**Mission, Vision, Outcomes and Strategies**

**Future of environmental measurements**

**(a proposal from the CIMO MG to WIGOS)**

**Mission:**

**Members achieve fit-for-purpose environmental measurements through appropriate standards and technologies.**

**Vision:**

**The WIGOS measurement community is the source of information on the suitability of measurements for specific environmental intelligence (applications).**

* Clarifying the place of measurements in the environmental information chain.

**Desired Outcomes:**

1. The WIGOS measurement community is a cadre of the measurement experts in a WMO organizational structure that supports and promotes the gathering and dissemination of knowledge on the quality of relevant environmental measurements and how fit-for-purpose measurements are achieved.
2. Users and providers understand the importance of the measurement process in the environmental information chain.
3. Users and providers are committed to traceability of ECV measurements.
4. The potential quality and uncertainty of emerging measurements are documented in the CIMO Guide and reference material.

**Strategies to achieve the Mission and Vision:**

1. Collaborate effectively with all users and providers of measurements;
2. Develop and promote the implementation of good measurement practices;
3. Develop, and provide effective access to, standards and guidance material;
4. Coordinate the transition from new science and technology to operational implementation;
5. Characterize the traceability that can be achieved from emerging alternative technologies.

**Shaping the Vision and Mission**

Several new drivers are impacting on WMO and particularly WIGOS, including the opportunity and threats of Big Data and its myriad of sources, the Minamata Convention, new generation satellites, and the pressing need to be more agile, innovative and informative. The CIMO MG meeting at Offenbach, in April 2016, provided an opportunity to discuss and then formulate the draft of a long term vision and mission of the measurement components of WIGOS. A concise vision, mission, desired outcomes and principle strategies on a page was the result.

At that CIMO MG meeting it was decided to take an agnostic approach to how the mission could be implemented structurally, but whatever structure came to pass it must enhance collaboration and cooperation and promote the role of measurements as an output.

At CIMO TECO 2016 in Madrid in September 2016, with wide representation from a number of other Commissions and Programmes, there was also an opportunity to have a two hour open forum to discuss the vision and mission on a page. There was a general consensus from those present that it had the right form but some expansion on the drivers and activities that should be pursued to achieve the desired outcomes. The following paragraphs address the latter request.

**Form of the Vision and Mission**

This vision and mission for nearly 25 years (2040) hence is necessarily limited in detail on planning, tactics, goals and concrete data forms, but does focus on ensuring the key elements of achieving effective measurements as one of the foundational elements of environmental intelligence regardless of what the future brings. The concise language was designed to be relatively easy to use as a litmus test for any future work for those developing, enhancing and encouraging measurement practises in support of environmental intelligence.

The foundation of any organization with the aim to be an effective high-quality environmental information service is access to a cadre of people with a fundamental understanding of the science and application of the processes of measurement and its ultimate output; fit-for-purpose data. In the current organizational context of WMO and its priority WIGOS, CIMO is but one of the current Commissions and Programmes involved in developing processes of measurement for the non-weather centric elements of environmental monitoring. So under the framework of WIGOS where does the user go for information to find out if a data stream is fit for their purpose? This vision, mission and strategy is not focused on the future of CIMO and is agnostic to there being a CIMO in the future. Rather it is a vision and mission for a strong, vital, agile and integrated cadre, the WIGOS measurement community, to further the aims of WIGOS and be the source of information on all measurement data streams.

**Overarching new and existing drivers**

Change is the only constant

The time when a meteorological measurement[[1]](#footnote-1) is primarily a measurement through observation by a human observer is now consigned to history. As has the time when one meteorological datum can be a representative of a quantity with assumed characteristics of assumed quality. Instead, the measurements used by the environmental community are automated, from numerous sources made up of multiple component and processes, and a diverse range of measurement methods. Furthermore, it is now understood by many that meta data associated with a datum is a critical information component.

Most importantly there is now a rapid acceleration and divergence in the measurement technologies (instrumentation, data dissemination and amalgamation to provide other measurements, etc.) that explicitly requires all involved in the data and information value chain to re-evaluate the methods of standardization from a measurement being represented by instrumentation (e.g. satellite, AWS, radar, ceilometer) to the quantity as an output (e.g. vertical temperature, vertical wind, temperature and humidity, rainfall, cloud base or aerosol profile).

