

Session II: Carbon measurement and other related climate variables: Global systems, principals and traceability

Pre-submitted Abstracts for Discussion Sessions:

1. The Role of WMO in Developing a Space-Based Architecture for Climate Monitoring,
Wenjian Zhang, Jérôme Lafeuille and Stephan Bojinski (WMO)
2. Overview of the 'Metrology for Climate' Workshop
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3. Coordination of U.S. Civil Earth Observations: Assessing Earth Observations for Societal Benefit and Greenhouse Gas Monitoring
Christopher Clavin, Jason Gallo (IDA)
4. METROLOGY ISSUES IN ESTABLISHING A CLIMATE REFERENCE UPPER AIR NETWORK
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6. Traceability of Greenhouse Gas Measurements within the Global Atmosphere Watch Programme: Results from the World Calibration Centre WCC-Empa,
Christoph Zellweger, Martin Steinbacher, Lukas Emmenegger, Brigitte Buchmann (Empa)
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Franz Josef Maringer (BEV)
8. Metrology for High Impact Greenhouse Gases
Paul Brewer (NPL)

Title: The Role of WMO in Developing a Space-Based Architecture for Climate Monitoring

Speaker: Wenjian Zhang, Jérôme Lafeuille and Stephan Bojinski

Institute: WMO

Abstract:

The development of an architecture for climate monitoring from space, formally initiated by the Sixteenth World Meteorological Congress (Geneva, 2011), received immediate response and strong support from space communities, including the Committee on Earth Observation Satellites (CEOS), the Coordination Group for Meteorological Satellites (CGMS), national space agencies, satellite operators. The architecture, respond to WMO Members' requirements and the requirements from WMO sponsored climate programmes and initiative like the Global Framework for Climate Services (GFCS), Global Atmosphere Watch (GAW), Global Climate Observing System (GCOS), and the World Climate Research Programme (WCRP), as well as broader user community (for example, Global Earth Observation Systems of Systems (GEOSS)) requirements on climate monitoring, calls for strengthening and enhancing international collaboration that ensures delivery of these observations over the time frames required for both: analysis of the Earth's climate system variables (including major GHG: CO₂, CH₄, H₂O, N₂O, O₃, etc.) over long-term, and monitoring climate extreme events in near real time. The architecture will initially build upon a constellation of research and operational satellites currently existing or planned programmes by space agencies, supported by open data-sharing policies, contingency planning, surface observations for validations and user interface seeking feedback, monitoring deliverables and meeting user-service needs. The task of climate monitoring, however, has requirements that must extend beyond the capabilities of one-time research missions and operational satellite systems in existence today. The role of WMO in developing the space architecture for climate monitoring will mainly the following: 1) Requirements Anylysis and Consolidation: to set broader requirements for climate monitoring by consolidating the requirements from climate programmes and initiatives like IPCC, GFCS, GCOS and WCRP; 2) Promotion of climate data and products policy: The WMO 66th Executive Council (June 2014), adopted a resolution on "Exchange of data and products to support the implementation of the GFCS" with an annex defining climate relevant "essential data" for the purposes of implementing Resolution 40 (Cg-XII) and Resolution 25 (Cg-XIII); 3) Coordination on Space capability assessment, planning and implementation: WMO Space Programme will work together with CEOS and CGMS to define future CGMS baseline and CEOS Virtual Constellation meeting the needs of climate monitoring requirements, detailing missions and instrumentations, and coordinating the implementation; (iii) Fostering the collaboration with broader international partners and stakeholders, like BIPM, GEO etc., for building synergies of different technologies, including the integration of the surface-based with space-based observations by taking the advantages of the comprehensive surface observing networks from WMO Members, partners new technological development, and on-going as well as future space activities. 4) Data management, access and dissemination: The role of WMO Information System (WIS) in the space architecture development is to ensure timely accessibility of observations and products in compliance with agreed interoperability standards. Metadata, catalogue interfacing, and formats should be standardized in compliance with the WIS standards for WMO Members. 5) User interface and Feedback: WMO as an organization will be a natural user interface with its Members as the key end users community for climate monitoring and services should be maintained in order to seek feedback, monitor deliverables and use the products from the architecture for climate monitoring services. All WMO Members, relevant WMO Programmes, relevant UN agencies, international agencies & organizations and the general public, will benefit from the development of the architecture by using more timely products and information of climate monitoring from space.

