The European Metrology Network for Climate and Ocean Observation: updates and perspectives

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The European Metrology Network for Climate and Ocean Observation: updates and perspectives

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***Abstract* – In the present paper, the EURAMET European Metrology Network for Climate and Ocean Observation (EMN ClimOcNet), established in 2019, is presented. The EMN is focused on three different thematic areas, among which is ocean observation and metrology for Essential Ocean Variables. The main goal of the network is to establish a solid, long-term, European infrastructure to enhance the cooperation between the metrological and the oceanographic communities, to support the global understanding of climate change and the sustainable use of the oceans. The structure and the objectives of the EMN are described, together with an overview of the outputs of the first year of the EMN.**

I. INTRODUCTION

Climate change and its impact on oceans, land, atmosphere and biosphere, led the United Nations to ratify in 2015 the "Sustainable Development Goals" (SDGs) [1]. Amongst these, goal 13 states: "Take urgent action to combat climate change and its impacts" and SDG 14 states: "Conserve and use the oceans, seas and marine resources for sustainable development".

The Global Climate Observing System (GCOS) has defined a set of more than 50 Essential Climate Variables (ECVs), physical, chemical, and biological, that characterise Earth's climate. Each variable poses challenging measurement accuracy targets, to enable the global observation of small climate trends [2].

Metrology can provide expertise and a sound basis for the reliable monitoring of the ECVs over the long timescales needed to detect and understand climate trends.

The Global Ocean Observing System (GOOS), a programme of the Intergovernmental Oceanographic Commission (IOC) of UNESCO, has similarly defined Essential Ocean Variables (EOVs), including both the GCOS oceanic ECVs and additional EOVs that support the economic and social applications of the ocean system and has established a framework for ocean observing centred on EOVs [3]. It is a sustained collaborative system of ocean observations, encompassing *in situ* networks, satellite systems, governments, UN agencies and individual scientists.

The European Association of National Metrology Institutes (EURAMET) [4] has recently established European Metrology Networks (EMNs) to support its vision to ensure that Europe's metrology capability meets the rapidly advancing needs of end users. The European Metrology Network for Climate and Ocean Observation (ClimOcNet) is one of the first six EMNs established by EURAMET.

EMNs will analyse the European and global metrology needs and address these both in coordinating the research and services of European metrology institutes and in providing a single point of contact for information, to underpin regulation and standardisation and to promote metrological practice [5].

Fig. 1. The EMN for Climate and Ocean Observation logo

II. METROLOGICAL REQUIREMENTS FOR EOVs OBSERVATIONS

GCOS recognises the importance of metrology and, in 2010, a Memorandum of Understanding was established between the World Meteorological Organization (WMO) and the Bureau International des Poids et Mesures (BIPM), to promote metrology into environmental observation.

The accuracy requirements specified by GOOS for the EOVs are, in many cases, difficult to achieve even in a laboratory and need to be carried out also in environmental conditions. To provide robust, interoperable and long-term data records of EOVs, GOOS must be underpinned by all the core metrological principles. At present, robust metrological methods are not routinely applied to many EOV observations, but there is a growing recognition by the observation communities in the value that metrology can provide in this field.

The marine communities already collaborate with European and international organisations, usually covering several EOVs. However, this integrated landscape is lacking a multidisciplinary and coordinated approach to providing metrological traceability, comparison and uncertainty evaluation to the EOV observations.

III. THE EUROPEAN METROLOGY NETWORK FOR CLIMATE AND OCEAN OBSERVATION

The Memorandum of Understanding of ClimOcNet was signed in May 2019. The new established EMN held its first meeting in June 2019. The EMN is structured in three technical sections: Atmosphere, Ocean, Land and Earth. The thematic areas broadly correspond to the divisions of the GCOS ECVs and principal observational techniques.

A. Atmosphere

The Atmosphere Observation Section supports *in situ* surface, upper air and composition measurements of the GCOS Atmospheric ECVs. These include measurements of gases, aerosols, water vapour and properties of clouds, together with physical ECVs such as temperature, pressure, wind speed and direction.

B. Ocean

The Ocean Observation Section covers the metrological contribution to support *in situ* measurements of GCOS Oceanic ECVs along with the broader GOOS EOVs. These include physical (e.g. temperature, salinity, currents, ice), biogeochemical (e.g. dissolved gases and nutrients, acidification, particulate matter and tracers) and biological (e.g. phytoplankton, ocean sound) variables. The Ocean Observation Section reflects the broader variety of economic, social, and environmental perspectives relating to the oceans.

C. Land and Earth

The Land and Earth Observation Section covers the metrological contribution for *in situ* measurements of the GCOS terrestrial ECVs (hydrology, cryosphere, biosphere and human resource use), along with the remote sensing observations of ECVs in all three GCOS categories: Land, Ocean and Atmosphere.

