/FORMOSAT-7, METOP/GRAS, and (once demonstrated) FY-3/GNOS, however the COSMIC-2/FORMOSAT-7 programme is not fully confirmed. The workshop stressed the importance of realizing these plans.

### ***Architecture for Climate Monitoring from Space, with focus on the space-based component and its contribution to the provision of Fundamental Climate Data Records (FCDRs)***

5.3.9 Following the publication of the “Strategy Towards an Architecture for Climate Monitoring from Space”<sup>28</sup> jointly drafted by CEOS, CGMS and WMO representatives, the Architecture for Climate Monitoring from Space (the Architecture) is seen as a key component of the Observations and Monitoring pillar of the Global Framework for Climate Services (GFCS)

5.3.10 The workshop noted that the CGMS and the Committee on Earth Observation Satellites (CEOS) have developed the terms of reference of a proposed joint CEOS-CGMS working group on climate that will take up the task of further developing the Architecture concept.

5.3.11 The workshop noted that current activity is focused on the development of an inventory of Essential Climate Variable (ECV) products. Three particular recommendations were made by ET-SAT and supported by CGMS: (i) to extend the ECV product inventory to include fundamental climate data records (FCDRs); (ii) to develop a finer categorization of CGMS baseline missions that could be used to draw a list of sustained FCDRs coordinated by CGMS; and (iii) to include in the design phase of every new sensors an analysis of compatibility with heritage sensors.

### ***OSCAR, risk analysis and contingency matters***

5.3.12 The workshop recalled that the Observing System Capability Analysis and Review (OSCAR) tool is available on-line to serve as a reference for information on requirements, space capabilities and (in future) surface observing capabilities, and to support gap or risk analysis. For the space capabilities part, significant developments are envisaged in the coming years with the aim to support the qualitative assessments by a quantitative evaluation of the typical resolution and uncertainty of each class of instrument. OSCAR supports ET-SAT and CGMS gap analyses and contingency planning.

24 [http://www.wmo.int/pages/prog/sat/documents/CGMS\\_LEO-TigerTeam-Final-Report-April-2013.pdf](http://www.wmo.int/pages/prog/sat/documents/CGMS_LEO-TigerTeam-Final-Report-April-2013.pdf)

25 *to ensure and maintain a radio-occultation constellation of GNSS receivers onboard platforms on different orbits producing at least 10,000 occultations per day (to be refined by impact studies) [and to] organize the real-time delivery to processing centres.*

26 <http://www.wmo.int/pages/prog/www/OSY/Publications/EGOS-IP-2025/EGOS-IP-2025-en.pdf>

27 [http://www.irowg.org/docs/Status\\_Global\\_Observing\\_System\\_for\\_RO.pdf](http://www.irowg.org/docs/Status_Global_Observing_System_for_RO.pdf)

28 [http://www.wmo.int/pages/prog/sat/documents/ARCH\\_strategy-climate-architecture-space.pdf](http://www.wmo.int/pages/prog/sat/documents/ARCH_strategy-climate-architecture-space.pdf)

5.3.14 The general issue of user preparedness for new generations of satellites was raised by WMO, following the CBS Expert Team on Satellite Utilization and Products (ET-SUP) and ET-SAT discussions and the “CBS Guidelines for Ensuring User Readiness for New Generation Satellites” adopted by CBS-XV. CGMS agreed to form a task team to support the implementation of best practices in this respect, and the development of a portal to inform users on these matters.

5.3.15 In terms of OSND principles, the workshop noted the following comments:

- There is already network design activity – essentially undertaken by WMO, CGMS and the space agencies – that is implicit in the Vision for the GOS in 2025 (or guided by the Vision)
- Overarching OSND principles include for example: assuring a certain coverage with observations uniform in space and time; assuring some level of interoperability; addressing the GCOS Climate Monitoring Principles; data access and in real-time in particular.

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

5.4.1 The vice-chair of the IPET-OSDE, Mr Jay Lawrimore (USA) provided an overview of network design issues associated with the WMO-IOC-UNEP-ICSU Global Climate Observing System (GCOS) *in situ* surface and upper air observing networks. He recalled that GCOS includes *in-situ* and remotely sensed systems for the atmosphere, ocean, and terrestrial environments. The breadth of environments from ocean depths to the upper atmosphere requires the integration of multiple networks of various design using *in situ*, radar, and satellite based systems. Guidance associated with network design is provided by three GCOS science panels which work to define the observations needed in each of the main global domains, to prepare specific program elements and to make recommendations for implementation: (1) the Atmospheric Observation Panel for Climate (AOPC), (2) the Ocean Observations Panel for Climate (OOPC), and (3) the Terrestrial Observation Panel for Climate.

5.4.2 The breadth of observing system requirements requires GCOS to span a wide-range of observing systems and organizations. GCOS has started the process of identifying network design principles to meet global climate observing requirements by focusing on land-based *in situ* observing systems associated with the most fundamental essential climate variables, primarily temperature and precipitation. To date the primary emphasis has been on network implementation while the design of networks has been implicit. Implementation is reviewed while broadening the discussion to network design issues. This consists of creating standards of network design to meet GCOS requirements in terms of spatial and temporal coverage (observation spacing and diurnal cycle) as well as station representativeness and homogeneity (how well and consistently do measurements represent the true climate of the area currently and throughout the station's lifetime). Network design also includes consideration of issues associated with good data stewardship needed to produce a sound long-term observational record including data and metadata collection and sharing practices, data archive and access.

5.4.3 Mr Lawrimore presented a summary of the current state of GCOS *in situ* surface observing systems, including the GCOS Surface Network (GSN), and future design requirements for GCOS, including future network configuration with reference climate stations, baseline networks, better use of national and other networks, siting and instrument considerations, as well as possible improvements in global collection and dissemination.

5.4.4 Mr Lawrimore presented a summary of the current state of GCOS *in situ* upper air observing systems, including the baseline Global Upper Air Network (GUAN), and the Global Reference Upper Air Network (GRUAN). Future design requirements of such systems for GCOS were discussed.

5.4.5 The workshop particularly noted that the continued development and completion of the GRUAN network as originally designed is essential to establishing reference upper air observations across all areas of the globe, most importantly as reference standards for the larger GUAN network. GRUAN will be a heterogeneous network that includes sites from both the research community and

the operational meteorological community. While providing data to fully characterize the properties of the atmospheric column, GRUAN also will provide a traceable reference standard for global satellite - based measurements of atmospheric essential climate variables and will ensure that potential gaps in satellite measurement programs do not invalidate the long - term climate record.

5.4.6 The workshop further noted that GUAN network will continue to provide baseline observations for the globe. Assistance to developing nations in the acquisition of replacement parts and expendables will be essential to maintaining the network. As with the in situ surface networks, ensuring homogeneity of GUAN stations will remain a high priority.

5.4.7 Mr Lawrimore finally reported on GCOS data stewardship and metadata requirements, and the need to produce a sound long-term observational record including data and metadata collection and sharing practices, data archive and access.

5.4.8 In terms of OSND principles, the workshop noted the following comments:

- Data stewardship has to be considered in network design;
- It is import to consider instrument metadata collection as part of quality management;
- We can build on GCOS experience (including the GCOS Climate Monitoring Principles in particular) for identifying important network design principles;
- There can be embedded networks that are demanding higher quality data;
- There are constraints that are specific to certain applications (e.g. the effect of the growth of urban areas must be treated differently for climate monitoring compared with other application areas).

## **5.5 Update on the Global Framework for Climate Services (GFCS)**

5.5.1 Veronica Grasso (WMO Secretariat) provided an update on the development of the Global Framework for Climate Services (GFCS). She recalled that the vision of the Global Framework for Climate Services (GFCS) is to enable society to manage better the risks and opportunities arising from climate variability and change, especially for those who are most vulnerable to climate-related hazards. Effective climate services will facilitate climate-smart decisions that will reduce the impact of climate-related disasters, improve food security and health outcomes, and enhance water resource management, among other societal benefits. All countries will benefit, but in the initial stages priority shall go to building the capacity of developing countries vulnerable to the impacts of climate variability and change. The GFCS aims to bridge the gap between those that need to know the climate and those that have such knowledge, thus empowering, in particular, the vulnerable.

5.5.2 The GFCS has five main components or pillars whose implementation is critical to ensure that the entire value chain for the production and application of climate services is effectively addressed (User Interface Platform, Climate Services Information System, Observations and Monitoring, Research, Modelling and Prediction, and Capacity Building).

5.5.3 The workshop noted that the first session of the Intergovernmental Board on Climate Services, was held from 1 to 5 July 2013, under the initial Chairmanship of WMO President, Mr David Grimes. The session (i) approved the implementation plan of the GFCS and a compendium of initial GFCS projects for immediate implementation; (ii) agreed on the definition of processes and substructures supporting its advancement; (iii) established a stakeholder engagement mechanisms; (iv) elected Dr Anton Eliassen (Norway) as the Chair, Dr Linda Makuleni (South Africa) and Dr Laxman Singh Rathore (India) as the Co-Vice-Chair, and (v) selected the Members forming the Management Committee of the Board in all Regional Associations.

5.5.4 The Management Committee was entrusted with the following responsibilities:

- Draft recommendations to be submitted by the Intergovernmental Board on Climate Services (IBCS) to the Seventeenth Congress on appropriate interaction mechanism between the

IBCS and WMO constituent bodies, including the technical commissions as well as constituent bodies of partner institutions;

- Review and update the “Principles and Criteria” for funding projects and activities from the GFCS Trust Fund;
- Design a monitoring and evaluation criteria and process for the implementation of the GFCS;
- Review the composition and criteria for membership of IBCS;
- Establish a process to capture the various contributions made by Members at the global, regional and national levels, which support the implementation of the GFCS.

