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NEW CHALLENGES IN ENVIRONMENTAL METROLOGY

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Abstract: An overview is given on metrology for climate observation needs. The focus is put on remote monitoring of the Earth system. Global observation can be carried out terrestrially, seaborne, airborne and from space. It can provide the necessary information to support politics in deciding appropriate climate change mitigation strategies. However, harsh measurement environments in space, air or seaborne applications limit the uncertainty of measurement results currently attainable. In the specific case of climate observation this is often a factor of ten larger than required. The metrological challenges of a reliable earth observation for climate change detection and verification are discussed.

Keywords: Climate change, earth observation, remote sensing, ocean salinity

1. INTRODUCTION

Climate change is one of the greatest challenges of our time. There is unequivocal evidence that climate change and global warming are already happening and have significant effects on the earth and society. Last decade, the issue of climate change has arrived at the top of the global political agenda. The Kyoto Protocol obliges cuts in greenhouse gas emissions averaging at least 5.2 percent below 1990 levels during the period 2008-12 [1]. The agreement of the UN Climate Change Conference in Copenhagen 2009 (COP15) recognizes the scientific view that the increase in global temperature should be kept below two degrees Celsius to avoid dramatic problems in adapting our life to a fast changing environment. It also calls for a review of the accord by 2015, along with a consideration of strengthening the long-term goal “in relation to a temperature rise of 1.5 degrees Celsius.”[2] The outcome of the United Nations Climate Change Conference, Durban 2011(COP17 and CMP 7) included a decision by Parties to adopt a universal legal agreement on climate change as soon as possible but not later than 2015 [12].

Climate change is often discussed as a process, which should be mitigated on a global scale. Mitigation strategies therefore are a main focus of the post Kyoto activities as agreed at the United Nations Climate Change Conference in Cancun 2010, COP 16 / CMP 6 1 [3]. The Cancun Agreements include a comprehensive package to help developing nations to deal with climate change, including a Technology Mechanism, Adaptation Committee and the Green Climate Fund in order to scale up the provision of long-term financing for developing countries. Governments also agreed to the long-term global goal of limiting the average global temperature rise below 2 degrees Celsius. To move toward low-carbon economies developed countries agreed to develop low-carbon strategies, while developing countries were encouraged to do so. For 2011, governments want to focus on details of a deal to set up a Green Climate Fund, measures to combat deforestation and ways to adapt to climate change, as agreed in Cancun [4]. During the preparatory conferences of the Rio20+ summit (United Nations Conference on Sustainable Development) „Global Environmental Governance“ and „Greening the Economy“ has been identified as core issues for the future [16].

Effective and meaningful policy needs to be based on sound science. Nowhere is this more important than in terms of the review of the adequacy of the long-term global goal. The Cancun Agreements call for this review to be guided by best available scientific knowledge, including from AR52, the observed impacts of climate change and an assessment of overall aggregate efforts by Parties. The review is scheduled to commence in 2013 and should be concluded by 2015, when Parties will consider strengthening the long-term global goal, including in relation to a 1.5 degree goal. In May 2012 the Intergovernmental Panel on Climate Change, IPCC, agreed and released a Special Report on Renewable Energy Sources and Climate Change Mitigation (SRREN)[13]. The IPCC Special Report on Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation (SREX), was approved and accepted by the Intergovernmental Panel on Climate Change (IPCC) in November 2011 in Kampala, Uganda.. This report will make an important contribution to the work of the newly created adaptation institutions, once they become fully operational [5].

However, still many aspects of the global climate system are not yet completely understood and, therefore, disputed both by the public, the politics and the economy. A reliable scientific research input is really critical for implementing international commitments of states and for their willingness to address the challenges related to the above objectives.

[1] Sixteenth session of the Conference of the Parties (COP 16); Sixth session of the Conference of the Parties serving as the meeting of the Parties to the Kyoto Protocol (CMP 6)

[2] AR5: 5th Assessement Report of the Intergovermental Panel on Climate Change IPCC

2. EARTH OBSERVATION FOR CLIMATE CHANGE

Only global observation from space can provide the necessary information to support politics in the development of appropriate mitigation strategies to respond to climate change.

