W O R L D M E T E O R O L O G I C A L O R G A N I Z A T I O N

COMMISSION FOR INSTRUMENTS AND METHODS OF OBSERVATION

CIMO-WIGOS EXPLORATORY WORKSHOP:

Improving Surface-based Data Quality through Improved Standardization of Procedures

Langen, Germany

3 to 5 December 2014

FINAL REPORT

DISCLAIMER

Regulation 43

Recommendations of working groups shall have no status within the Organization until they have been approved by the responsible constituent body. In the case of joint working groups the recommendations must be concurred with by the presidents of the constituent bodies concerned before being submitted to the designated constituent body.

Regulation 44

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

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EXECUTIVE SUMMARY

The CIMO-WIGOS Exploratory Workshop: Improving Surface-based Data Quality through Improved Standardization of Procedures, was held at the Deutscher Wetterdienst's Meteorological Training and Conference Centre (BTZ) at Langen, Germany from 3 to 5 December 2014, at the kind invitation of the Permanent Representative of Germany with WMO. 19 observations experts, including at least two representatives from each region, participated in the workshop, the main objectives of which were:

- To explore mechanisms for improving the quality of surface-based observations through standardization of calibration, maintenance, and operational (algorithms, etc.) procedures, as a WIGOS Standardization initiative;
- To explore mechanisms for ensuring optimal communication of such standardized procedures to Members, as a WIGOS Capacity Development initiative.

The workshop comprised presentations from many of the participants on a) data user requirements for standardization, b) the experience of the Regional Instrument Centres in improving the standardization of in-situ observations and on regional needs, and c) on the needs of the remote sensing observing system operators.

Much of the workshop comprised open discussion of the key issues requiring attention, before the participants divided into three groups to explore in more depth:

- Improving the performance of the Regional Instrument Centres;
- Improving the performance of the CIMO Testbeds and Lead Centres; and
- The needs for standardization for remote sensing technologies.

The participants then met as one again to report on their deliberations and to prepare eleven workshop recommendations for the consideration of the CIMO Management Group. These are as follows:

Recommendation 1: Regional Associations ensure that the Regional Instrument Centre activities defined in each Regional WIGOS Implementation Plan are implemented with priority.

Recommendation 2: Other NMHS calibration laboratories should become accredited under ISO 17025 to achieve WIGOS traceability and quality improvement goals.

Recommendation 3: Regional Instrument Centres should establish traceability of and calibration services for precipitation, wind and solar radiation measurements.

Recommendation 4: Regional Instrument Centres should provide support to the surface-based remote sensing community in its efforts to develop traceability of measurements made by existing and emerging remote sensing technologies.

Recommendation 5: CIMO and CBS Management Groups seek the support of the Inter Commission Coordination Group on WIGOS to establish a CIMO/CBS-led international coordination mechanism for weather radar systems and their data and products, which involves the participation of nations operating large weather radar networks, capitalizes on the positive experience achieved within regional cooperation mechanisms, such as OPERA and BALTRAD in Europe, and includes a strong focus on capacity development.

Recommendation 6: The CIMO Management Group review the work plan of the relevant Expert Teams to ensure that high priority is assigned to tasks examining the traceability and quality

improvement of the more mature remote sensing products, for example, vertical wind profiles (from radar wind profilers and weather radars), and develop guidance material for inclusion in the CIMO Guide and other relevant material.

Recommendation 7: The CIMO Management Group review the work plan of the relevant Expert Teams to ensure that high priority is assigned to tasks proposing a quantitative definition for cloud base to assist subsequent establishment of traceability for ceilometer measurements.

Recommendation 8: CIMO Management Group should encourage Members to nominate Testbeds and/or Lead Centres for those technologies currently under-represented by existing Testbeds and Lead Centres.

Recommendation 9: The CIMO Management Group should review the relevant Expert Team workplans to include tasks aimed at developing a roadmap for Regional Instrument Centres, Testbeds and Lead Centres for progressively improving performance against their Terms of Reference.

Recommendation 10: That CIMO Management Group review relevant workplans to include investigations, guidance and the use of Observations Systems Capability Analysis and Review (OSCAR) Tool to increase the utility of, and benefits from, observational products derived from the integration or compositing of measurements from multiple technologies.

Recommendation 11: That WMO consider allocating additional resources to the Instruments and Methods of Observation budget to enable priority attention to be given to these matters.

GENERAL SUMMARY

1. WELCOME AND INTRODUCTIONS

1.1 Opening of the Workshop

1.1.1 The CIMO/WIGOS Exploratory Workshop: Improving Surface-based Data Quality through Improved Standardization of Procedures was opened on Wednesday 3 December 2014 at 9:00am, by its Co-Chair, Dr Jochen Dibbern. Dr Dibbern welcomed the participants to Langen on behalf of the President of Deutscher Wetterdienst (DWD), noting that his organization had been strongly involved in WIGOS since its beginnings, being one of the first NMHS to migrate to integrated observing systems. DWD had implemented arrangements with its hydrology networks that extend to operation of the same instrumentation, its calibration laboratories have achieved ISO 17025 accreditation, and DWD enjoys strong collaboration with Germany's neighbouring countries. Dr Dibbern noted that WIGOS is not only concerned with operations and maintenance, but places strong emphasis on data quality improvement, so DWD was particularly happy to host this important workshop, which addresses standardization of observational process and procedures, an important aspect of quality improvement. Dr Dibbern extended his best wishes for a productive and successful workshop.

1.1.2 Dr Zhang, Director of WMO's Observing and Information Systems Department, then welcomed the participants to Langen, noting the excellent facilities made available to the participants by DWD, for which he thanked the organization. He noted that WMO is in transition from the implementation phase to the pre-operational phase of WIGOS, for which standardization of observations practices and procedures would be critical. He expressed his hope that the workshop would provide a roadmap for the coming three to five years for standardization under WIGOS, which could lead to the provision of guidance to WMO Members on best practices in the integrated operation of their observing systems, a key aim of CIMO in its role of promoting better observations. Dr Zhang noted that the workshop objective was to explore methods and mechanisms for improving the quality of surface based observations for WIGOS. He hoped that the participants would use the time available to brainstorm ideas and propose new activities to help Members. In closing he wished the participants an enjoyable and successful meeting in the excellent DWD environment.