5.5.5 With respect to implementation, the workshop noted that a number of countries are conducting their national consultations intended to establish the internal coordination mechanisms needed to ensure that the entire value chain for the production and application of climate services in the country is effectively addressed (see <http://gfcs.wmo.int/events>). These consultations are allowing the identification of key gaps in the various components of the GFCS to support the development and application of climate services in the country such as the need to improve the current status of declining observing networks in some parts of the world, particularly Africa, the Pacific Islands and Latin America. These consultations are facilitating the identification of critical elements that are supporting the development of guidelines for the establishment of frameworks for climate services at national level.

5.5.6 Early efforts for implementation of GFCS are taking place through specific activities supported by various donors such as Australia, Canada, China, Ireland, Korea and Norway. Early implementation will also be effected through the implementation of the activities contained in the documents that describe the components of the GFCS (Annexes to the implementation Plan) and the compendium of initial GFCS projects approved by IBCS-1. These activities will require the support of various actors, particularly as they relate to observation networks.

5.5.7 The meeting noted that the Annex on “Observations and Monitoring” of the Implementation Plan of the GFCS identified a number of gaps and deficiencies.

5.5.8 To address the above gaps and shortcoming, particularly with respect to network design, the workshop noted the need to design networks based on requirements to address user needs for climate services as well as the requirements from the research, modelling and prediction pillars of the GFCS to advance knowledge of the climate system, its predictability and impacts of climate variability and change.

5.5.9 The workshop noted that gaps identified between user needs and present/planned capabilities should be addressed through the mechanism of the WMO RRR process and through the EGOS-IP and its further development. They should also inform WMO guidance on observing system design.

5.5.10 In terms of OSND principles, the workshop noted the following comments:

- For GFCS, there is a need for taking into account non-traditional data, and to address biological, environmental and socio-economical data;
- Data policies, data exchange and interoperability between data systems, including with the WIS, are important;
- There is a need to address data loss and data rescue;
- Interoperability and sustainability can be addressed through cooperation at the regional level;
- The work done by GCOS on user requirements and gap analysis should be taken into account by GFCS. However, user requirements for GFCS may go beyond those of GCOS requirements, addressing issues such as regional monitoring requirements.

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

5.6.1 The Secretariat reported on the development and implementation of the Global Cryosphere Watch (GCW<sup>29</sup>), which is currently coordinated by the Executive Council Panel of Experts on Polar Observations, Research and Services (EC-PORS) on behalf of the Executive Council. A draft of the GCW Implementation Plan (GCW-IP<sup>30</sup>) was completed and has been widely circulated for comments. The GCW-IP will be presented to EC-66 for consideration before submission to Cg-16. Efforts are also underway:

- Establish GCW as a WMO programme with a GCW “International Project Office” (IPO) in the Secretariat to provide for an optimal and effective contribution across the Organization. EC-PORS is preparing a Resolution for consideration by EC-66 (May 2014) on the establishment of the GCW Programme;
- Establish a GCW “International Project Office” (IPO) in the Secretariat in co-ordination with interested partners in their institutions;
- Address the current state of snow data, products and information from *in-situ* and satellite sources, to identify critical issues for attention of GCW and to recommend activities to address issues and gaps;
- Develop the GCW portal (operated by the Norwegian Meteorological Institute – [www.met.no](http://www.met.no)) to ensure access to real-time, near real-time and historical cryospheric data and products through the WMO Information System (WIS);

### **CryoNet**

5.6.2 The workshop noted that one of the main initial priorities of the GCW is the initiation of CryoNet, the surface-based observational network. CryoNet will initially be comprised of existing stations/sites, rather than creating new sites. CryoNet stations will agree to provide prescribed sets of measurements taken according to GCW standards, guidelines and best practices, thus ensuring high quality data for scientific research and operational use. Over 80 sites and/or networks were proposed for initial consideration. Links are being identified and clarified, as many of the cryospheric networks are external to WMO. It is recognized that CryoNet will take some time to become fully operational as a component of WIGOS.

5.6.3 GCW held its first implementation workshop on “CryoNet” in November 2012, Vienna, Austria (see Final Report on the web<sup>31</sup>). This workshop aimed to initiate the process to define the types of surface sites, e.g., supersites, reference sites, and/or tiered sites in cold climate regions, on land or sea, operating a sustained, standardized programme for observing and monitoring as many cryospheric variables as possible. This would also involve initiation of the development of formal procedures for establishing the GCW network, evaluation of potential supersites, discussion of the measurement standards and determination of data availability and exchange. The CryoNet Task Team is developing a draft CryoNet Guide based on available guidelines and inputs from contributors and through extensive group discussion. It will hold its 1<sup>st</sup> session in Reykjavik in January 2014. The CryoNet Guide will become a part of the WIGOS Regulatory Material.

5.6.4 The workshop noted that in order to meet different user-needs and because of the spatially distributed nature of different components of the cryosphere, the CryoNet network of in-situ observations is structured into three different classes of observational sites: Integrated, Reference, and Baseline Sites. These are described in **Annex VI**.

5.6.5 In terms of OSND principles, the workshop noted the following comments:

- The GCW is learning from the CBS experience with regard to system design (rather than the other way around);
- Observing stations in a network need to be managed in a coordinated way;
- Cryonet is a good example of “network design” being about more than the number, spacing and type of observing stations; it also involves getting existing stations to work together as a

29 <http://globalcryospherewatch.org/>

30 [http://www.wmo.int/pages/prog/www/polar/GCW/GCW\\_IP.pdf](http://www.wmo.int/pages/prog/www/polar/GCW/GCW_IP.pdf)

31 [http://www.wmo.int/pages/prog/www/OSY/Meetings/GCW-CN1/Final\\_Report\\_CryoNet\\_1.doc](http://www.wmo.int/pages/prog/www/OSY/Meetings/GCW-CN1/Final_Report_CryoNet_1.doc)

network.

- In the context of WIGOS, it is important to understand which Application Areas GCW user requirements” are seeking to serve.
- Where practicable, observations from Cryonet should be made available by WIS in near real-time.

## 6. REVIEW OF IMPACT STUDIES RELEVANT TO OBSERVING SYSTEM DESIGN

6.0 Under this agenda item, the workshop considered input from recent OSEs/OSSEs in order to illustrate issues arising when developing observing system design principles and guidance.

### 6.1 *Update on recent OSEs/OSSEs relevant to observing system design*

6.1.1 The Rapporteurs on Scientific Evaluation of Impact Studies (R-SEIS), Dr Erik Andersson (ECMWF), and Dr Yoshiaki Sato (Japan) provided an update on recent Observing System Experiments (OSEs) and Observing System Simulation Experiments (OSSEs), focusing on aspects relevant to observing system design. The following activities were presented:

- Impact studies for the early morning orbit satellite;
- Impact studies for the advanced microwave scanning radiometer 2 (AMSR2) onboard the Global Change Observation Mission 1 – Water (GCOM-W1) satellite
- Impact of radiosonde balloon position information
- The international Joint OSSE studies
- Production of a new high-resolution nature run using ECMWF IFS T1279L91 in May 2013;
- The workshop proposed by CEOS dedicated to study the contribution of future GEO<sup>32</sup>/Air Quality instruments to the global observing system of atmospheric composition using OSSEs
- The workshop on "Atmospheric Composition Observation System Simulation Experiments" was held in October 2012 at ECMWF;
- White paper<sup>33</sup> submitted to the Arctic Observing summit on the benefits of OSSE for justifying new Arctic observation capabilities;
- Studies on adjoint-based sensitivity to forecast error;
- The use of FSO tool for Weather Research and Forecasting (WRF) system for the adjoint sensitivity study for regional models;
- Observation impact tool for ensemble Kalman filters;
- Land surface data assimilation: snow, soil moisture;
- Regional observation networks in Europe;
- Saturation of the number of radio occultation profiles;

6.1.2 Details about these activities can be found in this workshop preparatory document no.6 (see website<sup>34</sup>).

### 6.2 *Next OSE/OSSE workshop*

6.2.1 The workshop recalled the series of WMO Workshops on the Impact of Various Observing Systems on NWP, which have been organized in Geneva, Switzerland in 1997, in Toulouse, France in 2000, in Alpach in 2004, in Geneva again in 2008 and in Sedona, USA: in 2012. The series of workshops has proved very successful providing substantial input for reviewing the Statements of Guidance for Global and High-resolution NWP, the Vision of the Global Observing System (GOS) for 2025 and the ET-EGOS IP. With this fruitful result, CBS-15 requested OPAG-IO to organize the Sixth WMO Impact Workshop in 2016. Since the last workshop provided very successful result, the next workshop should be organized with similar size and set-u. The location and date are under

32 Group on Earth Observations

33 [http://www.arcticobservingsummit.org/pdf/white\\_papers/matsutani\\_et\\_al\\_observing\\_system\\_simulation\\_experiments.pdf](http://www.arcticobservingsummit.org/pdf/white_papers/matsutani_et_al_observing_system_simulation_experiments.pdf)

34 <http://www.wmo.int/pages/prog/www/OSY/Meetings/OSDW1/documents/OSDW1-2013-Doc-6-Rev1-Impact-Studies.doc>

consideration.

6.2.2 Dr Andersson (ECMWF) briefly presented the outcome of the Fifth WMO Workshop on “The impact of various observing systems on NWP” (Sedona, Arizona, USA, 22-25 May 2012).

6.2.3 The workshop noted that the existing tools could be refined to address a wider range of scientific questions with regard to the impact of observations on NWP (and perhaps a wider range of applications).

6.2.4 The workshop expressed the view that it is expecting the CBS to address the planning of the next NWP “impact” workshop as a key contribution to WIGOS Framework Implementation KAA#3 with the view to have a well-elaborated plan by the CBS Extraordinary Session in late 2014.

