WORLD METEOROLOGICAL ORGANIZATION

COMMISSION FOR BASIC SYSTEMS
OPEN PROGRAMMME AREA GROUP ON
INTEGRATED OBSERVING SYSTEMS

INTER PROGRAMME EXPERT TEAM ON
OBSERVING SYSTEM DESIGN AND EVOLUTION
(IPET-OSDE)
First Session

GENEVA, SWITZERLAND, 31 MARCH – 3 APRIL 2014

CBS/OPAG-IOS/IPET-OSDE1 / Doc. 10.1
(25.02.2014)

ITEM: 10.1

Original: ENGLISH

OBSERVING SYSTEM NETWORK DESIGN (OSND) - PRINCIPLES AND GUIDANCE

OUTCOME OF THE OSDW1 WORKSHOP (GENEVA, NOV. 2013)

(Submitted by John Eyre (United Kingdom))

SUMMARY AND PURPOSE OF DOCUMENT

The document provides a summary of the outcome of the ad hoc workshop on Observing System Design and its activities to prepare for the development of WIGOS Principles and Guidance for Observing System Network Design (OSND). It describes work done subsequent to the workshop to develop draft OSND Principles and some associated guidance. It also presents a roadmap for the further development of these Principles, including the role of IPET-OSDE in this work.

ACTION PROPOSED

The Meeting is invited to note the information contained in this document when discussing how it organises its work and formulates its recommendations.

Appendix: **A.** Draft version of Observing System Network Design Principles and associated guidance material.

Appendix: **B.** Proposed roadmap for the development of OSND Principles and associated guidance material.

DISCUSSION

1. An ad hoc workshop on Observing System Design was held, under the auspices of the CBS OPAG-IOS Inter-Programme Expert Team on the Observing System Design and Evolution (IPET-OSDE), 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). A full report on the workshop is available at: http://www.wmo.int/pages/prog/www/CBS-Reports/IOS-index.html.

2. 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 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.

3. 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).

4. 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 EUMETNET), including impact studies relevant to OSND. It developed a substantial body of material from which OSND principles could be extracted.

5. The workshop agreed a roadmap for the development of guidance for OSND (Appendix B), including the proposed role of this workshop's participants and of IPET-OSDE, on the understanding that the first session of the IPET-OSDE would review and revise the OSND principles, and draft a more complete plan for preparing OSND guidance, in which IPET-OSDE members would be tasked to draft specific materials in close coordination with their respective teams and groups. The IPET-OSDE recommendations would also be submitted to the eight session of CBS OPAG on Integrated Observing Systems' Implementation and Coordination Team (ICT-IOS) in preparation for CBS Extraordinary Session in late 2014.

6. Following the workshop, work on developing OSND Principles and associated guidance material has proceeded according to the plan set out in Appendix B:

6.1 A report on the outcome of the workshop was provided to the third session of the Inter-Commission Coordination Group on WIGOS (ICG-WIGOS) Task Team on Regulatory Material (Geneva, 25-29 November 2013),

6.2 A set of “OSND Principles” was extracted by the workshop Chair from the material generated at the workshop, by separating out “design principles" from guidance on how such principles should be interpreted or executed. Useful material was also identified which, although not relevant to network design, may be relevant to observing system design in general.

6.3 The draft OSND Principles were sent to workshop participants for comment, and they were revised following comments received.

6.4 A version of the draft OSND Principles was prepared for the third session of the ICG-WIGOS (Geneva, 10-14 February 2014). ICG-WIGOS noted the progress on the draft OSND Principles.

6.5 The latest version of the draft OSND Principles appears at Appendix A of this document. It is organised in 3 parts:

A. Proposed (12) Observing System Network Design (OSDN) Principles.

B. The OSND Principles and, for each Principle, points that amplify or explain them, or that indicate how appropriate guidance material could be developed for each.

C. Additional material related to guidance on observing system design, but not network design.

Parts B and C are intentionally incomplete - it is intended as a task for IPET-OSDE-1 and for future meetings and other groups to expand these and to develop them further. This draft also contains some comments from workshop participants that have yet to be resolved, and these are also referred to IPET-OSDE-1 for consideration.

APPENDIX A

DRAFT VERSION OF OBSERVING SYSTEM NETWORK DESIGN PRINCIPLES AND ASSOCIATED GUIDANCE MATERIAL

Version dated 22 January 2014

A. Observing System Network Design (OSND) Principles[1]

1. SERVING MANY APPLICATION AREAS
Observing networks should be designed to meet the observational needs of many application areas within WMO and WMO co-sponsored programmes.

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

3. MEETING NATIONAL, REGIONAL AND GLOBAL REQUIREMENTS
Observing networks designed to meet national needs should also take into account the needs of the WMO community for applications for which requirements are regional or global.