1.1.3 Dr Dibbern then invited the participants to introduce themselves (see Annex I for a list of the participants). It was clear that there was a wide cross-section of expertize present, with representatives of RICs and national calibration laboratories from several countries and regions, representatives from some of the other WMO technical commissions, and a selection of representatives from the surface-based remote sensing community.

1.2 Adoption of the Workshop Programme

1.2.1 The Workshop Programme, developed to address the matters briefly discussed in the Workshop Rationale and Plan document (Annex II), was adopted by the participants as reproduced at Annex III.

1.3 Working Arrangements for the Workshop

1.3.1 The working hours and tentative timetable for the workshop were agreed upon.

2. SETTING THE SCENE

2.1.1 To set the scene for the three day workshop, Dr Zhang described the observing systems of a number of WMO Member countries, and noted that by putting them all together we can obtain a

much better picture of what we have globally. However, he noted that this also emphasizes the challenges we face, with different standards and practices in place in different countries. He noted that a flash flood in one country had resulted in many lives being lost, but that, despite having a new weather radar in place, its products weren't available in realtime so could not be used to warn of the impending danger. If standardized guidance on how to do this had been available, the disaster may have been mitigated or avoided. He noted that the Turkish radar database now contains the details of almost 1000 radars, and that with even more unlisted radars the global network is now over 2000, but that there is little standardization of operating procedures or products in place, which makes integrated use of the data very difficult. Dr Zhang noted that in the case of the United Kingdom, large improvements had been achieved by standardization of their radars and products and suggested that countries with more than ten radars should be encouraged to establish radar centres to facilitate this process globally.

2.1.2 Dr Zhang's address to the participants raised the question of how far along the data service delivery chain CIMO's responsibilities extend. For some remote sensing systems in particular, such as weather radars, the boundary between data provision and product provision is indistinct, and the question was raised as to whether the domain of CIMO reached as far as product delivery. Dr Zhang noted that it is in CIMO's defined terms of reference to respond to the requirements for standardized and compatible observations, including data content, quality, metadata and observational product generation, so product generation was in-scope for CIMO. Dr Forgan noted also that integrated data products are a major focus of WIGOS for which CIMO and CBS jointly share the leadership responsibility, and, since integration of data from different sources implies production of data products, this was clearly at least partly CIMO's responsibility.

2.1.3 Prof. Calpini then provided further context for the workshop. He praised the ambitious vision of Dr Zhang, noting that without such vision our prospects for advancement would be limited, but that we must also take into account practical constraints, and the aim must be to find a balanced middle road. He noted that the RICs are doing a good job, and that we have in place a clear process for review and auditing of RIC performance, but that we are not so well configured to deal with the requirements for standardization of remotely sensed observations. Although weather radar technology, for example, is relatively mature, it is continually in evolution, and a weather radar system is a combination of hardware and software solutions, the ideal combination of which can depend on the ultimate purpose of the system: whether for severe weather, precipitation, forecasting or research. Prof Calpini went on to suggest that the advantages of a common reference are provision of data and products of common quality, but that the common reference should be driven, not by the manufacturers, but by the needs of service provision. He noted that a recent ISO meeting in Pretoria had discussed the potential needs for a 'precipitation radar' standard. The consensus view of the CIMO experts present was that such a standard was not presently desirable, but that, if ISO were to choose to go ahead with such a standard, then WMO should join forces to ensure the development of a common WMO/ISO standard that addresses the needs of the service providers. Prof Calpini noted that the situation with Doppler wind lidars had been somewhat different. Involving similarly mature technology, but being simpler systems to operate than weather radar systems, it had made clear sense to team with ISO in developing a joint standard for these systems to bring about improved standardization of processes and procedures, hence improved and consistently high quality, interoperable data. But what of other remote sensing technologies? How can we best bring about improvements in standardization to increase the effectiveness of WIGOS? These questions would comprise the topics for discussion over the coming few days.

3. PRESENTATIONS

3.1 Data User Requirements

3.1.1 Dr Dibbern next provided a presentation on the needs of the World Weather Watch community for standardized data. He described these needs in the context of WIGOS, which aims to provide for all of WMO's user communities, including weather, climate, hydrology and ocean

applications. Dr Dibbern pointed out that now weather radar data are being assimilated into NWP systems, for example, the need has become critical for the provision of standardized techniques for radar operation, data reduction and data exchange, so that their data can be used interoperably in near real time, and that although both CIMO and CBS have been tackling these issues, more is needed to provide what is required by the user community. He noted that there are similar requirements for other data assimilated into the NWP models, such as radar wind profiler data and lidar products. Dr Dibbern stressed that we must obtain optimal value from these expensive systems so that we can clearly demonstrate to the NMHSs the value of these significant investments in observing infrastructure.

3.1.2 Dr Xiong then made a presentation on the needs of the climate community for standardized data and information. He divided the concerns of the climate community into two key areas: long-term climate monitoring, and climate services. He noted that the two sources of uncertainty in climate series are: uncertainties in observations records (due to instrument errors, representativeness and physical changes in instrumentation) and; uncertainty in a dataset or product (due to parametric uncertainty). Dr Xiong stressed that the main requirement of the climate community was for observing system operators to abide by the ten GCOS climate monitoring principles, which implies the need for global standardization of observing system practices and procedures.

3.2 In Situ Observations Experience & Regional Needs

3.2.1 The presentations on data user requirements were followed by a series of brief presentations on the role and performance of the Regional Instrument Centres (RICs). A number of common themes ran through almost all of these presentations. The strengths of the RICs lie in their being focal points for regional needs in calibration and traceability of classical (primarily in-situ) instrumentation, their ability to host training events for regional participants, and to provide guidance on calibration and maintenance of these instruments to the community. The problems most RICs face are similar: staff shortages, lack of resources for replacement of aging equipment, lack of spares to enable field instrumentation to be taken off-line for calibration, difficulties recommending suitable modern cost effective instruments to enable retirement of obsolete equipment, and difficulties obtaining ISO accreditation when resources are lacking for the required staff training. It was stressed that these problems, though most prevalent in the RICs of developing countries, affect all RICs and limit their ability to function optimally and to embrace additional responsibilities.