### **6.3 Recommendations on observing system design**

The workshop discussed possible recommendations to be made to the CBS regarding observing system design (proposals for new OSEs/OSSEs to be promoted by IPET-OSDE. The workshop invited the first meeting of the IPET-OSDE to address the following ones:

1. Encourage continued development and research of adjoint-based observation impact assessment tools, as a complement to traditional OSEs;
2. Encourage OSEs for the optimization of regional composite networks;
3. Encourage NMHSs to conduct OSEs and OSSEs to address the he specific science questions listed in table 1 of this workshop’s preparatory document no. 6 (see website<sup>34</sup>).

## **7. PREPARING WMO GUIDANCE ON OBSERVING SYSTEM DESIGN**

7.1 On the basis of the discussion under the previous agenda items, and the guidance from the Chair as detailed in **Annex III**, the workshop explored the different aspects of observing system design in which WMO may wish to propose guidance. These included for example:

- (i) Design principles for single technology observing systems;
- (ii) Design principles for composite observing systems;
- (iii) Capacity development issues;
- (iv) Others aspects to consider; and
- (v) Proposals for document(s) to be developed.

7.2 The outcome of the workshop’s discussion with regard to OSND principles and guidance is reflected in the following annexes:

- Annex II:** Action sheet from OSDW1
- Annex VII:** Writing Group 1 outcome: OSND principles derived from relevant OSND activities, including impact studies
- Annex VIII:** Writing Group 2 outcome: Overarching OSDN design principles in keeping with GCOS priorities
- Annex IX:** Writing Group 2 outcome: OSND principles derived from the GCOS Climate Monitoring Principles
- Annex X:** Writing Group 2 outcome: OSND principles derived from weather radar network design activities
- Annex XI:** Writing Group 2 outcome: OSND principles proposed by the Chair of ICT-IOS
- Annex XII:** Writing Group 2 outcome: Draft OSND Principles derived from the review of existing regulatory material
- Annex XIII:** Roadmap for the development of OSND principles and guidance

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

## **8.1 Recommendations for consideration by IPET-OSDE and ICT-IOS-8**

8.1.1 The workshop agreed on a roadmap for developing OSND Principles and Guidance. The roadmap provides details on the role of this workshop's participants, and of the IPET-OSDE in this regard. In particular the first session of the IPET-OSDE (tentatively scheduled in Geneva from 31 March to 4 April 2014) will review and revise OSND principles, draft a more complete plan for preparing OSND guidance, and task IPET-OSDE members to draft specific materials in close coordination with their respective Teams and groups. The IPET-OSDE recommendations will then be submitted to the eight session of CBS OPAG on Integrated Observing Systems' Implementation and Coordination Team (ICT-IOS) (tentatively scheduled in Geneva from 7 to 11 April 2014) in preparation for CBS Extraordinary Session in late 2014. The roadmap is provided in **Annex XIII**.

8.1.2 The workshop acknowledged that there will be a CBS focus on regulatory materials in the WIGOS framework. IPET-OSDE will therefore have to look into these aspects as far as the RRR and Observing Network System Design is concerned.

## **9. ANY OTHER BUSINESS**

The workshop considered the following relevant matters not covered in the above agenda:

- GCOS Network meeting, Ispra, Italy, 7-8 April 2014: At the 18th AOPC Meeting (from 2 to 5 April 2013) there were discussions on the performance of the GCOS networks and the operational challenges at the global scale, in addition to discussions on new technologies/systems and how these relate to the Atmospheric Essential Climate Variables. A number of key questions were identified; the capabilities of the long standing networks (GSN and GUAN) in meeting the current/emerging Climate Requirements; the prioritization of stations within the networks and the benefits of incorporating other observing networks. To discuss this further and propose recommendations to AOPC, it was agreed by GCOS to hold a network review workshop in advance of the 19th AOPC (2014) to which relevant experts would be invited to attend/contribute. The IPET-OSDE is invited to consider its participation at the meeting.
- GRUAN Workshop in Geneva from 5 to 9 May 2014. Planning is led by Dr Stephan Bojinski (GCOS Secretariat). Dr John Eyre has offered to be a member of the organizing committee, and he will bring the IPET-OSDE perspective at the workshop.

## **10. CLOSURE OF THE SESSION**

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

10.2 The Chair thanked the participants and the Secretariat for their contributions. The session closed at 15:45 on Thursday, 14 November 2013.

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## ACTION SHEET RESULTING FROM OSDW1

<b>No.</b>	<b>Action item</b>	<b>By</b>	<b>Deadline</b>
1	Finalize documents produced by the writing groups, and include them as annex of final report of this workshop	L.P. Riishojgaard E. Andersson D.Michelson S. Goldstraw J. Lawrimore J. Eyre	22 Nov. 2013
2	Consolidate information and materials for submission to TT-WRM in Nov. 2013	J. Eyre + Sec	22 Nov. 2013
3	Consolidate the draft OSND principles for review by workshop participants	J. Eyre	15 Dec. 2013
4	Workshop participants to review the draft OSND principles and provide feedback to J. Eyre	Workshop participants	15 Jan. 2014
5	Consider participation of IPET-OSDE at the GCOS Network meeting, Ispra, Italy, 7-8 April 201	J. Eyre	15 Jan. 2014
6	Finalize the draft OSND principles together with supporting information in order to understand the principles; for submission to ICG-WIGOS	J. Eyre	27 Jan, 2014
7	Taking account of review by ICG-WIGOS, finalize draft OSND principles for input to IPET-OSDE-1	J. Eyre	15 Mar. 2014
8	Develop proposal for development of OSND guidance as input to IPET-OSDE-1	J. Eyre	15 Mar. 2014
9	First IPET-OSDE meeting to review and revise the draft OSND principles; to draft a plan for preparing OSND guidance, and to task Team members for drafting materials	IPET-OSDE-1	4 Apr. 2014

## ANNEX III

### Guidance from the IPET-OSDE Chair on observing system network design (OSND)

**Note:** The proposals and ideas offered below concern the development of OSND strategies, i.e. guidance on how to approach the problem of OSND; they do not result directly in proposals for the design of specific observing systems.

1 Given the very wide range of applications of observations covered by WMO Programmes and the very wide range of observing systems that contribute to meeting the requirements of these applications, the potential scope of the Workshop is huge. It will therefore be necessary to focus on a few key observing system design issues in which it is desirable and feasible to make early progress. However, in addition, it will be helpful to outline others, which deserve attention in future, in order to address other areas of OSND contributing to WIGOS.

2 Some WMO activities already have OSND activities well established. These include:

- an integrated space-based observing system to meet the needs of WMO Programmes, described within the WMO “Vision for the GOS in 2025” [link] and coordinated under the WMO Space Programme,
- the ARGO network of ocean measurements under JCOMM.

Many other examples could be given.

3 Other areas were the subject of OSND many years or even decades ago when both the scope of WMO applications was much smaller than it is today and the requirements of the applications that did exist were considerably less demanding. As a consequence, some of the WMO guidance that exists on OSND relates to a bygone era and is no longer appropriate for today’s systems.

4 In general, key applications within WMO programmes are capable of making use of observations in numbers and densities that cannot be afforded even by Members with the most advanced economies. The radiosonde network is a good example; global NWP is today capable of exploiting of density ~10 km, should it be available. Some other applications could exploit even higher densities. These densities are not available for reasons of cost. So the challenge is, through international cooperation and through appropriate combinations of technologies, to meet as many user requirements for observations as possible within available resources. Moreover, the challenge for OSND at WMO level is to provide advice on which technologies should be used, which combinations of technology are likely to be most effective and, for each technology, what type of network is likely to be both effective and good value-for-money.

5 Within this general framework, advice on OSND is likely to provide helpful guidance at two levels:

5.1 Observing systems based on a single technology. Here advice on network density is helpful. User requirements will tend to support the case for quasi-uniform networks. Reasons to depart from uniformity will include a variety of issues, e.g. the desirability for the network to be meteorological or climatologically representative. An elaboration of these reasons in the form of guidance will be helpful. Of course, when implementing any guidance at national level, it is likely that many other reasons will be found for departing from a network design based purely on user requirements, such as: economic reasons (e.g. the high costs of maintaining stations in remote locations), “strategic” reasons (e.g. the need to maintain observations on specific sites to serve specific users, and the consequences for the rest of the network), and reasons of continuity (e.g. the need to maintain a climate record). Again, an elaboration of these reasons in the form of guidance will be helpful.

5.2 Composite observing systems, i.e. those composed of a combination of different observing technologies. Here it is even more difficult to establish what the most cost-effective combination of observations is likely to be. I would expect this Workshop to discuss how we should approach this difficult problem and to consider a range of approaches to it. As one example, I can offer the approach we have used in recent years in the Met Office (UK) to establish priorities for investment in

ground-based observations to cover the UK land area and coastal waters in support of weather forecasting. The strategy can be summarised as follows:

- First establish which investments are already “given”. For the UK in recent years these have included:
  - Satellite observations, from EUMETSAT platforms and those of other space agencies to which we have access. UK contributions to EUMETSAT are, of course, part of its investment in observations, but these systems are planned on timescales such that, in practice, investment decisions can be decoupled from those on ground-based observations. This does not necessarily lead to the most cost-effective overall system. However it does represent the reality of the decision-making process!
  - Rainfall radar network, for which a customer base exists even if it were not needed for weather forecasting.
- Given these “sunk costs”, establish a programme to ensure that the data from these systems are exploited effectively.
- Then consider the gaps between user requirements for observations and the capabilities of the “given” networks. This involves assessment of the key applications areas to be served. In the case of the UK, this includes principally high-resolution NWP and nowcasting, although other applications are also taken into account.
- Given this gap analysis, in terms of geophysical variables for which enhanced observations are needed, establish cost-effective enhancements to the “given” network. In the case of the UK this has led to decisions to:
  - Dopplerize the radar network, to give additional wind observations at relatively low additional cost.
  - Maintain radiosonde stations as required to meet climate monitoring commitments (i.e. very few stations).
  - Purchase aircraft observations in order best to supplement observations from systems listed above. This has involved OSEs to determine the impact of aircraft observations.
  - Consider other observations to fill remaining gaps, e.g. wind profilers.