Title: Overview of the ‘Metrology for Climate’ Workshop

Speaker: Nigel Fox

Institute: NPL

Abstract:

By the time of the BIPM conference, NPL will have run a workshop on ‘Metrology for Climate’ and I can update delegates on the outcomes of this workshop. The concept of ‘Essential Climate Variables’ (ECVs) provides a crucial systematic framework of variables to facilitate the monitoring and understanding of climate change. The ability to reliably detect trends from a background of natural variability requires decades of measurements, each with robust uncertainty estimates to enable the necessary long term Climate Data Records (CDRs) to be established. To generate trustable and robust climate data, it is essential that the metrology community develops a work programme to ensure its research outputs address the highest priorities in a timely manner. Early cross community dialogue is needed so that resources can be coordinated and allocated appropriately. There is, therefore, a need to prioritise each ECV based on its current level of focus from the metrology community and its potential impact to our understanding of climate change. The presentation will discuss the outcomes of an ECV prioritisation exercise with stakeholders. It will also suggest how this output can help the Earth Observation community to steer new research activities, prioritise investment and establish mechanisms for future interactions.

Title: Coordination of U.S. Civil Earth Observations: Assessing Earth Observations for Societal Benefit and Greenhouse Gas Monitoring
Speaker: Christopher Clavin, Jason Gallo
Institute: IDA

Abstract:

Globally, the United States Government is the largest provider of environmental and Earth-system data. These data support and provide numerous societal benefits to the U.S. and its international partners. The U.S. Federal Government is responsible for generating, curating, and rapidly disseminating Earth observations data for decision support by a wide range of stakeholders, from local community planners through international climate change researchers. In July 2014, the White House Office of Science and Technology Policy released the first-ever National Plan for Civil Earth Observations. The Plan describes the U.S. Federal Government's approach and priorities for developing sustained and experimental observations for a multiple societal benefits including long-term climate monitoring. Earth observations supporting scientific understanding and the development of operational products that help identify the sources and sinks of greenhouse gases, including changes in short- and long-lived greenhouse gas emissions and concentrations over time are identified in the plan as a sustained Earth observation priority. In developing the U.S. National Plan for Civil Earth Observations, a U.S. Government-wide assessment of Earth observations was conducted in 2012. This Earth Observations Assessment (EOA) provided an objective and analytical basis for identifying the various societal priorities, including greenhouse gas monitoring, of the U.S. Earth Observation enterprise. The 2012 EOA reviewed the impact of 362 observing systems over 13 societal benefit areas spanning priorities such as agriculture and forestry, climate, disasters, terrestrial and freshwater ecosystems, energy and mineral resources, weather, and reference measurements and their associated standards that provide an underpinning for other societal benefit areas. U.S. Federal agencies are currently undertaking efforts to improve upon the EOA 2012 and develop a new EOA that will further identify the role that Earth observations play in supporting societal benefits. This session will provide a detailed overview of the greenhouse gas monitoring priorities described in the U.S. National Plan for Civil Earth Observations, a description of the current status and review of the process for conducting the on-going second Earth Observations Assessment, and provide a integrative review of the multiple types of Earth observations, including non-climate observations, that support greenhouse gas monitoring that identified by this comprehensive assessment approach.

Title: METROLOGY ISSUES IN ESTABLISHING A CLIMATE REFERENCE UPPER AIR NETWORK

Speaker: Tom Gardiner

Institute: NPL

Abstract:

The GCOS Reference Upper Air Network (GRUAN) is an international reference observing network, designed to meet climate requirements and to fill a major void in the current global observing system. Upper air observations within the GRUAN network aim to provide high-quality reference data to establish long-term climate records; improve the quality of data for numerical weather predictions; constrain and validate data from satellite remote sensors; and provide data for the study of atmospheric processes. The network covers measurements of a range of key climate variables. One of the primary goals for the GRUAN measurements is that all data is provided to users with traceable uncertainties. Establishing rigorous uncertainties for measurements in the upper atmosphere presents a significant challenge, particularly given the range of different measurement techniques involved, which include radiosondes, lidars, microwave radiometers, GNSS water vapour and FTIR spectrometers. The presentation will review some of the research activities being undertaken within GRUAN to address this metrological challenge.