Projects to use very high resolution optical satellite sensor data started in the late 90s and are believed to be the major driver for the commercialization of earth observation [6].

Currently, the harsh and challenging environment of space limits the uncertainty of measurement results attainable from remote monitoring. In the specific case of climate this is often a factor of ten larger than required by the community [7].

Relevant key uncertainties involve the role of air humidity in the atmospheric water cycle; the sea-level rise; sources, sinks and transport within the carbon cycle; reliable spectral data for remote sensing, and the impact of anthropogenic aerosols. Reducing these knowledge deficits and uncertainties will assist governments and international organizations to adopt more effective policies for mitigating, and adapting to climate change.

There is an increasing need to accurately measure and interpret small changes in the state of the environment on a climatic time scale. This, however, requires internationally accepted, traceable measurement standards with lower uncertainties and precisely monitored and well-controlled long-term stability. Many of the challenges faced by climate change forecast are measurement challenges, such as, for example assessing the sinks and sources of greenhouse gases or assessing the spectral absorption properties and effects of these gases or other trace atmospheric constitutes, and the resulting changes in surface and atmospheric temperature or chemical composition of the atmosphere. Main areas which require the support of metrology are: Long term stable trend monitoring in the atmospheric overall composition, standards and calibration methods for the measurement of greenhouse gases (GHG), atmospheric trace species and air humidity as well as general support of earth-system science. The latter includes earth observation and remote sensing from space as well as in-situ sensing platforms like balloons, aircrafts, buoys or ships.