The details here are, of course, specific to the UK – to the status of its observing system, to its specific requirements and to its resources. However, the overall strategy could probably be generalised.

5.3 I look forward to hearing and discussing similar ideas from other participants at our Workshop.

6 It is also necessary for us to consider how generic guidance on OSND relates to the design and evolution of systems that have provided the backbone of our observational capability for decades, and particularly (though not exclusively) the Regional Basic Observing Networks (RBONs). What is the relationship between requirements for observations, as collated through the RRR process in the database for user requirements and the Statements of Guidance, and the design of RBONs? It is my view that, unfortunately, this relationship is not a simple one. For example, the “threshold” requirements in the database cannot simply be converted into minimum standards for networks, in part because we have different requirements for different applications, and in part because of the issues related to “single” and “composite” networks discussed above. Therefore the translation of RRR outputs into RBON guidance is a non-trivial activity. For this reason, it is important that this Workshop should give some consideration and guidance as to how the translation might be done.

7 It should be noted that the proposals and ideas offered above concern the development of OSND strategies, i.e. guidance on how to approach the problem of OSND; they do not result directly in proposals for the design of specific observing systems. In discussing its goals, the Workshop should attempt to clarify whether it accepts this as its main aim.

**REGIONAL OBSERVATION NETWORK RE-DESIGN STUDY OVER EUROPE  
BASED ON OBSERVING SYSTEM EXPERIMENTS (OSEs)  
PERFORMED WITH THE ALADIN LIMITED AREA MODEL (LAM)**

*(Report submitted by Gergely Bölöni (Hungary))*

1. The Hungarian Meteorological Service took part in an extensive Observing System Experiment (OSE) for assessing a) the relative impact of radiosondes and aircraft data; b) the impact of spatial thinning of both radiosonde and aircraft data, in terms of short range model forecast performance (0-48 hours).

2. The experiments have been performed over a summer (01/06/2007-15/07/2007) and a winter period (15/12/2006-31/01/2007) with the ALADIN limited area model (LAM), which involves a 3DVAR data assimilation system for the upper-air and an optimum interpolation (OI) scheme for the surface/soil variables. Lateral boundary conditions (LBC) were provided by ECMWF IFS model..

3. The following observation denial scenarios have been run based on the recommendations of the EIG EUMETNET<sup>1</sup> EUCOS Scientific Advisory Team (E-SAT):

- Sc2:** control – full operational observation usage (surface stations, radiosonds, aircrafts, satellite radiances and atmospheric motion vectors, windprofilers)
- Sc3b:** all radiosonde data at 00 UTC + 100 km thinning at 06, 12, 18 UTC + all aircraft data
- Sc3a:** 100 km thinning of radiosondes + all aircraft data
- Sc4:** 250 km thinning of both radiosondes & aircraft data
- Sc5:** 500 km thinning of both radiosondes & aircraft data
- Sc1:** baseline (basic network including GUAN radiosonde network, flight level aircraft data, aircraft profiles of less than 3 hourly visited airports and full remaining part of the observation network)

4. The scenarios above have been run using a 6-hour data assimilation cycle, mimicking production forecasts starting from 00 and 06 UTC analysis times (up to 54 and 48 hours lead times respectively). Note that ECMWF has run the same scenarios above with the IFS model and each LAM scenario has been coupled with the corresponding global IFS scenario.

5. The results of the OSE experiments are summarized in the table in the Appendix. It has been found that the 250 and 500 km thinning of the radiosonde and aircraft data (Sc4 and Sc5) has a detrimental impact on the short range forecasts (up to 30 hours lead time) as well as the reduction of the observing system to the Baseline scenario (up to 18 hours lead time). A 100 km thinning of the radiosonde data implies a significant negative impact on the forecasts up to 12 hours lead time, if performed for all analysis times (Sc3a). However if 00 UTC radiosondes were kept at full resolution (Sc3b), no degradation has been found with respect to the Control scenario (even a slight improvement has been found for relative humidity and geopotential). Based on the neutral to positive impact of Sc3b with respect to the Control scenario, it is presumed that aircraft data compensate well the reduction in the radiosonde data in the ALADIN LAM data assimilation system at 06, 12 and 18 UTC analysis times.

6. Based on the above conclusions, it is recommended not to degrade the resolution of the radiosonde network (and the number of aircraft measurements), otherwise a significant degradation of regional short range forecasts for Europe is expected. In case of a strong constraint for reducing the costs of the radiosonde network, it is recommended to thin only at 06, 12 and 18 UTC because at these network times aircrafts might compensate the radiosonde data reduction. One has add, that the impact of the above denial experiments was not measured on forecasts starting from 12 and 18 UTC.

Note: The related presentation made at the 5<sup>th</sup> international workshop in the impact of various observing systems on NWP (Sedona, USA, April 2012) is available on the web<sup>1</sup>.

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<sup>1</sup> [http://www.wmo.int/pages/prog/www/OSY/Meetings/NWP5\\_Sedona2012/2a5\\_Boloni.pdf](http://www.wmo.int/pages/prog/www/OSY/Meetings/NWP5_Sedona2012/2a5_Boloni.pdf)

**APPENDIX OF ANNEX IV**  
**VERIFICATION SUMMARY**

	Baseline		Sc3a		Sc3b		Sc4		Sc5	
	00 UTC	06 UTC	00 UTC	06 UTC	00 UTC	06 UTC	00 UTC	06 UTC	00 UTC	06 UTC
winter										
T850	12	18	12	6	0	0	12	18	12	18
RH700	12	6	0	6	-12	0	12	12	12	18
Geo500	12	6	12	6	-24	0	12	6	12	6
summer										
T850	12	6	0	0	0	0	6	0	12	6
RH700	6	6	0	6	0	0	30	6	30	6
Geo500	12	6	0	0	0	0	12	0	12	6

Lead times of significant degradations in the forecasts with respect to the Control scenario due to the data denial applied in the different scenarios (negative values indicate improvements compared to the Control scenario). The verification has been based on RMSE and BIAS scores computed with respect to observations (surface stations and radiosondes) including a statistical significance test.

**MARINE OBSERVATIONS: A VALUE-FOR-MONEY INDEX**

Chris Hall, Surface Network Manager, Met Office (UK),  
Met Office internal report, 2003

**Annex 1 :** Annual costs in £K for operating marine observing systems (2003)

**Annex 2:** Weightings to surface marine observations – A NWP perspective compiled by Richard Dumelow, 5 Sept 2003

1. Introduction

Met Office strategy recognises the importance of developing value-for-money (VFM) indices for all its main activities. This paper proposes one such index for marine observations. Its principal purpose is for the clarification of the user requirement across a wide range of different observing systems and for informing the decision making process where difficult choices have to be made between investment in one system or another.

2. User requirements for marine data

A review of the user areas for marine data was undertaken in 2000-01 (UKON1 Marine Network Review by Nathan Powell). An updated summary is given in the table below.

Process area	Requirement	Requirement detail	Comment on value
Models – atmosphere and ocean	Initial conditions for forecasting process	Global, but most important close to UK and in Atlantic development areas. Pressure, wind, wave, SST are used currently.	OSE show measurable impact of all surface data, thought to be greatest in Atlantic development areas. Recent research on 4DVAR shows extra value of hourly data.
Forecasting	Observations as aid to the forecaster	Principally in UK waters, but also further afield: Atlantic and worldwide. Wind, wave, pressure & tendency, visibility, weather.	Important for gale warnings, shipping, inshore waters, oil industry
Data applications – climate research	Record of past weather	Global. In order of importance: SST, air temperature, humidity, pressure, wind. Accuracy vital.	Climate research
Data applications – satellite systems	Ground truth for development and operational use of satellite systems	Global. Most elements. Accuracy vital.	Contribution to international effort. Accurate satellite data vital for NWP.
Data applications – business	Record of past weather	Global. Wind, wave. To lesser extent SST. Accuracy important.	Marine consultancy – hindcasts, legal, etc. Target area for growth.
International	Various	Global. All elements.	Contribution to WMO/WWW and specific international undertakings (EUCOS, SOLAS, GCC). Recognition of overriding importance of global observations to Met Office interests.

### 3. Observing systems

The main components of the marine observing systems operated by the Met Office are listed in the table below. Argo floats which measure temperature and salinity profiles in the open oceans have been excluded since they are fully funded by MOD and DETR and are therefore not a variable component of the Met Office's marine operations. Costs are based on 2002-03 actuals with adjustments made for anomalies in the IDC attributions.

System	No.	Obs '000 p.a.	Cost £K p.a.	Cost £/ob	Comments
Open ocean moored buoys	13	114	1315	12	Located in critical data sparse ocean areas around the UK. Some defence and oil industry funding
Island systems & light vessels	8	70	360	5.1	Islands north of Scotland, Light vessels in the Channel. Same system as used in the open ocean
Platforms & rigs	49	130	110	0.85	Automatic and manual observations from North Sea and Shetland Basin
Drifting buoys	25	219	170	0.80	Most deployed in W Atlantic
VOS – UK area		8		8.7	Some ferries and in-shore shipping
VOS N. Atlantic		17		8.7	Regular trans-Atlantic routes
VOS Worldwide		430		63	765

The breakdown of costs (£K p.a.) is given in Annex 1. The cost per observation presented here is a very crude measure of value as it takes no account of:

- The value to the user of the observed elements
- The accuracy of the observed elements
- The area where the observations are made
- The local density of observations
- The frequency of observations.