Title: IAEA stable isotope reference materials: addressing the needs of atmospheric monitoring,
Speaker: S.Assonov, M.Groening, A. Fajgelj
Institute: IAEA

Abstract:

Stable isotope analyses of atmospheric CO₂ and methane are widely used in order to understand complex processes involved in the carbon cycle and to constrain carbon fluxes. To get reliable data supporting meaningful interpretation, all data of atmospheric monitoring have to be on the same scale and compatible within established limits. Presently compatibility goals for delta C-13 data of air CO₂ and air methane have been set at the level of 0.01 permil and 0.02 permil respectively. These challenging limits can only be achieved through the proper use of reference materials (RMs). Delta C-13 measurements are traditionally based on isotope ratio mass-spectrometry. Recently, optical laser analysers (both for CO₂ concentration and isotopic measurements) become available. Optical CO₂ concentration analysers being more and more in use for atmospheric measurements require a correction for CO₂ isotope difference between reference gases and samples. Therefore all reference gases in use have to be characterised for CO₂ isotopic composition, thus increasing the demand for suitable C-13 RMs.

For practical reasons all isotope measurements are performed on relative delta scales realized through the use of international, scale-defining RMs; in fact all these RMs are artificially chosen selected materials. The VPDB C-13 scale is realised via two international RMs (carbonates NBS19 and LSVEC) maintained and distributed by IAEA. The priority task is to maintain these highest-level RMs at the required level of low uncertainty, ensuring the long term scale consistency. The second complex task is to introduce replacement RMs when needed (currently needed for NBS19 being exhausted), and to do so with the lowest achievable uncertainty. The next task is to produce lower level international RMs (secondary, tertiary) being calibrated via the highest level RMs, and to determine their total uncertainty being traceable to the delta C-13 VPDB scale. There are three most urgent issues to be addressed at IAEA related to delta C-13 reference materials:

- ensuring small measurement uncertainty and long term stability of RMs in use for climate change related measurements and fulfilling associated metrological requirements;
- urgent need for introducing the replacement of NBS19 (delta C-13 scale defining RM), potentially also for LSVEC;
- the need for a range of RMs addressing existing and newly emerging analytical techniques (e.g. optical isotopic analysers) in form of calibrated CO₂ gases with different delta C-13 values.

The presentation will give an overview of the current status of the delta C-13 reference materials, the strategic plan of developments and steps for the near future.

**Title: Traceability of Greenhouse Gas Measurements within the Global Atmosphere Watch
Programme: Results from the World Calibration Centre WCC-Empa,
Speaker: Christoph Zellweger, Martin Steinbacher, Lukas Emmenegger, Brigitte Buchmann
Institute: Empa**

Abstract:

Empa operates the World Calibration Centre for Surface Ozone, Carbon Monoxide, Methane and Carbon Dioxide (WCC-Empa) since 1996 as a Swiss contribution to the Global Atmosphere Watch (GAW) programme. WCC-Empa has conducted over 70 system- and performance audits over the past 20 years. This activity significantly contributes to sustain and improve the data quality required for climate and environmental research. The concept of the performance audits was recently expanded by the addition of parallel measurements with a travelling instrument using an entirely independent inlet system and calibration scheme. This presentation will give an overview of the results obtained during these audits with a focus on measurement capabilities. It will further highlight the advantages of the new performance audit approach based on recent CO₂ and CH₄ comparisons. Results from various stations acquired with different analytical techniques will be compared, and instrumental aspects such as water vapour interference as well as the influence of the calibration interval, data coverage, and aggregation times will be addressed.

References:

Rella, C. W., Chen, H., Andrews, A. E., Filges, A., Gerbig, C., Hatakka, J., Karion, A., Miles, N. L., Richardson, S. J., Steinbacher, M., Sweeney, C., Wastine, B., and Zellweger, C.: High accuracy measurements of dry mole fractions of carbon dioxide and methane in humid air, *Atmos. Meas. Tech.*, 6, 837-860, 2013.

Zellweger, C., Steinbacher, M., and Buchmann, B.: Evaluation of new laser spectrometer techniques for in-situ carbon monoxide measurements, *Atmos. Meas. Tech.*, 5, 2555-2567, 2012.