3.3 Observations System Needs

3.3.1 Dr Forgan then gave a presentation on quality management systems for observations. He noted that the workshop had two objectives: to improve the quality of surface based observation through standardization of procedures, and to explore mechanisms for communicating these procedures to WMO Members. He asked the participants to think about whether use of a quality framework would improve the quality of observations, or simply improve our ability to quantify that quality. He described the various ISO quality frameworks: ISO 9001 (covering management, governance and process reproducibility), ISO 17025 (covering quantity, technical capability, providence and traceability) and the ISO Guide to Measurement Uncertainty. He described the process chain (loop) for a quality system: from user requirements, through design and build, measurement, assurance/control and ending in a feedback loop to provide guidance for improved design. He described the various ISO standards related to these individual steps in the process chain, then the way in which WIGOS realises these processes. Dr Forgan then examined other influences on data quality, such as the availability of metadata, performance monitoring, training and education, asset management and the ability to learn lessons for both failures and successes. Dr Forgan suggested a dilemma faced by WIGOS, in that the ultimate use of the data determines the quality requirements for those data. Whereas, for example, data is required urgently by the real

time forecasting community, yet the required data accuracy is not necessarily high, for the climate community data accuracy is of critical importance yet data latency is less so. So for each application area, the definition of quality is likely to be different. Dr Forgan noted that CIMO and GAW use different definitions of the term 'traceability', another issue for WIGOS to face. In regard to the matter of data quality, Dr Forgan proposed that, while the WMO data processes are currently underequipped to provide uncertainty information with each piece of data, this would be the best way to provide for all users: if each piece of data were accompanied by an estimate of its uncertainty, then the users could decide for themselves whether the data is of adequate quality for their purposes. The last point made by Dr Forgan in his presentation was that most remote sensing systems have complex measurands, and the major challenge in achieving traceability for these systems is in appropriate definition of that measurand.

3.3.2 Dr Stephan Klink then described EUMETNET and its mission, which is the development of an integrated European composite observing system for NWP and climate and ensuring that its observational data are of requisite quality. Dr Klink then discussed the key standardization issues faced by EUMETNET. He noted that while there are no key issues to report in regard to SYNOP or radiosonde stations, E-ASAP or E-GVAP, there are two AMDAR-related issues: observed systematic differences in temperature biases from aircraft of different models, and different turbulence algorithms for different aircraft. Perhaps bigger issues require resolution in regard to E-PROFILE (wind profilers and ceilometers), for which heterogeneous hardware, data processing and quality control algorithm are in use for different instruments, which leads to large differences in output data quality. In regard to OPERA (weather radars), he noted the use of different clutter cancellation methods and thresholds, different metadata and different measurands, again making the data products of variable quality. Similarly, in E-SURFMAR different algorithms are employed for computation of marine meteorological variables. In addition to these configuration issues, Dr Klink noted a number of coding and reporting issues for various observation types that make the data less interoperable than should be the case. Dr Klink suggested that two types of solutions were required: agreement on common standards to increase the uniformity output data quality, and the identification of 'monitoring centres' to monitor output, provide notification of diagnosed issues, and request corrective action.

3.3.3 The final presentation of the workshop was provided by Dr Volker Lehmann, who described the global radar wind profiler (RWP) network, its data impact on NWP, the fundamentals of their principle of operation, and their data accuracy assessment and possibilities for global standardization. He noted that the current global network includes more than 70 RWPs which provide their data via WIS in near real time, located in Europe, USA and Japan. ECMWF data withholding statistics show that the impact on NWP of the global RWP network is positive but small compared to the radiosonde network. On the other hand, some individual sites can in certain meteorological situations have a very strong impact on forecast accuracy. Dr Lehmann spoke about the wide diversity of available instruments, configurations and operating frequencies, with different combinations having different strengths and weaknesses: design choice is strongly dependent on purpose. Dr Lehmann went on to describe the principles of operation of both Doppler beam swinging and spaced array mode profilers, noting the strengths and weaknesses of each. Finally, Dr Lehmann turned to accuracy assessment and consideration of the possibilities for standardization of RWPs. He noted that the four major sources of error in RWP data are due to incorrect system settings, hardware issues, clutter and external radiofrequency interference. In closing he described some possibilities for standardization for these systems: standardization of subsystem calibration (antenna, transmitter/receiver), the sampling settings, and the processing algorithms and implementation (moment estimation, clutter filtering, wind retrieval)

4. PLENARY DISCUSSION

4.1.1 The invited presentations were followed by a general discussion session on how CIMO can assist WIGOS in improving data quality through improved standardization of observational procedures and processes, not only for the historical in-situ observations but also for the newer

remote sensing systems. Prof Calpini opened the discussion by noting that the workshop participants had now heard about the challenges confronting the RICs and some suggestions as to how the RICs might assist WIGOS to further improve standardization of observations, particularly for remote sensing technologies. He noted that we need to act now to address this and develop guidance for WMO Members. Dr Forgan suggested that, because the RICs understand what uncertainty is and how to calculate it for in-situ measurements, they may have a useful role to play in assisting the remote sensing communities to perform uncertainty calculations for their observations. Dr Forgan also reiterated the importance of carefully defining the required measurand of a remote sensing system. For example, how is cloud base defined? He suggested there are likely to be two entirely different definitions for manual and automated observations.

4.1.2 With regard to the view of the RICs to this suggestion, Dr Groselj agreed that the RICs may have useful role to play. On the other hand, Mr Merrouchi suggested that there is little scope for RICs to assist the remote sensing community in quantifying the uncertainties of their observations. He noted that in Africa, only Morocco's RIC would be in a position to assist, because few other African countries have implemented the remote sensing technologies (e.g., radars, wind profilers, lidars) and have enough difficulty in correctly calculating uncertainty for their more basic measurements. Further, human resource constraints in these countries would prohibit the RICs from taking on more than they are currently responsible for.