The next section attempts to take all these factors into consideration in the development of a VFM index.

### 3. Value for money

There is an enormous range of observations delivered from marine observing systems: some are close to the UK and some at the other side of the globe; some are in relatively data rich areas and some are in data voids; some report hourly and some only infrequently; some deliver a complete range of meteorological and oceanographic elements and some only one or two. The VFM index proposed here attempts to take these factors into account. It has been reviewed by users of marine data and modified as best as possible in the light of their comments. It is inevitable, though, that a large degree of subjectivity enters such a scheme and it should be used with appropriate caution within the decision making process for the supply of observations.

#### **Value to the user of the observed elements**

The first issue to consider when assigning a value to an observing system is the range of elements observed. Each element will have a different value for each group of users; pressure, wind and sea temperature will be of particular value to NWP models, wave observations will be used by wave modellers, while visibility, cloud and weather at sea will be of greatest interest to the marine forecaster. The relative weight given to each type of observation should take into account the availability of data from other sources, including from satellites. Estimated relative values will have to

be provided by the user and weighted according to the relative importance of the group of users. The main user areas identified in section 2 will be given the following weights to reflect their relative importance to the business processes of the Met Office:

Atmospheric NWP	0.45
Ocean models	0.05
Forecasting	0.20
Climate	0.15
Consultancy	0.15

The relatively low weight given to ocean models (wave and FOAM) reflects the fact that at present, and in the foreseeable future, surface observations play a small part in the determination of the initial state: they are however very important for validation, particularly in the case of the wave model.

The following matrix links the relative importance to each user area of the observed elements again using weights reviewed and modified by the user areas (see Annex 2 for detailed comments). The current generation of NWP models only uses pressure, SST and wind over the oceans. The weights given reflect future requirements for the other elements.

	NWP	Ocean	Forecasting	Climate	Consultancy
<b>Pressure &amp; tendency</b>	55	0	15	20	5
<b>Air temperature</b>	5	0	10	20	10
<b>Sea temperature</b>	15	20	5	30	20
<b>Wind</b>	15	40	30	15	25
<b>Humidity</b>	5	0	10	15	5
<b>Waves</b>	0	40	15	0	25
<b>Visibility</b>	2.5	0	10	0	5
<b>Cloud &amp; weather</b>	2.5	0	5	0	5

The element value of an observing system is the weighted sum across all user areas of the values assigned to each of the elements observed; a ship report containing all the elements listed above will be assigned a value of 100 while a drifting buoy report of just pressure and sea temperature would be assigned a value of 48 ( $=0.45(55+15) + 0.05(0+20) + 0.2(15+5) + 0.15(20+30) + 0.15(5+20)$ ).

### **Accuracy**

Clearly elements are only of full value if they are regularly reported to an accuracy required by the user. Wave height, period and direction estimated by an observer on a voluntary ship might only be considered of much less value than data from wave sensors on a fixed buoy. For the purposes of this exercise all voluntary observations (VOF and North Sea platforms and Rigs) will be assigned a weight of 0.8 to reflect their lower reliability. This reduces the value index of the observation from the voluntary ship in the example above from 100 to 80.

### **Area**

The relative importance of observations depends greatly on the area from which they are reported and the use to which they are put. Forecasting for the oil and gas industry will attach high importance to observations from the North Sea, PMS forecasting to inshore waters, NWP will obtain great use from observations in the Atlantic, while observations from any data sparse ocean area will represent a valuable UK contribution to WWW and the international community. The following weights are suggested as a representative average across all user areas:

UK waters	1.0
Atlantic	0.5
Other	0.3

Clearly the relative importance of observations in different locations, particularly within the vicinity of the UK, could be refined further with user consultation. The value of 0.3 assigned to observations in distant oceans reflects, in particular, requirements of (1) climate, (2) the Met Office's contribution to global observing, and (3) business expansion into global markets. Following the example given in above, the report from the ship observing a full set of elements from the Pacific would be given a value of 24 (80 x 0.3) while a drifting buoy report in the Atlantic containing pressure and sea temperature would also have value 24 (48 x 0.5). At this stage the importance of filling data gaps should not be part of the assignment of values since data density enters the next step of the process.

### **Density**

A critical issue in the assignment of values to observations is the gap they fill in the network and to some degree the representativeness of the observation within the surrounding data void. Where the observation density varies from day to day, because drifting buoys or moving ships come and go from within the local area, it will have to be calculated as an average value over time. The following density weighting function is proposed:

$$\text{weight} = 1.0 / (\text{no. of obs within 200km})$$

In the most data sparse areas the weighting function will not be given a value greater than 1.0. Under this definition, the fixed buoys to the west of the UK, most drifting buoys and voluntary ships in the open ocean will have a weight at or close to 1.0, those in the relatively data rich parts of the North Sea will have a weight between 0.2 and 0.5, while over the UK land area, where the station separation is about 50km, the weight takes a value of less than 0.1. Continuing the example above, the observations from the voluntary ship and the drifting buoy will both have values of 22 after taking the observation density into consideration, the weight being close to unity (0.9) because both are from data sparse areas.

### **Frequency**

The frequency of observations from the observing systems is another important factor to take into consideration. It is fairly intuitive to feel that an observation every 6 hours from an ocean station is 4 times more valuable than one every day, but at higher frequencies the relationship ceases to be linear. Put the other way round, there is increasing redundancy in the information contained in observations as their frequency increases. The following relative weights have been used here:

Daily	1.0
6 hourly	1.0
3 hourly	0.8
Hourly	0.3

Completing the original example, the observation from the ship in the Pacific has value 22 (assuming 6-hourly) while that from the drifting buoy has weight 6.4 (assuming hourly reporting). The total value per observation evaluated by this method may be simply converted into a VFM index as follows:

$$\text{VFM} = \text{Value per ob} \times \text{Number of obs} / \text{Total cost}$$

Applying this method to all marine observing systems gives VFM indices contained in the final column of the table below:

System	Area	Elements	Weights and total value V per ob						Obs '000	Cos t £K	VFM
			El	Acc	Area	Den	Freq	V			
Open ocean moored buoys	Approx 200km offshore	pp,ddff,Ta,Td,Ts, wave	93	1.0	1.0	1.0	0.3	28	114	1315	2.4
Island systems &	Inshore waters	pp,ddff,Ta,Td,Ts*	85	1.0	1.0	0.3	0.3	7.7	70	360	1.5

OSDW1, Final Report

light vessels		wave*										
Platforms/Rigs	North Sea	pp,ddff,Ta,Td,VV*, C&W*,wave*	80	0.8	1.0	0.2	0.4	5.1	130	110	6.1	
Drifting buoys	N Atlantic	pp,Ts	48	1.0	0.5	0.9	0.3	6.4	219	170	8.3	
Voluntary ships	UK area	pp,ddff,Ta,Td,Ts, VV,C&W,wave	100	0.8	1.0	0.5	1.0	40	8	69	4.6	
Voluntary ships	N Atlantic	pp,ddff,Ta,Td,Ts, VV,C&W,wave	100	0.8	0.5	0.9	1.0	36	17	148	4.1	
Voluntary ships	World-wide	pp,ddff,Ta,Td,Ts, VV,C&W,wave	100	0.8	0.3	0.9	1.0	22	63	548	2.5	

\* element weight reduced to reflect variable observing practice

4. Where next?

The object of the exercise is to provide greater objectivity to the setting of observing strategy and the managing of marine networks. It is proposed that the VFM index described here informs all decision making processes that concern marine observations. However, it should only be one of a number of factors that need to be considered; there are a great many other requirements and constraints, not quantifiable by this scheme, which will always have to be given an appropriate weight. Clearly review and acceptance of the index by users is essential, not only initially but each time that requirements change.

**ANNEX 1 OF ANNEX V****Annual costs in £K for operating marine observing systems***Deep ocean moored buoys*

Ship hire	550		
Equipment	210		
Servicing	25		
Comms	45		
Staff costs	320	Total	1150

*Inshore moored buoys, islands, light vessels*

Transport	40		
Equipment	100		
Servicing	15		
Comms	40		
Staff costs	300	Total	495

*Platforms and rigs*

Data collection	55		
Staff costs	55	Total	110

*Drifting buoys*

Buoy (each)	2		
Comms (each)	3.4		
Staff costs	35	Total	170 (assuming 25 buoys)

*Voluntary Observing Fleet*

Equipment	70		
Publications	90		
Comms	85		
Staff costs	520	Total	765

**ANNEX 2 OF ANNEX V****Weightings to surface marine observations –  
A NWP perspective compiled by Richard Dumelow, 5 Sept 2003**

Below is a table of containing surface marine elements and their estimated importance to NWP. Since the requirements for the atmosphere and wave models are markedly different, separate columns have been provided for the two models. Some elements, such as air temperature, are not currently used but may be in the future as assimilation and modelling techniques develop. Hence an estimate has been given of the future importance of each element.

Element	Estimated weight			
	Global and regional atmosphere models		Wave model and FOAM	
	Current	Future	Current	Future
Pressure and tendency	60	55	0	0
Air temperature	0	5	0	0
Sea temperature	20	15	20	20
Wind	20	15	40	40
Humidity	0	5	0	0
Waves	0	0	40	40
Visibility	0	2.5	0	0
Cloud & weather	0	2.5	0	0

**Notes**Pressure and tendency

Direct measurements of surface pressure are essential for NWP forecasts, according to recent Observing System Experiments carried out by the Met Office and ECMWF. Results from the ECMWF OSE suggest that surface pressure measurements are much more important than wind. (*Richard Dumelow*)

Surface pressure obs over sea (from buoys and ships) have a (marginally) larger impact than surface wind obs (from ships, buoys, SSM/I and Quikscat) in the N.Hem. However, in the presence of surface wind data, a limited number of accurate surface pressure obs is sufficient to achieve most of the forecast impact of the surface marine obs. (*John Eyre quoting ECMWF*)

The following statement is generally accepted: *pressure observations from surface based systems are particularly valuable because there is as yet no means of observing pressure remotely.*

Air temperature

Air temperature from marine observations is currently not used in either the global or limited area models but its future use cannot be discounted. (*Bruce Macpherson*)

Sea temperature

There is evidence that an accurate SST analysis is important to producing good forecasts. During one of the early trials of 3DVAR it was noticed that the NWP index was gradually getting worse compared to the operational (then AC) scheme. This affect was traced to the fact that the SST was not being reconfigured daily. Although a formal trial on the benefit of an SST analysis has never been done, this evidence is a good indicator of benefit.