Quality and fit-for-purpose

The assignment of the quality of a measurement has always been dependent on being fit for a user’s requirements. In the past the focus on making all measurements fit for climate analysis has dominated the measurement regime. That is no longer the case with tiering of networks (e.g. climate, weather, aviation), 3rd party data availability, and crowd sourcing. As the methods and sources of the same measurement, for example, ‘temperature’, become more heterogeneous there is a temptation to use an instrumental method (if known) to estimate the quality through assumptions, rather than finding a quantitative measure based on the facts of the process of measurements. One solution to replacing belief with knowledge for some quantities is traceability[[2]](#footnote-2) where there is a framework of physics and chemistry metrology. However, some existing measurements and new measurements being integrated into the WIGOS framework either require a significant amount of work to achieve traceability (e.g. satellite radiances) or have yet to consider traceability (e.g. 3rd party data, crowd sourcing, camera imagery). A potential substitute where traceability is not feasible, is a combination of meta data and ancillary co-located measurements that can be used without human interpretation. As a result, to serve the user community, a clear and readily visible source material must be available to provide assurance for the user that the datum or data series they use will indeed serve their needs.Big Data - opportunities and issues

The meteorological community has been at the forefront in contributing to ‘Big Data’ initially through its rapid take up of space and surface-based remote sensing, and now is actively pursuing 3rd party data sources and crowd sourcing. The volumes are increasing exponentially and have a velocity (speed and direction of analysis and information paths) heading in directions unheard of in the past, ultimately providing opportunities for greater insight into the nature of environmental phenomena in increasingly small scales in space and time. However, the down sides are inconsistency in the information content, and particularly how they impact the data quality on information extraction. Perhaps, the most significant issue for the environmental measurement community is to use assumptions rather than knowledge, largely because the data are only a datum loosely related to meta data, that provides only a partial description of the measurand leading to an increase in false conclusions. A mitigation of the risk in some cases can be provided by making sure all the requirements for traceability accompany what was in the past a single datum (e.g. a relative humidity value in a SYNOP message). However, in doing so would in turn expand the volume of data for the most basic of quantities by a factor of three as traceability mandates including uncertainty and degrees of freedom.

The language and integration

Given the focus on integration in WIGOS, does the distribution of activities on standardization of measurement through a number of Commissions and associated agencies make sense for the future? While the CIMO Guide provides a focal point on quantities and methods of measurement, the large number of Commissions tends to lead to well-intentioned duplication and may not be maximizing the available expertize. Furthermore, linkages between Commissions may not be as effective for communicating user requirements, as each Commission has developed its own vocabulary on their processes for measurement. Integration in WIGOS cannot succeed unless all the relevant communities use the same vocabulary with the same semantic intent, and can communicate effectively with the innovators, industry and users. It is of little value, if Commissions’ processes of measurement are translated by the CIMO Editorial Board into the international recognized standard vocabulary that remains outside the comprehension of the source community (e.g. is it accuracy or uncertainty?). Hence in continuing the implementation of WIGOS there is considerable work to do in standardization of the language of measurement.

Hence the vision, mission and strategies stated at the start of this document cannot be just for the existing CIMO community, but should be for the WIGOS measurement community made up of all the relevant current Commissions and partner programmes (GAW, GCW, WCRP, etc.).

**Strategic elements**

1. **Collaborate effectively with all users and providers of measurements**

The current mode of providing focal points for communication between the Commissions and Programmes will continue, as will incorporation into the CIMO Guide chapters provided by JCOMM, CAS, CBS (satellite), space weather and other future contributing entities to WIGOS measurements. The value of TECO and METEOREX/MetExpo in providing a venue to initiate, promote and disseminate methods of measurement has been demonstrated on a number of occasions and should be continued, as well as the partnership with HMEI.

The value in the collaboration with BIPM and associated NMIs has been proven in the last four years and demonstrated at CIMO TECO 2016, and hence the expansion of the collaboration must be pursued with increased vigour.