4.1.3 Dr Lehmann suggested that the CIMO Testbeds may have a key role to play in improving standardization for the remote sensing technologies. He suggested a model where Testbeds serve as centres for visitors to come to work for a limited time, to work with the instruments and data to gain familiarity with it, and assist the Testbeds to develop standardized practices. He stressed that it would be important for the focus to remain first on the physical principles of the measurement method rather than on implementation details of particular instruments.

4.1.4 The discussion next turned to priorities for standardizing specific types of technologies. Because WPRs and Doppler wind lidars are relatively simple systems, compared with weather radars with their wide range of products, it was suggested that it would make sense to start by developing standards for these 'simple' instrument systems, despite the greater importance to Members of weather radars, as judged by the number of units deployed worldwide. Then the experience gained from these types of technologies could be used to advantage in tackling a more complex system such as a weather radar.

4.1.5 Returning to the effectiveness of the RICS, it was pointed out that 10 years ago, few if any RICs had achieved ISO 17025 accreditation, whereas today amost half have accomplished this. The Terms of Reference of the RICs already describe exactly what is required of the RICs. So perhaps all that is needed to assist the RICs to become still more effective is the preparation of a roadmap for RIC development, that RICs of all stages of development would find useful in evolving further.

5. BREAKOUT GROUPS AND THEIR REPORTS

5.1.1 At the conclusion of the discussion session, the co-chairs proposed that the participants break into three separate groups to tackle the main ideas that had been suggested in the course of discussion.

5.1.2 The first group was to address the RICs: how to improve their performance against their existing Terms of Reference, are their current governance arrangements adequate, and to what extent might they be charged with responsibility for remote sensing technologies. Dr Groselj (RA VI) was invited to chair this group, with Mr Merrouchi (RA I) as rapporteur, and participants Karanja (RA I), Garcia (RA III), Prescod (RA IV), Heriyanto (RA V) and Holfelder (RA VI).

5.1.3 The second group was to address Testbeds, Lead Centres and/or other mechanisms for improving standardization of surface based remote sensing technologies: are the current Terms of Reference for these centres appropriate and adequate, would the establishment of a 'virtual centre' be necessary and viable, and if so should it focus on a particular type of technology, such as

weather radar, and finally, what should be the relationship between these centres and the Expert Teams? Dr Dibbern (RA VI) offered to chair this group with Dr Atkinson (WMO) as rapporteur and participants Li (RA II), Cucurull (RA IV), Calpini (RA VI) and Zhang (WMO).

5.1.4 The third group was to address each of the remote sensing technologies: should these include active and passive sensing, should we begin simply, which technologies are close enough to maturity to pursue standardization, and what do we understand: where are the gaps and how do we transfer new knowledge? Dr Lehmann (RA VI) was invited to chair this group, with Dr Forgan (RA V) as rapporteur and other participants Chan (RA II), Xiong (RA II), Nakamoto (RA II), Duarte Mol (RA III), Trihadi (RA V) and Klink (EUMETNET).

5.1.5 The following sections provide the reports presented by each breakout group.

5.2 Breakout Group 1: Regional Instrument Centres (RICs)

How we can improve RIC performance against their existing ToR?

5.2.1 The main points of discussion on this topic were:

- Ensure traceability of the available standards to the international chain (some of the RICs are experiencing problems assuring traceability);
- Widen the current calibration activities to include other parameters than the traditional basic parameters (precipitation, solar radiation, wind);
- Encourage RIC to be involved in Accreditation process with regards to ISO 17025 (RIC of developing countries need specific help and technical assistance in order to prepare accreditation);
- Perform regular internal or external assessment in order to report activities done and the technical procedures established;
- Reporting to the regional association should be coordinated and encouraged (mechanisms to be established) by the secretariat. The CIMO Expert Team on Operational Metrology should develop the report template; and
- To improve cooperation between RICs, organize annual teleconference for all RICs within the region.

Are current governance arrangements adequate (with respect to advancement of WIGOS)?

5.2.2 The Regional WIGOS Implementation Plans (R-WIPs) established for the different regional associations include the following activities related to RICs:

- Enhance RIC capabilities including ISO 17025 accreditation;
- Bring the necessary assistance to members (technical guidance, documentation, training…);
- Conduct inter-laboratory comparisons (inter-RIC and between RICs and NMS Labs);
- Establish mechanisms to enhance collaboration between RICs and Members.

However some RICs are not aware of the role assigned to them in their R WIP, so regional associations should play a more active role in coordinating all the R WIP activities.

How far can/should we open the door to remote sensing technology?

5.2.3 How well equipped are the RICs to take on a role in standardization with regard to remote sensing technologies?

- RICs have insufficient knowledge and competence related to remote sensing technologies. The capabilities of the RICs are related to the calibration of meteorological parameters for in-situ observations.

- RICs could provide assistance with expertise on calibration and traceability (e.g. procedures, uncertainty calculation) to support development of procedures for remote sensing sensors.
- Some members have established entities having large experience dealing with those technologies which are not connected to the RIC.
- One solution could duplicate the concept of RIC to deal with remote sensing technologies. But where would the resources come from (human and other)? (RICs have staff only from their host organization. There would need to be a mechanism to allow for expert staff from other countries. Would a regional model be best, or a single centre spanning more than one region?)
- Experiences gained in establishing operating RICs could be shared to ensure new concept is effective.
- Once technical procedures, standards and equipments dedicated to their calibration are established, RIC (or possible national calibration centre) activities could be expanded to some remote sensing technologies (ceilometers, vismeters).

5.3 Breakout Group 2: Testbeds and Lead Centres

Are the existing Terms of Reference of the Testbeds and Lead Centres (TBLC) appropriate, or is there a need to establish a `virtual centre'?

5.3.1 The current Terms of Reference seem appropriate, but some centres are not currently performing.

5.3.2 How can we improve their performance? There is a current lack of connectivity so there is little incentive to perform. Perhaps organize a meeting of representatives of each Testbed and Lead Centre (TBLC) to reinforce their role and the expectations on them. This in itself may help. Then, follow up with regular communications between each centre and the assigned Expert Teams. Prepare a roadmap for development of the TBLCs (similar to the process suggested for the RICs) so that they progressively and increasingly comply with their Terms of Reference and the needs of the user community.

