BIPM-WMO Workshop recommendations – next steps

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METROLOGY FOR CLIMATE ACTION

Bureau International des Poids et Mesures

WORLD METEOROLOGICAL ORGANIZATION

26–30 SEPTEMBER 2022

1000 Registered participants

200 Pre-recorded presentations producing over

100 Recommendations

Theme 1: Metrology in support of the physical science basis of climate change and climate observations

1. Atmospheric chemistry and physics
2. Oceans and hydrology
3. Earth Energy Balance
4. Biosphere monitoring
5. Cryosphere Monitoring

Theme 2: Metrology as an integral component of operational systems to estimate greenhouse gas emissions based on accurate measurements and analyses

1. Accuracy requirements for atmospheric composition measurements across economic sectors, and temporal and spatial scales
2. State of play in integrated approaches for advanced GHG emission estimates and the way forward to operational services
3. Novel GHG concentration and flux methods and sensors
4. Strengthening the linkage of remote sensing GHG concentration measurements to emission fluxes

Partners

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Report (with recommendations) and presentations available publicly at www.bipmwmo22.org

Number	Issue	Recommendation
1C.1 [a]	**Radiometric Energy Measurements: Uncertainties** Measurements of incoming and outgoing radiant energy lack the uncertainties needed to directly discern an imbalance in the Earth's energy budget, which determines climate change. Total solar irradiance (**TSI**) and globally averaged outgoing Earth radiation both need to be measured to **< 0.03 % standard uncertainties** to discern energy imbalances directly. These uncertainties are achievable for the incoming total solar irradiance but are much lower than those of the outgoing net radiation, which are more difficult due to spanning a broader spectral range, spatial inhomogeneities, and varying angular distributions. Achieving the needed uncertainties for the globally averaged outgoing measurements is difficult technically, requiring constellations of sensors, distant orbits, and improvements to angular-distribution models.	**[Ongoing work over next 10+ years]** **Lower Uncertainties from Ground-Based Calibration Facilities:** Research institutes and NMIs should create more stable spaceflight detectors and in-vacuum end-to-end ground-based irradiance- and radiance-calibration facilities capable of providing **radiometric uncertainties of < 0.01 % (*k* = 1)**. International spaceflight centers should utilize these facilities to calibrate higher-accuracy space-borne radiometric instruments and overlap on-orbit measurements to monitor long-term climate variability.

New meeting: https://bipm-cenv2024.org/

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Abstract deadline: May, 31 2024

Home | Meeting organization | Accepted abstracts | Registration | Program | Call for abstracts

BIPM

1st CIPM STG-CENV Stakeholder meeting

16 -18 September 2024 – BIPM Sèvres (France)

Specific requests to CEOS:

1) Can you provide a co-chair for the session on Energy Balance?
    - We also need a co-chair for cryosphere

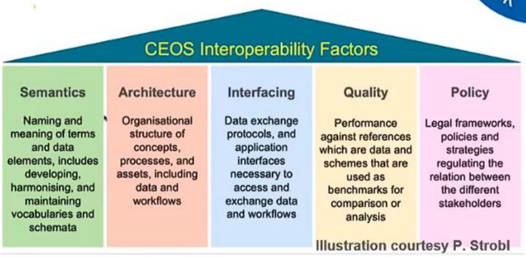
2) Please circulate information about this workshop, and please consider presentations on your work

Interoperability

interoperability is a characteristic of a product or system to work with other products or systems

Observations
- Satellite
- Non-satellite

Models
- Reanalysis
- Predictive



Action B1:
3. Better align the satellite FRM program to the reference tier of tiered networks and enhance / expand FRM to fill gaps in satellite cal/val.

Recommendation 1B.1 / 1B.2 (Oceans)

Number	Issue	Recommendation
1B.1 **[a]**	Joint efforts between observational scientists and metrologists are more effective when pursued within standing working groups, so that communications and collaborations can be effective over long periods. Areas that need collaborative attention include (1) developing common comprehension of metrological principles, traceability, and uncertainty; (2) practical guidance on measurement uncertainty estimation to assist in generating estimates that are complete, meaningful, and GUM compliant (important because the GUM is intended for laboratory measurements and is not easily applied to climate observations); (3) development of standard measurement methods with metrological principles embedded (networks to approach this problem exist, but without commonality in approach and level of detail regarding required data and metadata).	**[Within next 2 years]:** BIPM and WMO should, working with other existing groups (e.g., OBPS, GCOS, etc.) set up appropriate committees and working groups, or identify existing committees and working groups, where climate scientists and metrologists can effectively work together. (1) Metrological experts, working through OBPS, JCGM WG1, or other appropriate entities, should develop training on metrological principles, traceability, and uncertainty. (2) Metrologists should assist climate scientists in developing practical guides with examples, similar to the CITAC guide for analytical chemists. JCGM WG2, CCT, CCPR, CCQM, and RMOs are suitable venues, working individually or in cooperation. (3) Metrologists should work with OBPS (or other appropriate entities) to support the establishment of standardized methods with metrological principles embedded. Standardized methods should include requirements for reporting data and metadata.
1B.2 **[b]**	Earth Observation (EO) scientists need practical elaboration of GUM-compliant approaches to measurement uncertainty estimation to assist them in generating estimates that are meaningful and comparable. The GUM is not straightforwardly applicable for EO, hence there is a need for community-specific reference documents.	**[2+ years for scoping, 8 years for development of guidance]** BIPM and WMO should identify a suitable community where scoping could be undertaken to decide the details to be included in such practical guidance, after which development of guidance can be accomplished. A full international approach is needed, possibly undertaken in conjunction with space agencies like CEOS/CGMS JWGC or EO communities of practice like ESA CCI/Climate-Space.