Title: Metrology for well-established and innovative isotopic measurements in climate change research

Speaker: Franz Josef Maringer

Institute: BEV

Abstract:

Stable and radioactive isotopes are increasingly measured to assess the causes and effects of climate change. The accurate measurement of environmental stable and radioactive isotopes advances in climate monitoring, modelling, prediction and management. The metrological resources for these isotopic applications have been weakly developed so far. Measuring and modelling water flow in the oceans and atmospheric transport models on a global scale by radionuclide tracer applications will contribute to the understanding of possible climate change scenarios. Radionuclide dating techniques are useful tools in the investigation of geological materials, where stable isotope ratios and the relative levels of uranium, thorium and lead isotopes reveal information about climate conditions prevalent at the time of deposition and dating of such materials. Measurements of ice cores reveal data about climate in the more recent past, especially where such cores contain ancient dissolved air. Again, stable isotope ratios are of key importance, but radionuclides arising from cosmic ray irradiation also reveal data concerned with both climate conditions and solar output. At present much data is collected from the Pacific Ocean, where traces of radionuclides from Fukushima reveal the paths of ocean currents (at different depths), which are crucial to understand for climate studies and the radiotracers also help the understanding of uptake in the food chain. The list of other possible measurements is long, but ^{210}Pb , ^{210}Po , ^{81}Kr , ^{85}Kr and ^{39}Ar are examples of radionuclides that can yield important information. Using ^{39}Ar for dating ancient underground water reservoirs would have implications for water resource management. Fossil CO_2 emissions can be monitored by ^{14}C measurements. The same technique can be applied to distinguish between the use of fossil or biofuel which benefit the European guidelines where CO_2 emissions from fossil fuel must be paid for to an increasing extent.

The measurement of radionuclides in environment (i.e. atmosphere, soils, oceans and sediments) provides valuable information on the study of climate change at short, medium and long-term scale. Some key topics are the following:

- The fallout of anthropogenic radionuclides as ^3H , ^{14}C , ^{90}Sr , ^{137}Cs and Pu isotopes can serve to date a number of short-term processes.
- $^{137}\text{Cs}/^{90}\text{Sr}$ ratios can be used to check for seasonal changes.
- The radiotracers ^{41}Ca and ^{45}Ca are used to study calcifying rates in corals and other organisms.
- Cosmogenic radionuclides as ^7Be , ^{10}Be and ^{14}C can help to trace seasonal and long-term atmospheric processes but also to study the influence of solar activity in earth's atmosphere.
- The activity ratio $^{234}\text{Th}/^{238}\text{U}$ is used to assess the organic carbon flow in oceans and sediments.
- Disequilibrium between ^{210}Pb and ^{226}Ra can be used as a chronometric indicator in several processes as rate of marsh accretion.
- The isotopes ^{230}Th and ^{231}Pa produced from the decay of uranium give important information on several key oceanic processes that have affected global climate in the past.
- The isotope hydrology of quaternary climate change can be estimated from the decay of the radioisotopes ^{14}C , ^{36}Cl and ^{81}Kr over timescales comparable to the ice core record.

To support the international climate change research with reliable and traceable measurements, there is an increasing need on metrologically sound reference data, standards, procedures, instrumentation and traceable calibration methods for isotopes important for climate control that require extremely low detection limits. Mass spectrometry, low-level activity measurement techniques and atom trap trace analysis (ATTA) should be also developed based on demonstrated superior selectivity and detection efficiency.

This contribution is based on the submission of a potential research topic PRT in the EMRP call 2013 'Environment II - global metrological challenges for climate control' submitted by 8 European research partners.

Title: Metrology for High Impact Greenhouse Gases

Speaker: Paul Brewer

Institute: NPL

Abstract:

Understanding the chemistry of the atmosphere and the mechanisms that control the levels of the gases involved in radiative forcing are of major global concern. Consequently, there is substantial demand from policy makers to improve our understanding, control the increasing influence of human activity on it and address the effects of climate change. There is a requirement for long-term observations based on accurate and stable standards of the highest impact greenhouse gases to ensure that the data meets the requirements of WMO DQOs compatibility goals, environmental policy makers as well as academic and regulatory users.

We have made significant advances in preparing high accuracy, SI traceable and fully- synthetic gaseous reference standards of carbon dioxide and methane in a whole air matrix. Current research aims to improve the uncertainty and stability of these reference materials by optimising passivation chemistry used in cylinder treatment, making high-accuracy quantification of target impurities in the matrix gas, characterising the isotopic composition of the target component and understanding its influence on measurements made in the field.