5.3.3 But not all technologies are adequately covered e.g. **weather radar**. So, yes, perhaps we need a global weather radar initiative, similar to the global AMDAR programme., with a coordination mechanism between the nations operating large weather radar networks and a mechanism for capacity development for developing nations (e.g exchange of experts):

- Need for international coordination should be brought to the attention of CIMO and CBS Management Groups and raised at the Inter-Commission Coordination Group on WIGOS and before the WMO Presidents of Technical Commissions and Regional Associations;
- Arrange meeting(s) to share experience and develop standard practices and procedures, for hardware configuration, data processing, standardization of data products, data exchange, etc.;
- Engage with international weather radar conference(s) to hold a session on operational practices, etc., as a lead-in to establishing global standards;
- Continue to collaborate with ISO on the further development of appropriate standards;
- Arrange for experts from lead nations to assist developing countries in implementing standardized practices.

It was noted during the breakout discussion that China would be willing to establish a testbed for weather radar and wind profilers, and that there is an existing NOAA radar testbed; perhaps request NOAA's consideration for it to become a WMO/CIMO testbed.

5.3.4 Do we require **the same mechanism for wind profilers?** No, we are very close to being able to draft a standard for profilers thanks to the pioneering work of the German Institute for Standardization (DIN) and subsequent refinement of its standard by the E-Profile team, which can be fed into the work of the CIMO Expert Team on Operational Remote Sensing Technologies. Current CIMO mechanisms may well be adequate once this has been done.

5.3.5 **Doppler wind lidar**? An ISO standard is in preparation, so we may need no more for the immediate future. So, as for profilers, once WMO/ISO standard has been published, further needs can likely be satisfied by existing CIMO mechanisms.

5.3.6 **Aerosol/Volcanic ash?** CIMO has commenced an examination of the feasibility of proceeding with an international intercomparison of aerosol/volcanic ash profiles. If this is successful and results are fed back through the relevant Expert Team, resulting in guidance for members, this may suffice.

5.3.7 **Other technologies?** No, none appear to require a novel mechanism at this stage, apart from perhaps ground-based GNSS. This is still a relatively new technology but is becoming widely employed, so this is one that will likely warrant an additional coordination mechanism in the future.

How would we define a virtual centre?

5.3.8 We wouldn´t define a virtual centre. After in-depth discussion of the likely requirements for each type of technology, the breakout group concluded this would be unnecessary.

Should the focus of a ´virtual centre' be on a particular technology (e.g. weather radar)?

5.3.9 No, but yes. No virtual centre is required, but a global mechanism of some kind is seen as important for addressing standardization aspects of weather radars. For the other technologies, the existing CIMO mechanisms should suffice for the mid-term future.

Relationship to ETs?

5.3.10 Ensure that the new global radar mechanism is well-represented in relevant CIMO and CBS Expert Teams.

Summary:

5.3.11 The breakout group concluded that we need a new or improved mechanism for weather radar technology, but the need for standardization / guidance on other remote sensing technologies can probably be satisfied within existing CIMO mechanisms (TBLCs working with Expert Teams).

5.4 *Breakout Group 3: Remote Sensing Technologies*

5.4.1 This breakout group first considered the perceived **requirements of the meteorological community** to be:

- NWP / assimilation (high resolution);
- Aviation;
- Weather forecasting and nowcasting;
- Replacement of current manual observation with equivalent quantitatively-determined automated observations with the ultimate aim of adding to the "Climate" record;
- Satellite measurement adjustment (Cal Val) and composite observations;
- Provision of information over spatial areas and vertical extent.

5.4.2 **Primary Quantities to Measure in Space and Time:**

- Temperature, humidity and wind components;
- Particles (ice, liquid, solid, volcanic).

5.4.3 **Type of remote sensing methods that are readily available:**

- Passive: measuring the natural radiant energy components of the natural environment at a fixed location
- Active: sensing energy pulses from electromagnetic or sonic sources and observing the returned or transmitted signals

5.4.4 **Current Technologies and their mode and operational status:** The various technologies were examined for their current availability and their operational status. The following tables summarise the group's assessment of the technologies against the primary quantities necessary to satisfy user requirements:

Temperature			**Humidity**			**Wind**			**Particles**		
MWR	"O"	P	MWR	"O"	P	Wind Profiler	O	A	RADAR	O	A
RASS	E	A	GPS	O	A	LIDAR	O	A	LIDAR	E	A
LIDAR Raman	E	A	DIAL	E	A	SODAR	O	A	LIDAR Ceilometers	O	A
FTIR	E	P	Raman	E	A	RADAR	O	A			
			FTIR	E	P						
OPERATIONAL TECHNOLOGIES											
(MWR)			GPS			Wind Profiler (V)			RADAR – precipitation		
			(MWR)			RADAR (H+V)			Ceilometers – vol. ash		
						LIDAR (H+V)			Ceilometers – cloud base		

O = operational, that is providing operational guidance to NMHS
E = experimental and in research mode with irregular use in NMHS operations
() implies limited number in operations
P = passive remote sensing
A = active remote sensing
MVR = Microwave radiometers (ground based equivalent of microwave remote sensing)
FTIR = Fourier transform infrared radiometer
RADAR = millimeter to metre electromagnetic radiation
SODAR = electromagnetic or sound radiation
LIDAR = nm to micron electromagnetic radiation (includes ceilometers)

5.4.5 **Simple Technologies:** Those technologies that can be verified independently, and are capable of continuous monitoring in all weather conditions, were identified. MWR was a potential candidate for temperature but was deemed more qualitative than quantitative at its current development stage, and not widely operational.

Temperature			**Humidity**			**Wind**			**Particles**		
			GPS			Wind Profiler			RADAR – precipitation		
									Ceilometers – cloud base		

5.4.6 **Mature Technologies:** These are the 'simple' technologies that are commercially available and are used operationally by a significant number of NMHS. Both GPS moisture determination and QPE were identified as being dependent on co-existent measurements. GPS requires space based sources (satellites), and QPE requires a ground based real time rainfall monitoring system

to adjust the RADAR outputs. Ceilometers were not included as the property or quantity being measured was as yet poorly defined.