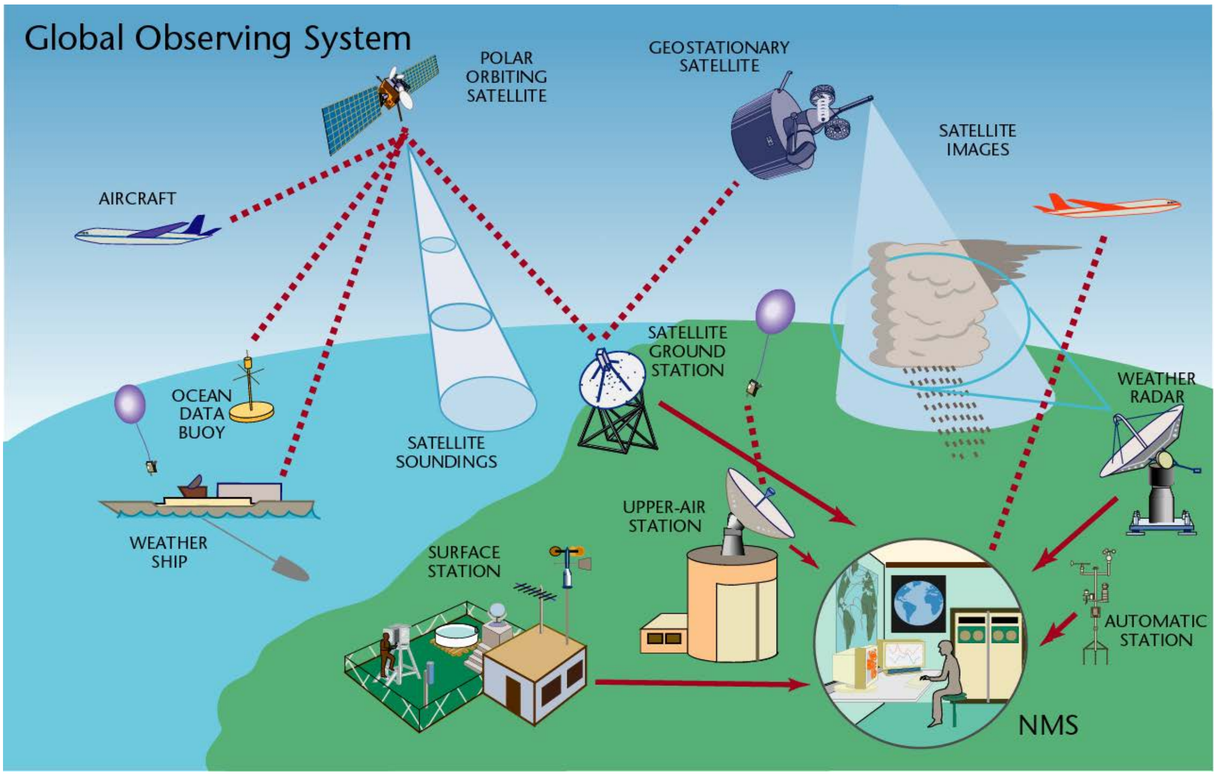

Fig.1 Overview on the current active Global Observation System from Dr W. Zhang, WMO Presentation @ 10 year anniversary of the CIPM MRA , Paris, France 10-MRA

3. QUALITY ASSURANCE FRAMEWORK OF EARTH OBSERVATION

In the case of satellites, improvements in uncertainty and traceability are needed throughout all stages of data production: pre-flight and post-launch calibration and validation as well as all intermediate processing steps. The technical scope required spans the full electro-magnetic spectrum from THz to the UV and entails the evolution of laboratory-based metrology into field (and space) situations whilst maintaining and in some cases improving the uncertainty available from existing primary standards and facilities [7].

Therefore, an establishment of pre-flight as well as post-launch calibration procedures which are traceable to internationally agreed reference standards is one of the most urgent metrological challenges. Novel calibration systems providing traceability will allow the comparison between various national/regional and field monitoring systems, measurement techniques and data acquisition systems operated worldwide in steadily growing observation networks. Novel in-flight calibration strategies allowing traceability to the SI in space or airborne applications are a fascinating vision of the metrology community. International attempts to tackle this goal are discussed.

One example is the Quality Assurance Framework for Earth Observation (QA4EO) which has been endorsed by the Committee on Earth Observation Satellites (CEOS) as a contribution to facilitate the Group on Earth Observations (GEO) efforts for a Global Earth Observation System of Systems (GEOSS). To set up GEOSS [9] is part of the ten years implementation plan of the Global Climate Observation Service Implementation Plan for the period from 2005 through 2015. The goal of GEO is to establish GEOSS in recognition that no nation or even region has the resources to enable or provide the full operational coverage that is needed for a global Earth observing system, let alone one with the accuracy needed for climate. It is thus clear that to achieve this vision requires full harmonised interoperability not only between similar sensors from different agencies but also across different spectral and technological domains e.g. optical and microwave as well as the observing location/platform: space, air, and ground. This requires the assessment and assignment of an internationally harmonised performance or quality indicator to all data products [7]. The core principle of the quality framework established by QA4EO is that data and derived information products must have associated with them a quality indicator (QI) based on documented evidence of its degree of conformity to community defined, ideally SI, traceable reference standards [8].

4. COOPERATION BIPM-WMO

World Meteorological Organization (WMO) and the *Bureau International des Poids et Measures (BIPM)*recognized in the jointly hosted international workshop on Measurement Challenges for Global Observation Systems for Climate Change Monitoring (in spring 2010) the urgent demand for SI-traceable measurement results obtained by global observing systems. During this workshop, a WMO-CIPM mutual recognition agreement, MRA, was signed "…to ensure that data, related in particular to measurements of state and composition of atmosphere and water resources… are poorly based on units traceable to the SI…"[10].

Important objectives and conclusions of this workshop and the 2012 follow-up WMO-BIPM liaison group meeting apply for example to spectroscopic background of remote sensing technologies, the long-term comparability of oceanic salinity and pH measurements, as well as establishing comparability in atmospheric humidity, and their traceability to the SI. At present, numerous remote sensing technologies are used in the observation for about one third of the essential climate variables (ECVs) of the International Climate Observation System (GECOS). Assessing climate change will depend crucially on the uncertainties associated with such measurements, the robustness of the derived climate data and their compliance with the internationally agreed climate monitoring principles of the Global Climate Observing System (GCOS). Measurement uncertainties can only be determined and hence minimized, if proper consideration is given to the metrological traceability of the measurement results to stated standards.

