Metrological challenges in earth observation

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Abstract – An overview is given on relevant climate observation needs. The main focus is on the use of remote monitoring of the Earth system. 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. The harsh environment of space limits the uncertainty of measurement results currently attainable from remote monitoring. In the specific case of climate this is often a factor of ten larger than required by the community. The necessity for reduced uncertainty has move forward the implementation of metrological traceability by the GEO (Group on Earth Observation) community. As a consequence a Quality Assurance framework (QA4EO) has been established to facilitate interoperability of GEO systems.

The metrological challenges of a reliable earth observation for climate change detection and verification are discussed.

Keywords Climate change, earth observation, remote sensing, traceability

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 having significant effects on the earth and human being. 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) recognize 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] 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 61 [3]. The Cancun Agreements include a comprehensive package to help developing nations 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 average global temperature warming 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].

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 degrees goal. In November 2011 the Intergovernmental Panel on Climate Change, IPCC, will issue a Special Report on Renewable Energy Sources and Climate Change Mitigation (SRREN). IPCC Special Report on Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation, which is in the final stages of preparation, 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.

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.

[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: fith Assessement Report of the Intergovermental Panel on Climate Change IPCC

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].
Today, 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 the clouds, the sea-level rise, the carbon cycle and the impact of human-caused aerosols. Reducing these knowledge lacks and uncertainties will assist governments and international organizations to adopt more effective policies for mitigating, and adapting to climate change.
The need for accurately interpreting small changes in the state of the environment on a climatic time scale requires internationally accepted traceable measurement standards with lower uncertainties and monitored and maintained 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, assessing the spectral absorption effect of these gases, and the resulting changes in surface and atmospheric temperature. Main areas which require the support of metrology are long term stable monitoring of trends in the overall atmospheric composition, standards and calibration methods for the measurement of greenhouse gases (GHG) and atmospheric species and the support of earth-system science. The latter includes earth observation and remote sensing from space and in-situ.

3. A 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 and all the intermediate processing steps. The technical scope required spans the full electro-magnetic spectrum and entails the evolution of laboratory-based metrology into field (and space) situations whilst maintaining and in some cases improving the uncertainty available from nominally primary standards and facilities [7].

Therefore establishment of pre-flight as well as post-launch calibration which is 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 monitoring systems, measurement techniques and data acquisition systems operated worldwide. Novel in-flight calibration strategies allowing traceability to the SI from space are a fascinating vision of the metrology community. International attempts to tackle this goal are discussed.

One example is the Quality Assurance Framework of 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. Climate is one of the driving forces of this plan. The goal of GEO is to establish GEOSS is recognition that no one nation or even region, has the resources to enable it to 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 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 knowledge 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

Recognizing the demand of getting SI-traceable measurement results obtained by global observing systems, in spring 2010 the World Meteorological Organization (WMO) and the Bureau International des Poids et Measures (BIPM) jointly hosted an international workshop on Measurement Challenges for Global Observation Systems for Climate Change Monitoring. During this workshop, a WMO-CIPM 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 apply for examples to remote sensing technologies. At present, remote sensing technologies are used in the observation of 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 measurements and the robustness of climate data and their compliance with the internationally agreed climate monitoring principles of the Global Climate Observing System. 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.

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. Examples are the surface and ocean in situ observing networks, the upper-air networks, the surface remote sensing (Radar) networks, the airborne and observations and the satellite constellations.

For example, the activities of Central Calibration Laboratories and World Calibration Centres within the WMO Global Atmosphere Watch 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, 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].

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

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 observing 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 a 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.

3. CONCLUSION

The 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. The JRP "Towards a European Metrology Centre for Earth Observation and Climate (EMCEOC)" 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. To build a long-term evolving and sustainable set of capabilities, infrastructure and expertise with minimal duplication requires a "European centre of excellence". The long-term goal of this project is to establish a virtual European Metrology Centre for Earth Observation and Climate (EMCEOC) [7].

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