Temperature	Humidity	Wind	Particles
	[GPS] Crosses domains: space and ground	Wind Profiler	(RADAR – precipitation intensity) requires support network

5.4.7 **Transfer of Knowledge and Information:** The key components required for the transfer of knowledge and the provision of information to enable decision making were identified as:

- Reliability of quantity being provided;
- Independence of measurement process from additional measurement sources;
- The measureand was well defined both by the basic physics and mathematical description;
- Uniformity, robustness of performance over a network and time, and could be periodically be verified using alternate technologies;
- The ability to explain and demonstrate the measurement process without ambiguity;
- As an operational measurement process it:
    - Was robust (well posed problem);
    - Employed robust hardware (MTBF high); and
    - Used robust software/ algorithms;
- Simple path from measurement to information and utility;
- Reproducible in both space and time.

5.4.8 **To improve the quality of observations for WIGOS for the Simple and Mature Technologies:** The functional requirements of CIMO through it Expert Teams and Task Teams to improve the quality of the mature and simple technologies are:

- Show mastery of the measurement (through demonstrating clear understanding of the measureand and the instrument);
- Identify and communicate practical independent verification measurement methods that are periodic rather than continuous;
- Understand all components of uncertainty including environmental influences;
- Propagate improved quality control methods based on understanding of the measurement requirement and process;
- Regular maintenance and inspection;
- Calibration of subsystems (for example, transmitter & receiver for Wind Profilers);
- For wind profilers identify opportunistic RF sources for antenna beam pattern checks;
- Encourage multiple user feedback on data through identification or influencing the construction of a feedback mechanism;

5.4.9 **Comments in regard to the breakout group's discussions:**

- Group 3 focused on 2 and 3d profiling, rather than point or column measurements, so has not included some atmospheric chemistry measurement techniques.
- Prioritization of advances in standardization of surface-based remote sensing techniques should include the needs of climate.
- Each technology has been considered independently. Must take into account the increased power afforded by integrating/compositing technologies.
- Re network considerations: RRR, OSCAR will provide input on needs for network aspects of standardization.

6. WORKSHOP RECOMMENDATIONS

6.1.1 Based on the outcomes of its discussion and of the breakout group reports the workshop developed the following ***Recommendations*** for the consideration of the CIMO Management Group.

6.1.2 Significant progress has been made in recent years by almost half of Regional Instrument Centres (RICs) in pursuing and achieving ISO 17025 accreditation and SI traceability of measurements, but the process has not been completed for all RICs. Over the coming three years the remaining RICs should more actively pursue these same goals.

Recommendation 1:

Regional Associations ensure that the Regional Instrument Centre activities defined in each Regional WIGOS Implementation Plan are implemented with priority.

Recommendation 2:

Other NMHS calibration laboratories should become accredited under ISO 17025 to achieve WIGOS traceability and quality improvement goals.

6.1.3 The major focus of RICs is at present the traceability of temperature, pressure and humidity. The number of traceable quantities needs to be extended to include other quantities of key interest to WIGOS.

Recommendation 3:

Regional Instrument Centres should establish traceability of and calibration services for precipitation, wind and solar radiation measurements.

6.1.4 The historical focus of RICs has been on traceability of measurements made using conventional technologies. There is a clear need to provide similar traceability for measurements using remote sensing technologies. The RICs have a role to play in assisting the remote sensing community to calculate measurement uncertainty and in providing advice, based on RIC experience, on best practice in sustaining traceability of measurements for routine operations.

Recommendation 4:

Regional Instrument Centres should provide support to the surface-based remote sensing community in its efforts to develop traceability of measurements made by existing and emerging remote sensing technologies.

6.1.5 Weather radars are increasingly and more widely deployed, including in less developed countries, with well over 1000 radars now in operation globally. WMO Members are making strong calls for guidance and advice. However, the historical development of weather radar systems and applications has resulted in a wide range of software and hardware solutions being used to derive the same quantities. There is a clear need to focus on harmonization and/or uniformity of processes and procedures where there is a clear benefit to the global user community and where this will not hamper innovation. Particular technologies can have clear advantages over alternative options, too. All this needs to be communicated to the user community, including, for example, at international radar conferences. A new mechanism is required, such as a global weather radar initiative similar to the approach taken for AMDAR, to achieve global consistency and the full benefit of these systems. This would provide a key contribution to the World Weather Watch's Global Observing System, the backbone of WIGOS.

Recommendation 5:

CIMO and CBS Management Groups seek the support of the Inter Commission Coordination Group on WIGOS to establish a CIMO/CBS-led international coordination mechanism for weather radar systems and their data and products, which involves the participation of nations operating large weather radar networks, capitalizes on the positive experience achieved within regional cooperation mechanisms, such as OPERA and BALTRAD in Europe, and includes a strong focus on capacity development.

6.1.6 The various technologies for surface-based remote sensing were examined, and it was clear that some technologies remain in experimental and development phases. Others have matured to the point that they have transitioned to operations for weather monitoring and their use for climate purposes can now be considered. However, the latter first requires establishing mechanisms for global traceability of their data and products to an agreed international reference, including the whole chain of data acquisition, processing and quality assurance. In particular, measurement of vertical wind profiles, quantitative precipitation estimation and cloud base are three of the more likely candidates.

Recommendation 6:

The CIMO Management Group review the work plan of the relevant Expert Teams to ensure that high priority is assigned to tasks examining the traceability and quality improvement of the more mature remote sensing products, for example, vertical wind profiles (from radar wind profilers and weather radars), and develop guidance material for inclusion in the CIMO Guide and other relevant material.

Recommendation 7:

The CIMO Management Group review the work plan of the relevant Expert Teams to ensure that high priority is assigned to tasks proposing a quantitative definition for cloud base to assist subsequent establishment of traceability for ceilometer measurements.

6.1.7 The Terms of Reference of RICs, Testbeds and Lead Centres (TBLC) encompass the activities necessary to improve the quality of observations for WIGOS. However, the current focus of the TBLC is on experimentation, whereas a larger contribution to transitioning to operations is required: in particular the establishment of traceability of measurements, and best practices for the technology. It is also important to investigate, develop guidance and provide tools for Members on observational products derived from the integration or compositing of measurements from multiple technologies. Additional TBLC may be required to cover all technologies transitioning to operations as part of WIGOS.