Topic 1C: Earth Energy Balance

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1C.2 [b]	**Radiometric Energy Measurements: SITSats** SI-traceable, low uncertainty, spatially and spectrally resolved radiance measurements in the visible to far-infrared can reduce times of trend detection of climate change in the presence of natural variability, enabling better attribution and more credible policy decisions. These require a **~ 10× reduction in on-orbit uncertainties**, nearly matching what is achievable in ground-based NMI laboratories.	**[Ongoing work with planned launches over next 10 years]** **SITSats**: NASA and ESA Earth-science divisions should create and fly SITSats (SI-Traceable Satellites), such as **CLARREO, TRUTHS, and FORUM**, to provide low-uncertainty measurements directly and to inter-calibrate other on-orbit sensors, extending the spatial, spectral, and temporal coverage of Earth-observing systems. The first SITSats should be launched within this decade and should have missions extended in time to overlap and validate each other.
1C.4 [d]	**Calibration Sources: Sun and Moon.** Consistent, SI-traceable, low-uncertainty, long-duration, on-orbit spectral calibration sources are needed for calibrating, adjusting, and checking Earth-observing instruments operating in the visible and near-infrared spectral regions. The Sun and Moon can provide these on-orbit sources if sufficiently characterized. Being inherently very stable, they can also bridge non-overlapping instruments, mitigating measurement data gaps (T1.C3). Solar measurements and models currently achieve the needed accuracies to provide such an on-orbit calibration source for any instrument able to directly measure the spectral solar irradiance. Lunar irradiances used as on-orbit calibration references need improved uncertainties from the current modelled levels of about 5 % to 10 % to less than 1 %. This will involve: 1. Acquiring lunar observations through full libration cycles to account for changes in the Moon's apparent size and orientation, and 2. Reducing discrepancies between lunar models.	**[Present and Near Future]** Space agencies (NASA, ESA, CMA) should recommend Earth-observing instruments begin regularly acquiring **irradiance measurements of the Sun and/or the Moon**. Spectral solar irradiance (**SSI**) measurements should be continued. Solar models based on these measurements can extend the SSI records to historical times for retroactive calibrations of past solar-viewing instruments. Operators of the SITSat missions **CLARREO Pathfinder** and **TRUTHS** as well as smaller, more dedicated missions such as **ARCSTONE**, should provide improved lunar-irradiance measurements within the next few years, to provide better data on which to build or improve **lunar-irradiance models**. Those models can then be applied to estimate lunar irradiances at any era for intercomparisons with instruments' lunar observations. Metrologists should continue working with space agencies to make lunar observations through full libration cycles (> 3 years) and develop methods that combine the observational results to improve agreement between lunar models.

Also:

Calibration sources
On-board blackbodies

Links to Earth-heat inventory

Assessing what uncertainties are <u>needed</u> for climate studies from detailed assessment …

Theme 2 (Topic 2D): Strengthening the linkage of remote sensing GHG concentration measurements to emission fluxes

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	Issue	Recommendation	Sources
2D.1	Reliable and traceable remote-sensing observations are needed to serve as an input to a greenhouse gas emissions monitoring system.	**[1-5 years]** Recommend the continuation and expansion of frequent profiling of atmospheric greenhouse gas concentrations in an ongoing fashion, including satellite, airborne (research and commercial platforms), and surface-based methods, and increased participation form the metrology community in these activities. Key constituents for collaboration with BIPM, WMO and their members are national space agencies and CEOS, national ministries of environment and Earth sciences.	Climate Action Workshop discussions T2-C6
2D.2	NMIs and the carbon cycle science community need better connection to enable robust development of greenhouse gas measurement and monitoring technologies including credible standards.	**[1-3 years]** Recommend an increase in collaboration among and across communities, starting with regular workshops led by NMIs to link with the greenhouse gas community. This would work toward to implementation of uniform measurement protocols endorsed by NMIs and other organizations that include use of measurements traceable to the International System of Units (the SI). These interactions could be conducted in junction with international workshops and conferences, such as GSICS, IWGGMS, and CALCON. Topics should include measurement techniques, calibration, and traceability to the International System of Units (SI).	T2-C2, T2-D6, T2-D9
2D.3	Stakeholders need robust estimates with defined uncertainties on facility scales for point sources of methane and carbon dioxide.	**[1-4 years]** Recommend that NMIs contribute their measurement expertise to design and develop (or identify) calibrated emissions sources to support validation and confidence in space-based estimates of point source emissions. This could include power plants with accurate ultrasonic stack flow metering and CO_2 concentration measurements as well as ongoing methane-controlled release experiments and controlled flaring. Implementation activities should be in collaboration and coordination with space agencies coordinated through CEOS as well as WMO Commission for Infrastructure and Research Board.	Discussion during the workshop

Community very keen to have more "satellite" participation in 2024 workshop

GHG task team!