IV. A FOCUS ON THE OCEAN SECTION

The oceans cover 71 % of the earth's surface. Oceans regulate the earth's climate and have absorbed almost 93 % of the enhanced anthropogenic greenhouse warming so far [6]; in doing this they have also been disproportionately impacted by climate change: sea levels have risen, changing coastlines, the oceans have become warmer, more acidic and with increased ocean stratification. They also serve as a natural sink for carbon emissions, with half of the photosynthetically absorbed emissions and thus a ¼ of those emitted, being locked into the Ocean through phytoplankton and algae or direct diffusion. These changes have altered ecosystems and increased the vulnerability of many marine species. Oceans are also a crucial source of food, water, energy and minerals for human life, and are a medium for transport (90 % of goods are shipped by sea), recreation and commerce. The value of marine activities is about 5 % of the global GDP, expecting to reach around US$ 3 trillion by 2030 through sustainable growth (the value following an unsustainable scenario is smaller) [7]. The European Union's Integrated Maritime Policy focusses on 'Blue Growth' – harnessing the potential of Europe's oceans, seas and coasts to stimulate economic development within the environmental boundaries of the ocean ecosystems that sustain that growth.

The marine communities collaborate in national, European and international organisations, usually covering several EOVs. Generally, the development of measurement systems and observational infrastructures are well coordinated, essentially because these structures are multidisciplinary and interconnected and must deliver data serviceable to every organisation member and to policymakers. However, this integrated landscape is lacking a multidisciplinary and coordinated approach to establish fundamental metrological concepts in EOV observations. Therefore, the ocean section of the EMN aims to support the oceanographic community with improved SI traceability for ocean ECVs and EOVs, quality assurance tools (e.g. reference materials, interlaboratory comparisons, uncertainty calculation, accreditation schemes), as well as training for scientific communities in metrology.

V. EXPECTED OUTPUTS OF THE EMN

European National Metrology Institutes (NMIs) and Designated Institutes (DIs) (i.e. members of EURAMET) can become members of the EMN, while any other interested organisation can become a partner of the EMN.

At present, 20 European NMIs and DIs are involved in ClimOcNet, together with more than five partner institutes. During the first year of EMN, several activities were carried out:

- a stakeholder needs review survey and report, that describes the stakeholder needs for metrology in the observation and use of ECVs and EOVs;
- a first stakeholder workshop in February 2020 (in webinar form); a second workshop is foreseen for 2022;
- a collated set of training material to teach the principles of metrology to the observation communities, and communication material to present the concepts of metrology to different stakeholder communities were prepared.

The establishment of a single point of contact for metrology support for climate and ocean observation with a website that presents European metrological capabilities is ongoing. The website will provide information for the end-users (e.g. stakeholder needs review report, training material).

Some of the main expected outcomes of the EMN activities are the establishment of metrological principles for *in situ* and space-based measurements, improved SI-traceable measurement techniques and reference standards for *in situ* and satellite observations, development of the skills of a greater number of scientists in both observations and metrology.

VI. STAKEHOLDER NEEDS REVIEW

Several measurement challenges for ocean observations were identified from the stakeholder needs review survey carried out within the framework of the EMN activities.

Several initiatives have been initiated to establish internationally agreed **quality assurance criteria, best practice guides and standards** [8].

An international group of experts endorsed by the International Oceanographic Data and Information Exchange (IODE) of the IOC to review ocean best practices stated that a first and foremost requirement for collaboration in ocean observing is the need to follow well-defined methods [9]. A first answer to these needs has been the creation of the Ocean Best Practices System (OBPS). [10]

Despite these efforts to establish internationally agreed quality standards, still it seems that fundamental metrological concepts are often not considered. For instance, quality criteria have been defined for EOVs by the concerned panels and correlated institutions of GOOS, but there are rather general demands for the assessment of the measurement method in terms of its technical maturity and a flagging system to exclude bad data, instead of using concepts as metrological traceability and measurement uncertainty to qualify measurement results. Measurement uncertainty is rather understood as the accuracy of a device as stated by the manufacturer. A fundamental point would consist in moving forward from best practice guidance documents and standard measurement procedures to **international documentary standards**, which can provide longer stability of measurement procedures over time.

The European Ocean Observation System (EOOS) Strategy and Implementation Plans [11, 12] further describe the importance of involving metrologists in developing “best practice” for the “systematic harmonisation of ocean observing in Europe”. The European Union’s Joint Programming Initiative: “Healthy and Productive Seas and Oceans” (JPI-Oceans), stated in its report on the need for EOOS [13], that all the incoming data have to be comparable and amenable to fitness-for-purpose assessments in relation to specific user-group requirements, to be useful for research and decision-making at a transnational level. To reach this goal, measurements will require to be metrologically traceable (i.e. linked to international and agreed references), but at present, such metrological traceability is limited to some EOVs.