Although satellite data are an important component of the SST analysis, they cannot be used effectively without the use of direct observations. In-situ measurements (of bulk SST) are required to benchmark satellite skin SST measurements and without this calibration the quality of the satellite SST data could not be guaranteed. Also, it is possible for the receipt of SST data from satellites to be interrupted due to problems with the satellite itself or the transmission of the data. Without an in-situ

network as 'back-up' to the satellites, the SST analysis is likely to drift. (*Clive Jones*)

Humidity

Humidity measurements are currently not used by models but may be in the future. (*Bruce Macpherson*)

Waves

Although wave and surface wind data are not assimilated, they are essential for validation of the wave model (and for validation of the NWP winds). This validation is in turn essential for both public sector wave modelling business, and also for commerce and enterprise business in providing a benchmark of model performance. For wave model use, wave and surface wind data should be given similar weight. (*Martin Holt*)

Visibility

Visibility measurements are currently not used by models but may be in the future. (*Bruce Macpherson*)

Cloud and weather

Cloud and weather measurements are currently not used by models but may be in the future. (*Bruce Macpherson*)

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## CLASSES OF CRYONET OBSERVING SITES

To meet different user-needs and because of the spatially distributed nature of different components of the cryosphere the CryoNet network of *in situ* observations is structured into three different classes of observational sites.

- **Integrated sites:** CryoNet station which monitors the physical and chemical properties of all components (GCW focal areas) of the local cryosphere in its full complexity and at high quality standards as well as the interaction with local/regional atmosphere. It has established linkages to satellite observations and to other disciplines such as hydrology, oceanography, ecology, etc.). In many cases the stations are supported by more than one research agency, have a strong scientific supporting programme and provide facilities for intensive campaigns. Such “super-sites” are stations/observatories with on-site personal for maintaining the monitoring and scientific experiments. An integrated site is a “high-level seal” of WMO-GCW for cryospheric observations similar to a GAW global station.
- **Reference sites:** CryoNet station monitoring at least 1 component of the cryosphere at high quality over a relatively long time period and with a long-term financial commitment; the primary site type for existing networks such as WGMS for glaciers and GTN-P for permafrost.
- **Baseline sites:** CryoNet station monitoring at least 1 component of the cryosphere at the level of accepted GCW standards.

Baseline Sites	Reference Sites	Integrated Sites
<ul style="list-style-type: none"> <li>• Single sphere</li> <li>• Standardized</li> </ul>	<ul style="list-style-type: none"> <li>• Single sphere</li> <li>• Long-term</li> <li>• Cal/Val</li> <li>• Standardized</li> <li>• Long-term financial commitment</li> </ul>	<ul style="list-style-type: none"> <li>• Multi sphere</li> <li>• Cal/Val</li> <li>• Strong research focus</li> <li>• Training</li> <li>• Onsite staff</li> <li>• Standardized</li> <li>• Long-term financial commitment</li> </ul>

Figure 1: Initial thinking on a tiered structure for CryoNet. Note that this structure is being refined as CryoNet is developed.

**WRITING GROUP 1 OUTCOME:  
OSND PRINCIPLES DERIVED FROM RELEVANT OSND ACTIVITIES, INCLUDING IMPACT  
STUDIES**

Writing Group 1 identified and proposed the following OSND principles:

1. Maximize data coverage through avoiding redundant observations of one parameter in one place, when measurements of these two technologies are equivalent;
2. Adopt tiered structure with a relatively small number of high quality reference stations, for bias correction and quality assurance;  
[rain-gauges for weather-radar composites; the idea of GRUAN]
3. For regional/national networks consider the existing stations with data available in neighboring countries/regions.
4. Size the network in order to capture severe and high impact events
5. Base network design decisions on results from scientific studies which assess the impact and importance of observations for various applications areas
6. Maximize the number of good quality observations through choosing the most cost-effective technology.
7. Network design may require investment outside member's territories (benefits?)
8. Adopt representativeness and effectiveness of observations as primary design drives, over spatial and temporal homogeneity.
9. High priority for additional observations should be focused on data-poor regions, poorly observed parameters, sensitive regions, and key measurements with inadequate temporal resolution.
10. Consider the needs of all WMO application areas, when designing national, regional and global networks.
11. The conversion of research observing systems or new observing technologies to long-term operations requires careful coordination between data providers and users.

**WRITING GROUP 2 OUTCOME:  
OVERARCHING OSDN DESIGN PRINCIPLES IN KEEPING WITH GCOS PRIORITIES**

Networks should be designed:

1. Within a tiered structure supporting collection of observations at multiple spatial scales: global, regional, and local. The tiered structure should include at its core reference climate stations to serve as benchmarks from which the quality and homogeneity of higher density regional to local networks of stations can be assured. Reference stations also serve for satellite validation/verification. National, university, and other networks should be leveraged to capture the finest local scale conditions as possible.
2. To collect observations at as fine a temporal scale as possible to meet the broadest community of requirements: Ideally 5-minute observations, hourly, daily, and monthly.
3. Incorporate multi-purpose design to the greatest extent possible through partnerships that make possible the integration of instrumentation and observations that extend beyond the meteorological and climate communities (e.g., air quality, ecology, agriculture, transportation, energy).
4. Use redundant data dissemination pathways that ensure rapid data delivery while also providing data dissemination pathways for less developed infrastructures - to ensure as close to 100% data collection as feasible. (e.g., GTS, point to point ftp, web services, web portals).
  - a. This can include satellite uplink, internet transfer, and web portals for hand entry of manually observed ECVs. In rare cases hard copy observing forms may be used if all other possibilities have been exhausted.
  - b. Capitalize on newly evolving mechanisms such as Daily CLIMAT observations, full use of elements in Synoptic reports, wider use of the data dissemination capabilities possible through use of BUFR formats.
5. Include mechanisms for collecting, archiving, and providing access to station metadata.
  - a. This should include details and history of local conditions, instruments, observing procedures, data processing algorithms and other factors pertinent to interpreting data. Should be given the same attention as the collection of the climate observations.
6. Include mechanisms for long-term preservation of climate data and metadata through permanent storage in a certified Data Center supported by signed agreements between the center and the network/data provider.
  - a. A fully documented dataset should include full data provenance information which is necessary for ensuring that users today and decades in the future will have a full understanding of the data. Included in the documentation should be all processes and pathways involved from the point of observation to its final state in archive including how and by whom it was collected, any quality control corrections and homogeneity adjustments applied, and information on data formats. An essential part of the archive process is ensuring future access is possible even as technologies continue to evolve.
7. Include established procedures for routine maintenance (e.g., annual or semi-annual) as well as unscheduled maintenance including instrument calibrations. This also should include periodic review of the station environment to document environmental changes.
8. Include mechanisms to support less developed nations in defining network configurations, installation, conducting maintenance, establishing data dissemination mechanisms, archive and access protocols, and acquiring spare parts and a consistent supply of parts
9. Employ redundant energy sources to provide continuous and reliable power (e.g., AC, solar, wind, other non-renewable such as methanol generators)
10. Networks should be established in line with the GCOS climate monitoring principles that include siting requirements, ensuring homogeneity, data continuity, geographical representativeness of observations, length and quality of the historical time series, and the available parameters.
  - a. The site should be well exposed and away from obstacles and obstructions that could influence the observation including instrument performance. Siting stations in areas near buildings or other man-made structures such as roadways should be avoided. It

also is important to avoid sites on steep slopes, in hollows, or other topographical influences such as ridges that would be representative of local features only

- b. A well-planned period of overlap (minimum of 1 year, optimum 2 years) between existing station and new location or new instrumentation can help assure the homogeneity of the record.
- c. Networks should be designed to ensure data continuity with existing network stations of high quality and lengthy historical record.

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**WRITING GROUP 2 OUTCOME:  
OSND PRINCIPLES DERIVED FROM THE GCOS CLIMATE MONITORING PRINCIPLES<sup>36</sup>**

The table below provides the GCOS Climate Monitoring Principles in its third column. The fourth column explains how such principles should or could be derived into OSND principles.

<b>No.</b>	<b>Status with regard to OSND principles</b>	<b>GCOS Monitoring Principle</b>	<b>IPET-OSDE Comment</b>
1	OK	The impact of new systems or changes to existing systems should be assessed prior to implementation.	
2	OK	A suitable period of overlap for new and old observing systems is required.	
3	Revise	The details and history of local conditions, instruments, operating procedures, data processing algorithms and other factors pertinent to interpreting data (i.e., metadata) should be documented and treated with the same care as the data themselves.	To be revised

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36 Effective monitoring systems for climate should adhere to these principles\* ([pdf](#)): (\* The ten basic principles (in paraphrased form) were adopted by the Conference of the Parties (COP) to the United Nations Framework Convention on Climate Change (UNFCCC) through decision 5/CP.5 at COP-5 in November 1999. This complete set of principles was adopted by the Congress of the World Meteorological Organization (WMO) through Resolution 9 (Cg-XIV) in May 2003; agreed by the Committee on Earth Observation Satellites (CEOS) at its 17th Plenary in November 2003; and adopted by COP through decision 11/CP.9 at COP-9 in December 2003.)