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

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

6. DESIGNING COST-EFFECTIVE NETWORKS
Observing networks should be designed to make the most cost-effective use of available resources.

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

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1 Editorial note from S. Klink 2/24/2014: I'm fine with the proposed set of 12 principles, but I would like to suggest a few changes to the order of the principles, because from my perspective a few of the principles can be grouped together. My proposal: 1, 2, 3, 7, 6, 10, (principles up to here relate closely to the specifications/data characteristics in the RRR) and then: 9, 8, 4, 5, 11, 12.

8. DESIGNING RELIABLE, STABLE AND SUSTAINABLE NETWORKS
Observing networks should be designed to be reliable, stable and sustainable.

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

10. ACHIEVING HOMOGENEITY AND CONSISTENCY IN OBSERVATIONAL DATA
Observing networks should be designed to deliver observational data of the level of homogeneity and consistency by intended applications.

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

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

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

1. SERVING MANY APPLICATION AREAS

Observing networks should be designed to meet the observational needs of many application areas[2] within WMO and WMO co-sponsored programmes.

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

2. MEETING USER REQUIREMENTS

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

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

3. MEETING NATIONAL, REGIONAL AND GLOBAL REQUIREMENTS

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

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

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

4. MAKING OBSERVATIONAL DATA AVAILABLE

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

- Many gaps in user requirements for observations can be filled by disseminating observations that are currently made but not collected centrally in a NMHS, or made but not disseminated internationally, or made but not disseminated in a timely manner.
- Mechanisms should be established to minimise loss of observational data and to promote recovery of old data for climate applications.
- Multiple and overlapping methods of dissemination should be used whenever possible to ensure continuity of data collection.
- … [others?]

5. PROVIDING INFORMATION SO THAT THE OBSERVATIONS CAN BE UNDERSTOOD

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

- Appropriate metadata are essential to ensure quality, traceability and homogeneity of observations [link to appropriate WIGOS guidance]
- Metadata collection, dissemination, archive and access systems should be designed with as much attention as those for observational data.
- Station metadata should be created at the time of network installation and updated at a minimum annually to include information such as station location, the surrounding environment, instrumentation type and calibration metrics, observing practices, and maintenance. Whenever possible photographic images of the station and environment should be made and archived annually.
- Metadata practices should adhere to international standards in use by the meteorological[3] community.
- … [others?]

6. DESIGNING COST-EFFECTIVE NETWORKS

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

3 Editorial noted from J. Eyre 2/24/2014: Should we generalize this?

- Observing networks should be designed using the most appropriate and cost-effective technologies or combinations of technology. [Develop guidance on how to do this.]
- Developments to observing systems should normally build on existing sub-systems, capitalising on both existing and new technology, and integrating new systems into existing WIGOS capabilities.
- Designs should be sufficiently flexible to allow for expansion without the need for complete network re-design. As requirements change the design of the observing system network may need to change, and its configuration should be sufficiently flexible to allow for incremental expansion, or contraction, without the need for entire network re-design.
- Partnerships with other organizations responsible for observations should be exploited in order to build on potential synergies, share costs and provide more cost-effective systems.
- Observing network design should, where possible, be based on the results from scientific studies which assess the impact, importance and cost-effectiveness[4] of the observations for the applications to which they contribute.
- Tools are required to aid design of cost-effective composite observing systems. They should include assessment of actual or anticipated impact of observations. A variety of such tools are available and widely used in some application areas (e.g. GNWP)[5].
- Tools are required to assess the cost-effectiveness of observations for each application and the combined value across all application. This will require consultation between observing system designers and application owners/experts.
- Spaced-based and surface-based observing networks should be designed and operated in such a way that they are complementary, with appropriate activities and cooperation between the communities responsible for these networks, to ensure that observations from each system are used to enhance the impact and effectiveness of the other.
- [Use of functioning baseline instruments that meet calibration and stability requirements should be maintained for as long as possible, even when these exist on decommissioned observing systems – originally written for satellite instruments, and should be generalized.]
- Observing networks should be designed taking into account measurements available from other networks in the vicinity, e.g. measurements using the same technology in neighbouring countries, or measurements from networks using different technologies.
- To optimize benefits within a Member’s own territory, an effective observing network may require investment outside the Member’s territory.
- Mechanisms should be developed for sharing best practice and lessons learnt on observing network design.
- … [others?]

7. DESIGNING APPROPRIATELY SPACED NETWORKS

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

4 Editorial note from E. Andersson 2/24/2014: could we mention ‘value’ of observations, too?
5 Editorial note from J. Eyre 3/24/2014: “…are required …” “…are available …”. There is an apparent contradiction here.