Fig.3 Michel Jarraud, Secretary General of the WMO, signed the Arrangement on behalf of the WMO. He is pictured below with Andrew Wallard (Director of the BIPM) and Ernst Göbel (President of the CIPM), accompanied by his WMO colleagues Len Barrie and Wenjie Zhang.

Stringent requirements for the stability of primary measurement standards remain a key objective for the WMO in order to meet data quality objectives. WMO now collaborates with BIPM and relies on its services to meet these objectives. Examples are the surface and ocean in situ observing networks, tropospheric and upper-air networks, the surface remote sensing (Radar) networks, the airborne observations and the satellite constellations.

For example, the activities of Central Calibration Laboratories and World Calibration Centres within the WMO Global Atmosphere Watch (GAW) Programme, or the World Radiation Centre within the WMO World Weather Watch Programme, have been important components of the quality assurance programme for key atmospheric and environmental measurements. These activities have been the recent focus of increased collaboration between the meteorology and measurement science communities to ensure, within the framework of the WMO Integrated Global Observing System, WIGOS, the development of standards and the delivery of highly accurate data for atmospheric and climate monitoring in support of the implementation of the Global Framework for Climate Services WIGOS, which was established in 2009 [10].

The major components of the WIGOS framework are the Global Observing System (GOS), the Global Atmospheric Watch (GAW) and the WMO Hydrological Global Observing System (WHYGOS). The WIGOS framework facilitates standardization and interoperability with co-sponsored systems (GCOS, GOOS and GTOS, etc). This will lead to better understanding of the Earth's environmental system and result in the delivery of improved and expanded services such as weather forecasts, climate outlooks or expanded advice and services to society.

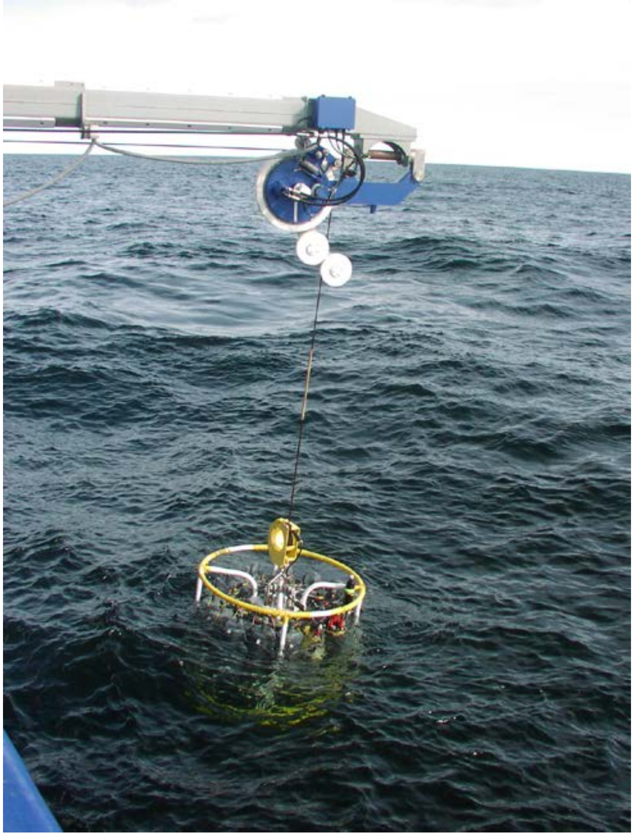

Fig3. A Conductivity-Temperature-Depth probe CTD, is the workhorse of marine scientists. Oceanographers use CTD´s to measure vertical variations in temperature and salinity of seawater. From that information, they can deduce ocean circulation. One task of the EMRP project ENV05 is to improve the long term comparability of the measurement results by ensuring SI traceability. The photo was taken from research vessel "Professor A. Penck" at the Baltic Sea in March 2010 by R. Feistel.