The past ECV focus of the CIMO Guide must be re-examined and other user requirements incorporated that enable a user to determine what type of processes of measurement are required to achieve a fit-for-purpose result; for example, incorporating aviation requirements and applications that will achieve fit-for-purpose results from 3rd party and crowd sourced data. These activities should be summarized in a significant revision of the Annex 1.E in the CIMO Guide, Part I, Chapter 1.

While there is now a significant volume of the CIMO Guide on space-based (satellite) measurements there have been limited advances in integrating satellite and surface-based data to produce new measurements. In particular, the bi-directional utility of downward and upward looking microwave radiometers, needs to be investigated as surface-based microwave technology advances have been rapid.

1. **Develop and promote the implementation of good measurement practices**

The continuation of intercomparisons is essential to address world-wide operational traceability, like the regular 5-yearly IPCs, and to improve knowledge of the components of uncertainty in the process of measurement (e.g. SPICE, screen, ceilometer and radiosonde intercomparisons). Also essential for the sustainment of quality management are the interlaboratory comparisons and training courses for continuing to develop an understanding of the fundamental aspects of good metrology and measurement practise; they are also essential in developing a common vocabulary across measurement disciplines. Promotion of these essential activities needs to be communicated to the highest levels within Members.

Regardless of whether the existing technical Commission structures remain or not it is essential that the principles and practice of standardization are promoted by effective liaison, and where required co-development of standards with partner global agencies (ISO, BIPM).

The most recent CIMO TECOs have shown their value in both promoting good measurement practices and introducing new methods for active discussion and dissemination within the measurement community. There is extra benefit from a CIMO TECO if there is participation from a heterogeneous collection of measurement sub-communities (e.g. surface meteorology, air chemistry, marine, hydrology and space weather) as new technologies, both instrumental and algorithmic, used in one community become visible and interaction can be direct and immediate. As an example, exploring synergies between the radar and space weather communities should be advanced. Hence any future TECO for the WIGOS measurement community must allow for diversity in measurement output, all the while promoting the use and dissemination of traceability in any new measurement stream or the merging of existing streams.

The provision of competencies for the processes of measurement must continue and be developed to incorporate an understanding of the fundamentals of measurement to senior leaders in NHMS. The dynamic nature of position rotation in NMHS can be lead to incorrect conclusions regarding organizational priority because of the use of assumptions rather than knowledge. While the focus in the past has been to provide a competency framework for the lower levels of NMHS with good outcomes, the focus in the future should insist on a basic level of understanding of what makes a measurement valuable for all organization levels within an NMHS and what is required to sustain fit-for-purpose operations and outputs.

1. **Develop, and provide effective access to, standards and guidance material**

The CIMO Guide, the International Cloud Atlas and other WIGOS documentation are dynamic documents that need to be updated as knowledge improves. IOM reports, an effective way to document investigations, technical findings and new methods of measurements, must remain an integral part of the WIGOS measurement community’s outputs, and in particular, documents that delineate the pathways from research to operations for new measurement outputs.

The liaison with BIPM and collaboration with ISO are fundamental pathways to the development of standards and guidance materials and it is essential that collaboration pathways are utilised effectively and strengthen where needed.

As in strategic element (a), the Annex 1.E of the Part I, Chapter 1 of the agile revision of the CIMO Guide is a key to access existing and new standards and guidance.

The impact of the future updates to the JCGM 100: Evaluation of measurement data - Guide to the Expression of Uncertainty of Measurement (so called ISO GUM) is of particular concern as the methodology of calculating measurement uncertainties moves from the calculus of variances to a Bayesian probability distribution framework. Specific guidance material needs to be developed to ensure that the significant benefits, including financial, that have accrued to environmental measurement community since the introduction of the ISO GUM as a key component of good measurement practise, are not lost because of the perceived complexities of a pure Bayesian approach (now preferred in the latest versions of the ISO GUM).

The work of the Regional Instrument Centres, both of the atmospheric and marine variants, must continue as should increasing the collaboration on the propagation of traceability with the atmospheric chemistry calibration centres. While likely to be difficult, if a suitable measurement culture exists, the role of the Regional Instrument Centres and their client base should be expanded to include active and passive remote sensing measurements when methods of traceability to SI become available for those measurement types.