Recommendation 8:

CIMO Management Group should encourage Members to nominate Testbeds and/or Lead Centres for those technologies currently under-represented by existing Testbeds and Lead Centres.

Recommendation 9:

The CIMO Management Group should review the relevant Expert Team workplans to include tasks aimed at developing a roadmap for Regional Instrument Centres, Testbeds and Lead Centres for progressively improving performance against their Terms of Reference.

Recommendation 10:

That CIMO Management Group review relevant workplans to include investigations, guidance and the use of Observations Systems Capability Analysis and Review (OSCAR) Tool to increase the utility of, and benefits from, observational products derived from the integration or compositing of measurements from multiple technologies.

6.1.8 The workshop recognized that implementing the above recommendations would place a significant additional administrative load on the WMO Instruments and Methods of Observation unit and the overall work programme of CIMO , which could only be absorbed with the injection of additional resources into the area.

Recommendation 11:

That WMO consider allocating additional resources to the Instruments and Methods of Observation budget to enable priority attention to be given to these matters.

7. DRAFT REPORT OF THE SESSION

7.1 The session agreed to finalize the report of the session by correspondence over the coming weeks.

8. CLOSURE OF THE WORKSHOP

8.1 The session closed on Friday 5 October 2014 at 14:00 hours.

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ANNEX I

LIST OF PARTICIPANTS

Bertrand Calpini (CIMO, Switzerland) (Workshop Co-Chair)

Jochen Dibbern (CBS, Germany) (Workshop Co-Chair)

WMO Regional Association I:

- Rabia Merrouchi (Morocco)
- Henry Karanja (Kenya)

WMO Regional Association II:

- Li Bai (RIC and RMIC, China)
- Xiong Anyuan (CCl, China)
- P.W. Chan (Hong Kong, China)
- Yoshihisa Nakamoto (Japan)

WMO Regional Association III:

- Mario Garcia (Argentina)
- Juliana Maria Duarte Mol (Brazil)

WMO Regional Association IV:

- Lidia Cucurull (USA)
- Damien Prescod (Barbados)

WMO Regional Association V:

- Bruce Forgan (Australia)
- Damianus Heryanto (Indonesia)
- Edward Trihadi (Indonesia)

WMO Regional Association VI:

- Stephan Klink (EUMETNET, Germany)
- Volker Lehmann (Germany)
- Tilman Holfelder (Germany)
- Drago Groselj (Slovenia)

WMO Secretariat:

Wenjian Zhang (Director, Observing and Information Systems Department)

Isabelle Ruedi (Head, Instruments and Methods of Observation Unit, Observing and Information Systems Department)

Roger Atkinson (Scientific Officer, Instruments and Methods of Observation Unit, Observing and Information Systems Department)

ANNEX II

WORKSHOP RATIONALE AND PLAN

Workshop Objectives:

1. To explore mechanisms for improving the quality of surface-based observations through standardization of calibration, maintenance, and operational (algorithms etc) procedures, as a WIGOS Standardization initiative.

2. To explore mechanisms for ensuring optimal communication of such standardized procedures to Members, as a WIGOS Capacity Development initiative.

Background:

Global improvements in the quality and traceability of observational data from basic observational instrumentation (surface pressure, temperature, humidity, wind, rainfall, radiation) have resulted from the implementation of standardized calibration, maintenance and operational procedures, partly as a result of the establishment of the WMO Regional Instrument Centres, Regional Marine Instrument Centres, Regional Radiation Centres, and from the role played by the Regional Training Centres in providing training on such standardized procedures.

WMO Members are increasingly transitioning from manual to automated observations for more than these basic measurements, yet similar success in ensuring global data quality has not yet been accomplished for the more complex associated observing equipment (such as ceilometers, vismeters, weather radars, radar wind profilers and lidars).

One of the aims of WIGOS Quality Management is to address this matter, initially by exploring mechanisms for improving the quality of observational data from surface-based remotely sensed observing systems, by improved standardization of calibration, maintenance and operational procedures for this equipment. At the same time the WIGOS Quality Management activity seeks to explore the scope for further improvement of the effectiveness of the RIC/RMIC/RRC model.

Workshop Plan:

The proposed three day workshop will address the above matters.

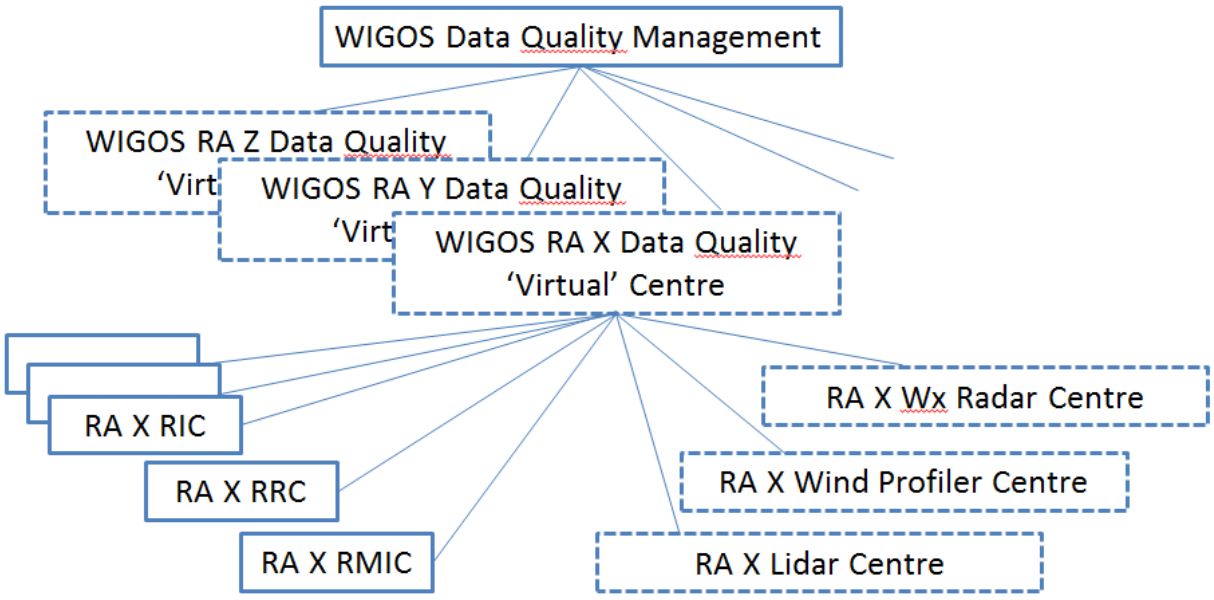
The first day will comprise a series of presentations on the topic. Participants will first hear from representatives of key application areas of their requirements for standardized data, both in situ and remotely sensed. To capitalize on the benefit of the in situ observations experience, this will be followed by presentations from representatives of the established instrument centres (RICs, RMICs, RRCs), on their perceived strengths and weaknesses, and presentations from regional representatives on current regional arrangements and additional needs for standardization of both in situ and remote sensing systems. The first day will conclude with presentations from representatives of the more commonly employed and emerging remote sensing systems on their current use of and additional needs for standardized processes and procedures.