In fact, apart from the EMN for Climate and Ocean observation, there is currently no definitive coordination on metrological issues for the oceanographic sector in or outside Europe that addresses the need to establish metrological concepts. Some respondents of the survey stressed the benefits of the interaction between the metrology community and the oceanographic community, but stronger interactions were requested.

The development of a **metrologically based QA/QC framework** and associated tools to facilitate field measurement reliability and consistent uncertainties also represents a challenge.

The EOOS Strategy 2018 – 2022 document [11] also stated that “data do not always meet user needs: despite the availability of relevant European ocean data, many are not used for environmental assessments (e.g. within the context of the Marine Strategy Framework Directive) due to lack of data provenance, low quality control and accreditation".

To ensure data quality with respect to internationally accepted quality standards, a few oceanographic institutes are implementing metrological principles in their quality assurance systems. In some cases, they are (considering) embedding the quality assurance of EOV measurements into existing national accreditation systems that, in turn, are embedded in European and international accreditation structures like the European Accreditation (EA) and the International Laboratory Accreditation Cooperation (ILAC). Institutions seeking accreditation for the measurement of specific EOVs would have to give evidence that their measurements are performed in compliance with international standards, e.g. ISO/IEC 17025 [14] for calibration laboratories or ISO 22013 [15] for sensor producers, which include metrological requirements like metrological traceability and uncertainty evaluation.

Another fundamental aspect is the **definition of proper measurands** and fit-for-purpose high order and working standards that ensure unbroken SI-traceable calibration chains. Currently, some of the EOV are not defined in term of SI units. This makes difficult to compare results obtained in different time and places, particularly when technology breaks occur.

Ocean observation provides data in support of decision-making for societal benefit, but comparability of these datasets is often lacking. Clear definitions of measurands and definition of traceability chains are needed for most of the EOVs. Moreover, suitable reference materials and common methodologies for uncertainty evaluation, including all influencing factors, are also missing, according to several respondents to the stakeholder survey.

Certified reference materials are essential tools to ensure the metrological traceability of results via the calibration of instruments, or to validate analytical measurement methods. Currently, very few reference materials exist for some of the ocean ECV and EOV and most of them are not certified by NMIs/DIs.

Fit-for-purpose **uncertainties for *in situ* measurements** are needed. For measurements done in real conditions and *in situ* all the factors influencing the final results have to be taken into account, and several factors may have a larger impact than the calibration step. Develop *in situ* calibration for instruments mounted on research vessels could ensure that environmental influences and their uncertainty contribution are taken in account.

In *in situ* observations, the reference networks provide a robust SI-traceable reference at their locations, but it is important that lower quality observations, and local low-cost sensor data can be combined with these reference observations to create a single observational system.

Uncertainty analysis is also crucial when dealing with modelling used in climate and ocean observation. Models are used to interpret observations, to compare different types of observation, transform measurands to bio-geo-physical parameters and to bring observations into reanalyses and prediction models.

Oceanographers combine data from observations with their models through a process of "data assimilation". Such methods use the difference between models and measurements to inform model parameters. To provide the right weighting to such differences, and to understand potential biases, it is necessary for the observations to be provided with robust uncertainty analyses.

A strong community requirement that has come up in the survey and in the stakeholder workshop is for metrology to support the **standardisation of a metrological vocabulary** for observations. In many cases, papers and reports by the different communities involved in climate and ocean observations, confuse the terms "error" and "uncertainty" and are inconsistent in the use of terms such as "bias", "noise", "random and systematic" etc.

During the discussions at the first EMN stakeholder webinar, it was recognised that in some countries there are missing or badly distributed capacities, including data management capacities. Trainings for countries with fewer capacities and a better coordination on data quality issues with these EU and international infrastructures are needed.

In addition, the organisation of interlaboratory comparisons for *in situ* measurements to establish 'degrees of equivalence' and biases could support international interoperability and harmonisation for long term comparability.

In conclusion, it must be underlined that the landscape of ocean observation is rather diverse, as there are currently over 30 EOVs. While metrological concepts are well established in some oceanic institutions, others are not aware of them. Therefore, the general needs of ocean observation summarised above cannot readily be applied to any EOV and each ocean measurand must be assessed individually.

VII. CONCLUSIONS

The establishment of a European Metrology Network for Climate and Ocean Observation aims to provide a single point of contact for European metrology in supporting climate and oceanographic observations.

A long-term sustainable European metrology infrastructure is fundamental to support the global understanding of climate change and the sustainable use of the oceans.

Apart from the EMN for Climate and Ocean observation, currently there is no definitive coordination on metrological issues for the oceanographic sector in or outside Europe that addresses the need to establish metrological concepts.

Some respondents of the survey stressed the benefits of the interaction between the metrology community and the oceanographic community, but stronger interactions are requested.

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