Continuing to link an operational measurement to a physical or chemical definition of a quantity needs to continue. One phenomena in particular, clouds, has proven to be difficult; determining physical definitions of cloud base height, cloud amount and type has been started recently to come up with definition to allow traceability and must be progressed. Similarly, the standards associated with soil moisture and evaporation will need to be developed and propagated.

The positive effect of short and sharp guidance material on the importance of the processes of measurement and supporting infrastructure cannot be underestimated, as shown by the recent initiative of MeteoSwiss on the importance of intercomparisons using the recent International Pyrheliometer Comparison as the most recent example. More visual, concise and to the point material needs to be developed and distributed widely within NMHSs and environmental agencies that are, or will be, providers of 3rd party data. The effectiveness of social media and web-based portals can also assist in providing information to the myriad of potential providers of crowd sourced data.

1. **Coordinate the transition from new science and technology to operational implementation**

Testbeds, Lead Centres, expert teams and Regional Instrument Centres will continue to play a crucial role in transitioning new science to operations. Intercomparisons’ primary role has been to provide traceability but they also play a role in introduction of new science and methods on the pathway to operation, and should continue to be used, particularly for the rapidly advancing detector science and engineering used in in situ methods, as well as, passive and active remote sensing.

Measurement community TECO-like fora must continue to be a venue that enables visibility of the new science to be considered for operations. The most recent candidates are: use of infrared all-sky imagery combined with ceilometers to provide cloud height, amount and vertical distribution based on physical processes (e.g. radiative transfer), and use of microwave transmissions for communications being used to derive rainfall.

Alternate approaches to increasing the value of new technologies must also be trialled, including inviting external experts to examine the potential measurement methods for operational use. A clear gap at present is an examination of the value of melding in a measurement sense, for example of melding space and surface-based remote streams.

Linkages between other WMO agencies and partners that focus on the science behind environmental physical and chemical processes must continue and be strengthened to ensure innovative methods of measurement and associated quantities are developed, and the resultant environmental intelligence can be introduced with confidence by operational service areas. As a result, the current broadening of the likely attendees of measurement TECO must be expanded further.

1. **Characterize the traceability that can be achieved from emerging alternative technologies**

When a new or alternative process of measurement is available, to ensure that its potential integration into the future environmental information chain is effective and efficient, the measurand must be critically assessed to determine if it is a traceable quantity, and at what organizational infrastructure cost is required to be fit for purpose for known applications.

If an emerging measurement technology is not traceable then the user community must be made aware. While the resultant data are of significant value ,the risks associated with their use must be available for consideration. IOM reports and specific reports are ideal vehicles for dissemination to the measurement community, but meta data bases like OSCAR, and short reference publications and handouts need to be developed. Alternative methods to publish measurement knowledge include sponsoring workshops on emerging technologies for operational use and the invitation of an external experts, from a parallel science stream or the NMI community, to provide a relevant perspective.

Once these emerging technologies are used in operations, the character of the measurements must be added to the CIMO Guide as a matter of cause. Other dissemination vehicles include their promotion through innovative award schemes like the Prof. Dr Vihlo Vaisala Awards, outreach documentation of the Testbeds and Lead Centres, as well as measurement community TECO.

1. **Measurement** - process of experimentally obtaining one or more quantity values that can reasonably be attributed to a quantity.

Note: The use of the word ‘observation’ or ‘observations’ has been deliberately avoided as it is a WMO re-definition of the term ‘result of a measurement’ and sometimes is equated to measurement.

**Result of measurement** - set of quantity values being attributed to a measurand together with any other available relevant information.

**Measurand** - quantity intended to be measured. [↑](#footnote-ref-1)
2. **Traceability** – property of a measurement result whereby the result can be related to a reference through a documented unbroken chain of calibrations, each contributing to the measurement uncertainty.

Note: It is important to understand that traceability is the property of the result of a measurement not an instrument or calibration report of laboratory. [↑](#footnote-ref-2)