- For some applications the representativeness and effectiveness of observations may be more important design drivers than spatial and temporal homogeneity.
- When considering priorities for additional observations, attention should be given to: observation-poor regions and domains, poorly observed variables, and regions sensitive to change.
- Observing capabilities should be established/maintained in the transition zone between sparsely populated and populated areas, with the extent of this transition zone being defined by the phenomenon that places populations at greatest risk.
- For the purpose of climate monitoring, special attention should be given to maintaining stations with long, historically-uninterrupted records
- Network design may need to take advantage of university and private-sector networks in order to provide adequate spatial coverage not possible from national and other networks alone.
- … [others?]

8. DESIGNING RELIABLE, STABLE AND SUSTAINABLE NETWORKS

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

- Observing systems and their telecoms should be designed to be robust against exposure to severe weather.
- A combination of AC power and renewable energy sources (e.g., solar, wind) should be used whenever possible better to ensure continued operation in all weather conditions.
- On-site data storage should be designed to augment real-time telecommunication and to ensure original observations are preserved on site for a minimum of 6 months to 1 year.
- Station sites should be selected in areas least likely to be impacted by factors such as new construction that will force station relocations.
- [Expand on other issues of reliability, stability and sustainability – with links to guidance material][6].
- … [others?]

9. DESIGNING THROUGH A TIERED APPROACH

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

- In addition to improving the quality and utility of observations, this approach to design will also lead to improvements in the understanding of the quality of the observations.
- The tiered approach should include at a minimum a sparse network of reference stations from which other stations can be benchmarked. Reference stations should be calibrated to NIST[7] traceable standards, have triplicate measurements of key variables such as temperature and precipitation, be well sited in locations least affected by urbanization and other non-climatic influences, have regular maintenance and replacement cycling of instruments, the highest standard of

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

7 Editorial note from J. Eyre 2/24/2014: Should this be “SI”?

metadata collection including photo documentation, and continuous monitoring of system performance to resolve instrument and environmental issues as they arise. Stations from university and public-sector networks will often be necessary for filling gaps and providing the spatial density required for climate service requirements[8].
- … [others?]

10. ACHIEVING HOMOGENEITY AND CONSISTENCY IN OBSERVATIONAL DATA
Observing networks should be designed to deliver observational data of the level of homogeneity and consistency required by the intended applications.

- Stations should be sited in locations that are least likely to be impacted by changes through time in the natural or man-made environment.
- Where possible, technologies with known performance characteristics should be deployed, to ensure consistent levels of observational quality.
- As part of routine operations the quality and homogeneity of data should be regularly assessed through an ongoing programme to monitor the health of the network[9].
- When[10] station relocations or instrument upgrades are made, a minimum of one year of overlap between the old and new systems should be made.
- The collection and archive of complete metadata are essential to ensuring the homogeneity of observations..
- For many applications including climate monitoring, it is important that calibration, calibration-monitoring and cross-calibration are designed as part of observing system;
- Observations should be disseminated in a consistent way according to relevant regulatory material [links]
- Observations should be disseminated in such a way that the quality and provenance of the original measurement is retained.
- Observations should be disseminated to meet agreed availability performance targets.
- … [others?]

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

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

8 Editorial note from J. Eyre 2/24/2014: Is this a duplicate of #7?
9 Editorial note from S. Klink 2/24/2014 for this bullet item, and the 2 bullet items below: As this aspect is mentioned here –which is actually also a sub-item of the “quality management” paragraph in section C-, I would like to suggest moving the entire “quality management” paragraph to this place! From my perspective homogeneity and consistency can be only achieved if comparisons are conducted, i.e. if QM is conducted.
10 Editorial note from J. Lawrimore 2/24/2014: Realizing this is included in #12 should it also be included here? With a specification of a minimum period of overlap. – Yes, I think so [JE]

software systems associated with data collection, quality control, archive and access.

- … [others?]

12. MANAGING CHANGE

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

- The conversion of research observing systems or new observing technologies to long-term operations requires careful coordination between data providers and users (both research and operational users).
- The impact of new systems or changes to existing systems should be assessed prior to implementation.
- A suitable period of overlap for new and old observing systems is required, to maintain the homogeneity and consistency of time-series observations.
- To avoid gaps in the long-term record, continuity of key measurements should be ensured through appropriate deployment strategies.
- Test-beds and pilot projects are required through which new systems can be evaluated and guidelines for operational transition developed.
- Guidance is needed on the transition of existing (legacy) systems to meet WIGOS requirements and standards. [Too general? Or anything specific to say on this?]
- … [others?]

X[11]

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

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

Quality Management

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

Data and dissemination

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

Other

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

APPENDIX B

PROPOSED ROADMAP FOR THE DEVELOPMENT OF OSND PRINCIPLES AND ASSOCIATED GUIDANCE MATERIAL

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