OSDW1, Final Report

4	OK	The quality and homogeneity of data should be regularly assessed as a part of routine operations.	
5	Revise	Consideration of the needs for environmental and climate-monitoring products and assessments, such as IPCC assessments, should be integrated into national, regional and global observing priorities.	
6	OK and add	Operation of historically-uninterrupted stations and observing systems should be maintained.	Refers to climate only, and needs to be clarified in the framework of the general OSND, which is addressing 12 Application Areas
7	Revise	High priority for additional observations should be focused on data-poor regions, poorly observed parameters, regions sensitive to change, and key measurements with inadequate temporal resolution.	Generalize as it applies to other application areas
8	Revise	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.	Generalize as it applies to other application areas
9	Revise	The conversion of research observing systems to long-term operations in a carefully-planned manner should be promoted.	To be turned into a principle. To observe things that are not currently well observed while useful, and turn them into operational or long term sustained systems; e.g. wind profilers
10	Revise	Data management systems that facilitate access, use and interpretation of data and products should be included as essential elements of climate monitoring systems.  Furthermore, operators of satellite systems for monitoring climate need to:	Generalize as it applies to other application areas (remove ref. to climate)

OSDW1, Final Report

10(a)	Revise	(a) Take steps to make radiance calibration, calibration-monitoring and satellite-to-satellite cross-calibration of the full operational constellation a part of the operational satellite system; and	Generalize so that it is relevant to all instruments (space-based and surface-based)
10(b)	Revise	(b) Take steps to sample the Earth system in such a way that climate-relevant (diurnal, seasonal, and long-term inter-annual) changes can be resolved. Thus satellite systems for climate monitoring should adhere to the following specific principles:	Generalize
11	Duplicate	Constant sampling within the diurnal cycle (minimizing the effects of orbital decay and orbit drift) should be maintained.	This item is covered by other items like 10(b) once generalized
12	Duplicate	A suitable period of overlap for new and old satellite systems should be ensured for a period adequate to determine inter-satellite biases and maintain the homogeneity and consistency of time-series observations.	Duplicate of item (2)
13	Revise	Continuity of satellite measurements (i.e. elimination of gaps in the long-term record) through appropriate launch and orbital strategies should be ensured.	Generalize to surface- and space- based observing systems  Assuring continuity of data record is important
14	Revise	Rigorous pre-launch instrument characterization and calibration, including radiance confirmation against an international radiance scale provided by a national metrology institute, should be ensured.	Generalize
15	Revise	On-board calibration adequate for climate system observations should be ensured and associated instrument characteristics monitored.	Generalize

OSDW1, Final Report

16		Operational production of priority climate products should be sustained and peer-reviewed new products should be introduced as appropriate.	Not relevant to OSND
17		Data systems needed to facilitate user access to climate products, metadata and raw data, including key data for delayed-mode analysis, should be established and maintained.	Not relevant to OSND
18	Dupl.	Use of functioning baseline instruments that meet the calibration and stability requirements stated above should be maintained for as long as possible, even when these exist on decommissioned satellites.	
19	Revise	Complementary in situ baseline observations for satellite measurements should be maintained through appropriate activities and cooperation.	Include how feedback mechanism between space-based and surface-based observing systems benefit each other
20		Random errors and time-dependent biases in satellite observations and derived products should be identified.	Not relevant to OSND

## WRITING GROUP 2 OUTCOME: OSND PRINCIPLES DERIVED FROM WEATHER RADAR NETWORK DESIGN ACTIVITIES

Note: specific comments are provided as footnotes for the text highlighted shaded below.

### Weather radar

Every partner runs, administrates and maintains, at an adequate quality level, weather radar(s) located in its own country, with the goal to reach and maintain full geographic coverage<sup>37</sup> or coverage that is feasible to meet its national and regional requirements. In some cases such feasibility can be expressed in terms of covering most of the country's population or economic production (e.g. 95 %), or similar criteria.

Members should strive to achieve network homogeneity and consistency. Radars and their networks should be configured and operated, where technically and/or economically possible, in such a way that the common need is satisfied<sup>38</sup>.

Each member should secure the availability of a telecommunications line for data exchange with other members. The bandwidth of this line should be great enough to support all exchange activities to and from that member without negatively impacting any other member. Minimum requirements for bandwidth are that all data must be exchanged within the given acquisition period, ie. the update cycle.

### More specific points

Universal Coordinated Time (UTC) should be used, and it is encouraged that NTP client/servers be used with the objective to achieve an accuracy of within one second.

Each member shall inform the others of its scan strategy, and changes to it, without delay<sup>39</sup>.

Data from each radar shall be exchanged with an update frequency not exceeding 15 minutes<sup>40</sup>.

Data in polar/spherical coordinates (azimuth and range) originating from each radar are the most desirable data for exchange. In some cases, it may be preferable for a partner to make available data on a scan-by-scan basis; in other cases polar volumes may be preferable.

Data exchange encompasses traditional radar moments (reflectivity, radial wind, spectral width) and parameters from polarimetric radars from those radars that measure them.

Weather radar data are exchanged according to WMO/OPAG-IOS/ET-SBO/TT-WRDE recommendations, or other WMO regulatory material in which these recommendations have been incorporated. Such recommendations address the combination of data model and file format, and also data exchange mechanisms.

Members are encouraged to exchange data with the highest possible data quality based on the radar's signal processing capabilities. Additional data processing (software-based, outside the signal processor) should be avoided prior to exchange. Data shall not be degraded in terms of spatial resolution or information content once they have emerged from the radar hardware and written to

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<sup>37</sup> Not good for global application. Other RM is more appropriately formulated.

<sup>38</sup> Massive generalization. Requires elaboration.

<sup>39</sup> This point is a dramatic departure from previous attempts at regulating data acquisition, ie. the ancient GORN/OPERA "rules".

<sup>40</sup> This is tricky. Globally, data acquisition is known to take place with 5, 6, 7.5, 10, and 15 minute update cycles, possibly others. How can minimum requirements on "common ground" be formulated?

digital file<sup>41</sup>.

Members are encouraged to endeavor to meet a high data availability performance target. (An example can be expressed as 96% per radar and month within 15 minutes of the data's nominal time.)

In case of absence of data from individual radars, information about such data outages from the originating member is greatly appreciated and should be offered without delay, along with an estimation of when data provision is expected to resume.

## Additional thoughts

1. Current data exchange functionality used in e.g. the GTS is based on largely outdated technology, both when it comes to security and to a lesser extent latency. Some of these issues were addressed at the workshop on WxR (April 2013). To what extent is IPET-OSDE able to accommodate new ideas on secure and fast data exchange functionality in concert with relevant WMO bodies? *Group 1 addresses this: "web portals" is a good generic term, consistent with WIS principles.*

2. New radar sites should be established with the requirement to ensure that there are sufficient precipitation gauges within the radar's coverage area to support residual bias correction as part of a QPE processing chain. Should these gauges not exist prior to the establishment of the radar site, then they should be included in the site design.

3. Similarly to point 2, there should be at least one radar in each country co-located (< XX km) with a radiosonde site, allowing reliable comparisons of wind profile information from each observing system. This contradicts Group 1's point 1: avoid co-location. Perhaps co-location can be "minimized", more aligned with Group 1's point 2 about the usefulness of reference sites.

4. General principles for establishing an "adequate" radar network that fulfills both national and regional requirements share those from other observing systems. There may be additional criteria that may be more specific to weather radar, such as

- If complete national coverage is not feasible, then coverage of e.g. 95% of the country's population may be a more reasonable objective. (or other criterion, see above)
- If radar-based QPE is a national requirement<sup>42</sup>, then radar density (spacing) should consider the precipitation climate, ie. Cold climates (shallow precip systems) will necessitate higher density (more radars) to mitigate the effects of overshooting.

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41 Very important to strive towards harmonized data quality prior to software-based data processing.

42 Should the WMO require QPE at the regional level, in order to provide the incentive for members to enable it?

**WRITING GROUP 2 OUTCOME:  
OSND PRINCIPLES PROPOSED BY THE CHAIR OF ICT-IOS**

The following OSND design principles are proposed:

1. Wherever possible, network design should be traceable to WMO requirements as captured in the RRR database on quantities such as temporal and spatial coverage/resolution, accuracy, precision and data latency.
2. While primarily driven by national needs and resources, decisions to establish specific networks should be made with a view toward addressing the needs expressed in the WMO (RRR) Statement of Guidance for the key target application area(s).
3. Where possible, networks designed to observe a specific geophysical quantity (e.g. atmospheric temperature) should address as many WMO application areas as possible with requirements for that quantity, in order to reduce the need to fund, develop and implement multiple networks with similar purposes.
4. Where possible, cost/benefit analysis should be driving the trade-offs made during the network design phase. This will inform not only choices regarding the physical nature of the network, but also the choice of which application areas it will primarily be supporting.  
*(Note: this assumes the existence or the development of a quantitative methodology to assess user benefits!)*
5. When implementing their global, regional or national observational networks, the operators are encouraged to make all of its data available to all WMO members, even where its performance exceeds the threshold requirements captured by the WMO Rolling Review of Requirements.

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**WRITING GROUP 2 OUTCOME:  
DRAFT OSND PRINCIPLES DERIVED FROM THE REVIEW OF EXISTING REGULATORY  
MATERIAL**

*(last updated 14/11/13 Stuart Goldstraw)*

Using the existing text within WMO No.544 as the source, a number of statements have been lifted and generalised to allow them to be considered as input to the observing system network design Principles discussed at OSDW-1

The statements identified cover the following subject areas:

Links between national, regional and global networks, see 2.1.1.2; Geographical spacing, see 2.1.2.3; Observing system consistency, see 2.1.2.3; National network design, see 2.1.4; Site selection, see 2.2.4; High temporal resolution, see 2.2.7; Site governance, see 6.1.2; Network compliance, see 2.3.2.8

The table includes, where possible the paragraph references used in the current version of WMO No.544.