Having heard from key stakeholders about the overall needs for standardization, and the current arrangements for satisfying these requirements, days two and three of the workshop will focus on proposing and exploring potential mechanisms for effecting improvements to the global situation.

A number of potential mechanisms can be envisaged for bringing about improvements to observational data quality by global standardization of processes and procedures:

- Expand the role of the RICs to include remote sensing instrumentation;
- Expand the RIC concept to embrace 'distributed' or 'virtual' WIGOS Regional Instruments Centres, with individual centres within a particular region dealing with a particular type of instrumentation;
- Establish Regional Remote Sensing Instrument Centres, with a model similar to and parallel to the RIC model;
- Address the issue via accelerated development and expanded scope of the CIMO Test Bed / Lead Centre model,
- Rely on the efforts of individual Members to improve their situation nationally, and focus on improved communication and sharing of best practices;
- A combination of the above.

Of all these possibilities, perhaps the most practicable would be the establishment of a 'virtual' centre model (see the schematic diagram below).



But would this be both economical and effective? Would it be equally successful in all regions? Is there a better model to pursue?

Day two will commence with a plenary brainstorming session to propose and discuss potential mechanisms. The workshop will then divide into breakout groups to explore the more promising ideas in greater depth.

On day three, the breakout groups will merge again to summarize their discussions and findings, followed by further discussion if required, distillation of a consensus view if possible and finally, drafting of a summary report with recommendations to CIMO Management Group and ICG WIGOS.

ANNEX III

WORKSHOP PROGRAMME

WORKSHOP PROGRAMME		
WEDNESDAY, 03 DECEMBER 2014		
09:00-09:15	**WELCOME AND INTRODUCTIONS** **Dr Jochen Dibbern (DWD)** **Dr Wenjian Zhang (D/OBS)**	
09:15-10:30	**SETTING THE SCENE** Dr Wenjian Zhang: WIGOS and the need for globally improved data quality. Dr Bertrand Calpini: Current arrangements for standardization of procedures and practices for surface-based observations, and their limitations.	
Coffee Break (10:30-11:00)		
Session 1	**Data User Requirements (Chair: Calpini)**	
11:00-11:30	Weather Requirements	Jochen Dibbern (Germany)
11:30-12:00	Climate Requirements	Xiong Anuan (China)
Lunch Break (12:00-13:00)		
Session 2	**In Situ Observations Experience & Regional Needs (Chair: Forgan)**	
13:00-13:15	RICs (Developed Countries)	Drago Groselj (Slovenia)
13:15-13:30	RICs (Developing Countries)	Rabia Merrouchi (Morocco)
13:30-13:45	RMICs	Li Bai (China)
13:45-14:00	RA I	Henry Karanja (Kenya)
14:00-14:15	RA II	Yoshihisa Nakamoto (Japan)
14:15-14:30	RA III	Mario Garcia (Argentina)
14:30-14:45	RA IV	Damien Prescod (Barbados)

14:45-15:00	RA V	Damianus Tri Heryanto (Indonesia)
Coffee Break (15:00-15:30)		
Session 3	**Observations System Needs (Chair: Dibbern)**	
15:30-16:00	Observations Quality Management Systems	Bruce Forgan (Australia)
16:00-16:30	EUMETNET	Stephan Klink (Germany)
16:30-17:00	Radar Wind Profilers	Volker Lehmann (Germany)
17:00-17:30	General Discussion	
End of Day One (17:30)		

THURSDAY, 04 DECEMBER 2014	
Summary of Day 1 and the Search for Solutions (Co-Chairs: Calpini & Dibbern)	
09:00-10:30	What is clear (consensus), and what is not (lack of consensus). What works well, and what doesn't.
Coffee Break (10:30-11:00)	
11:00-12:00	Brainstorming Session: Potential mechanisms for improving the situation
12:00-12:30	Selection of Topics for Consideration by Breakout Groups, Selection of Breakout Groups
Lunch Break (12:30-13:30)	
Breakout Groups (Chairs: Calpini, Dibbern, Forgan)	
13:30-15:00	Breakout Group Discussion
Coffee Break (15:00-15:30)	
15:30-16:30	Breakout Group Discussion
16:30-17:30	Breakout Group Report Preparation
End of Day Two (17:30) **18:30 Workshop Dinner, hosted by DWD at the Hungarium, Achat Hotel, Langen**	

FRIDAY, 05 DECEMBER 2014	
Breakout Group Reporting & Discussion (Co-Chairs: Calpini & Dibbern)	
08:30-09:30	Breakout Group Reporting
09:30-10:00	Plenary Discussion
Coffee Break (10:00-10:30)	
10:30-12:00	Plenary Discussion
Lunch Break (12:00-12:45)	
Workshop Wrap Up (Co-Chairs: Calpini & Dibbern)	
12:45-14:00	Summary, Conclusions
14:00-16:00	Drafting of Workshop Summary and Recommendations
End of Workshop (16:00)	