WIGOS is an all-encompassing approach to the improvement and evolution of WMO global observing systems. It will foster the orderly evolution of the present WMO global observing systems into an integrated, comprehensive and coordinated system. It will satisfy, in a cost-effective and sustainable manner, the evolving observation requirements of WMO Members, while enhancing coordination of the WMO observing system with systems operated by international partners [11].

The concept of metrological traceability is achieving an increasingly higher profile in the planning of climate monitoring systems, but, much work remains to be done to ensure that future climate science is based on the most robust metrology currently achievable across all measurements. These topics were discussed during a follow-up WMO-BIPM liason group meeting in February 2012 in Geneva. One issue of current interest is the world-wide uniformity and long-term comparability of spectral signatures used for global remote sensing, of oceanic salinity and pH measurements , as well as the absolute analysis of atmospheric humidity, and their traceability to the SI.

Water in its three ambient phases is the unrivalled key substance in the complex dynamical system of the terrestrial climate. Observing and modelling the global and local transport processes of water between all global compartments (atmosphere, hydrosphere, cryosphere, biosphere and pedosphere) is central for the understanding and predicting global warming. Water vapour in the atmosphere is by far the strongest greenhouse gas which controls not only the atmospheric radiation balance but also the oceanic export of latent heat, the temporal and spatial dynamics of clouds and the formation of drinking water. Melting polar glaciers not only raise the global sea level but also influence the surface salinity distribution. Trends in global humidity, evaporation and precipitation can also be measured in the form of small anomalies of the sea-surface salinity [14].

The very wide application of optical sensing technologies for the investigation of spatio-temporal dynamics of atmospheric chemistry indicates the critical importance of such technologies. Spectrometric techniques are indispensable, extensively used tools for environmental monitoring and remote sensing networks and commonly used for ground-based, airborne and satellite platforms. Quality, accuracy and traceability of these spectrometric techniques completely depend on the accuracy and traceability of the underpinning molecular spectral data, which often show a strong dependence on pressure and temperature. The wide range and strong spatio-temporal variability of atmospheric pressure and temperature thus causes significant problems for remote sensing. Considering the impressive size of existing and planned global atmospheric monitoring networks and the large number of satellites dedicated to environmental monitoring, each of which costs in the range from 100 M€ to a few G€, a global and urgent need for high quality spectral data and for long-term infrastructures to precisely determine such data is imminent. The need for such high quality data is even more required as early climate change detection or climate model validation require to accurately monitoring small changes on large background signals over time spans of months, years and even decades. Hence, data traceability of spectral data is absolutely essential in order to ensure comparability in remote sensing over long time scales or different instruments types used in global sensor networks

5. CONCLUSIONS

Te provision of new measurement technologies and standards that support the capability to monitor the environment and to mitigate and adapt to climate change requires a multi-disciplinary and collaborative approach. The 2010 Call on Metrology for Environment of the European Metrology Research Program (EMRP) opened the possibility for the European metrological community to strengthen its efforts in developing the necessary metrological infrastructure. Through the EMRP, the

European National Metrology Institutes and Designated Institutes are empowered to coordinate and collaborate with each other for achieving maximum impact of modern metrology. This enables them to underpin the international effort in defining environmental objectives and standard within the post-Kyoto process. Within the 2010 European Metrology Research Project (EMRP) call environment five of nine of the Joint Research Projects (JRP) are related to climate change. These are the following joint research projects [15]:

ENV03 Traceability for surface spectral solar ultraviolet radiation

ENV04 Traceable radiometry for remote measurement of climate parameters

ENV05 Metrology for oceanic salinity and acidification

ENV06 Spectral reference data for atmospheric monitoring

ENV07 Metrology for pressure, temperature, humidity and airspeed in the atmosphere

The JRP s recognises that there is a need to establish greater coordination and focus more effort on the underpinning metrology that is needed to realise a practical, efficient and cost effective means of establishing “fit for purpose“ traceability for the European Earth observation community.

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