<b>Original Text</b>	<b>Comments or revised text</b>
2.1.1.1 Corresponding to the three levels of requirements for observational data, three types of networks of observing stations — global, regional and national — shall be established.	Text not considered appropriate for a general design principle
2.1.1.2 The networks should be interdependent with selected stations of the national networks within a Region comprising the corresponding regional network, and with selected stations of the regional network forming the global network. Therefore, a station of the global network is part of a regional network and a national network.	Text could form part of a general design principle. Subject area is the links between national, regional and global networks.  Suggested revision to be included below:  Global surface based observing networks are made up of the sum of all national observing networks contributing to global networks.
2.1.1.3 The frequency and spacing of the observations should be adjusted to the physical scales of the meteorological phenomena to be described.	Text could form part of a general design principle but is repeated elsewhere and combined text is suggested at 2.3.2.8
2.1.2.1 A global synoptic network shall be established, based upon the Regional Basic Synoptic Networks (RBSNs).	Text not considered appropriate for a general design principle
2.1.2.2 The observing programme of the global synoptic network should provide meteorological data which have the necessary accuracy, spatial and temporal resolutions to describe the state of temporal and spatial changes in the meteorological phenomena and processes occurring on the large and planetary scales.	Text could form part of a general design principle but is repeated elsewhere and combined text is suggested at 2.3.2.8
2.1.2.3 The global synoptic network should be as homogeneous and as uniform as possible all over the globe, and the observations should be made at the main standard times of observation.	Text could form part of two general design principle, if generalise. Subject areas are geographical spacing and observing system consistency.  Suggested revision to be included below:  Global observing networks should be optimally spaced to ensure all phenomena are observed sufficiently to meet application area needs.  Where possible, technologies with known performance characteristics should be deployed in surface based observing networks to enable consistent levels of observational quality.
2.1.2.4 Members should implement the Global Climate Observing System (GCOS) Surface Network (GSN) — the	Text not considered appropriate for a general design principle

OSDW1, Final Report

global reference network of some 1 000 selected surface observing stations established to monitor daily global and large-scale climate variability.	
2.1.2.5 Members should implement the GCOS Upper-air Network (GUAN) — the global baseline network of about 150 selected upper-air stations established with relatively homogenous distribution to meet requirements of GCOS.	Text not considered appropriate for a general design principle
2.1.2.6 Members should also establish a network of Global Atmosphere Watch (GAW) stations designed to meet the need for monitoring, on a global and regional basis, the chemical composition and related characteristics of the atmosphere.	Text not considered appropriate for a general design principle
2.1.3.1 Regional networks shall be established in relation to the regional requirements. Note: Regional associations are responsible for the determination and coordination of the composition of these networks within the general framework established by the Commission for Basic Systems (CBS).	Text not considered appropriate for a general design principle
2.1.3.2 Regional Basic Synoptic Networks of both surface and upper-air stations and Regional Basic Climatological Networks (RBCNs) of climatological stations shall be established to meet the requirements laid down by the regional associations.	Text not considered appropriate for a general design principle
2.1.3.3 Together, the RBSNs shall form the main part of the global surface-based synoptic network.	Text not considered appropriate for a general design principle
2.1.3.4 Members shall implement the RBSNs.	Text not considered appropriate for a general design principle
2.1.3.5 The horizontal spacing of observing stations and the frequency of their reporting should be in accordance with the requirements laid down in Volume I, Part II, and Volume II of this Manual.	Text not considered appropriate for a general design principle
2.1.4 National networks shall be established by Members to satisfy their own requirements. When implementing these national networks, Members shall take into account the needs to complete the global and regional networks.	Text could form part of a general design principle. Subject area is national network design. It is suggested the current text is adequate.
2.2.1 The implementation and operation of each of the above elements should be as laid down by decisions of Congress, the Executive Council, the technical commissions and regional associations concerned.	Text not considered appropriate for a general design principle
2.2.2 In implementing the Global Observing System (GOS) surface-based subsystem, Members should ensure that the observing system meets the requirements placed on the subsystem.	Text not considered appropriate for a general design principle
2.2.3 In implementing the surface-based sub-system, Members should strive to meet the provisions indicated in 2.2.1 above as closely as possible, in particular as regards the main elements of the surface-based subsystem.	Text not considered appropriate for a general design principle
2.2.4 Each station should be located at a site that permits correct exposure of the instruments and satisfactory non-instrumental observations.	Text could form part of a general design principle. Subject area is site selection.  Suggested revision to be included below:  Stations forming part of any surface based observing network should enable the necessary parameters to be observed without compromise.
2.2.5 In general, observing stations shall be spaced at an interval and with observations taken frequently enough to permit an accurate description of the atmosphere for users of the observations for the purpose intended.	Text could form part of a general design principle but is repeated elsewhere and combined text is suggested at 2.3.2.8
2.2.6 If in certain desert and other sparsely populated areas it is not possible to establish networks with the recommended densities, networks with densities as near as possible to those recommended should be established. Special efforts should be made to establish an adequate network in such an area when it borders a populated area or is traversed by a regularly used air route.	Text could form part of a general design principle. Subject area is partial network compliance.  Suggested revision to be included below:  Establish observing capabilities in the transition zone between sparsely populated and populated areas, the extent of this transition zone being

	defined by the phenomenon that places the populous at greatest risk.
2.2.7 Asynoptic observations should be taken when necessary to supplement observations from the synoptic networks and in a manner which increases their spatial or temporal frequency.	Text could form part of a general design principle but is repeated elsewhere and combined text is suggested at 2.3.2.8.
2.2.8 Observations should be taken in areas where special phenomena are occurring or expected to develop. As many meteorological elements of standard observations as possible should be reported. Information should be communicated in real time.	Text not considered appropriate for a general design principle
2.2.9 Members shall ensure that a record of all surface and upper-air observations is made and preserved.	Text not considered appropriate for a general design principle
6.1.2 Criteria for inclusion of stations in the Regional Basic Synoptic Network	Text could form part of a general design principle. Subject area is site governance.  Suggested revision to be included below:  The RAs are responsible for the establishment and management of the criteria used to select stations as part of the regional and global networks.
2.3.2.8 Surface land stations, including those in the RBSN, should be spaced at intervals not exceeding the minimum horizontal resolution required by applications areas supported by the network and as described in the Rolling Review of Requirements Process. During the first decade of the twenty-first century, the interval, in general, should not exceed 250 km (or 300 km in sparsely populated areas).	Text could form part of a general design principle. Subject area is network compliance.  Suggested revision to be included below:  Surface based observing networks should be implemented to meet the requirements defined in the OSCAR database as defined using the Rolling Review of Requirements Process.
2.4.5 Upper-air stations making observation of pressure, temperature, humidity and wind should be spaced at intervals not exceeding the minimum horizontal resolution required by applications areas supported by the network and as described in the Rolling Review of Requirements Process. During the first decade of the twenty-first century, the interval, in general, should not exceed 250 km or 1 000 km in sparsely populated and ocean areas.	Text could form part of a general design principle but is repeated elsewhere and combined text is suggested at 2.3.2.8.

## PROPOSED ROADMAP FOR THE DEVELOPMENT OF OSND PRINCIPLES AND GUIDANCE

<b>Time</b>	<b>Milestone</b>	<b>Tasks</b>
Nov. 2013	OSDW1 TT-WRM	Produce input to OSND principles Provide input on OSND principles and guidance to WIGOS RM
Dec.		Draft OSND principles (J. Eyre)
Jan. 2014		Review by OSDW1 participants New draft of OSND principles produced based on feedback (J. Eyre by 27 Jan.)
Feb.	ICG-WIGOS	Review draft OSND principles Propose framework into which OSND principles & guidance will fit
Mar/Apr.	IPET-OSDE-1	Review and revise OSND principles Draft plan for preparing OSND guidance, and tasks for Team members for drafting materials
Apr.	ICT-IOS-8	Review/revise and approve OSND principles Review/revise and approve plan for preparing OSND guidance
May		
Jun.	EC	
Jul.		
Aug.		
Sep.	CBS Ext. (2014)	Consideration by CBS of (i) the OSND principles, and (ii) the roadmap for producing the OSND guidance, as part of WIGOS materials for approval
Oct.		
Nov.		Review of Cg-17 WIGOS RM by Members
Dec.		Review of Cg-17 WIGOS RM by Members
Jan. 2015		Review of Cg-17 WIGOS RM by Members
Feb.	ICG-WIGOS OSDW2	New experts invited to address all AAs
Mar.		
Apr.		
May.	Cg-17	Approve WIGOS Regulatory Material
Jun.		
Jul.	IPET-OSDE-2	
Aug.		
Sep.		
Oct.		
Nov.	ET-SBO	
Dec.		
Jan. 2016	ICG-WIGOS	Draft version of OSND guidance available and reviewed Draft OSND guidance submitted to EC (fast-track)
Feb.		
Mar.		
Apr.	IPET-OSDE-3	Draft version of OSND guidance reviewed by IPET-OSDE (slow track)
May	ICT-IOS-9	Final draft version of OSND guidance available (slow track)
Jun	EC	OSND guidance approved by EC (fast track)
Jul.		
Aug.		
Sep.		
Oct.	CBS	OSND Principles and Guidance endorsed by CBS (slow track)

OSDW1, Final Report

Nov.		
Dec.		
Jan. 2017		Draft OSND guidance submitted to EC (slow-track)
Feb.		
Mar.		
Apr.		
May	EC	OSND Guidance approved by EC (slow track)

**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
RBN	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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