

## **Title: Earth observation metrology for net zero and climate**

### **Abstract**

Remote sensing of Earth from space is the primary means to obtain the trustable global data needed for climate change research and knowledge to enable policy makers to adopt appropriate mitigation and adaptation strategies. Changes in the data of a few tenths of a percent per decade need to be detected which currently relies on measurands only realisable in NMI laboratories. Calibration and validation standards and methods, covering pre- and post- launch as well as complimentary in-situ networks, for land, ocean and atmosphere need to be developed. This will extend the capabilities of the SI to meet the needs of climate monitoring.

### **Keywords**

Remote-sensing, climate change, radiometry, satellites, Earth Observation, Essential Climate Variables (ECV), retrieval algorithm, machine learning

### **Background to the Metrological Challenges**

The Paris Agreement [1] seeks to contain the rise in temperature of the Earth to  $<2$  °C above pre-industrial levels with a highly ambitious target of  $<1.5$  °C. Even if this higher-level goal is achieved, the world still faces significant consequences from climate change and there is an urgent need to establish a robust integrated global climate observing system to monitor the essential climate variables (ECVs), to facilitate greater trust in climate forecasts and increased confidence for adaptation and mitigation policies. The harshness of the launch and operational environment in-space, aircraft and at extreme remote sites of earthbound observation cause significant and unpredictable change in the performance of instrumentation. Re-assessment of the uncertainty of satellite instrumentation post-launch as well as regular recalibration of airborne & ground-based instrumentation is therefore essential before the validity of data can be guaranteed. Calibration and validation sites and networks are being established by international organisations such as WMO (World Meteorological Organisation) and CEOS (Committee on Earth Observation Satellites) and they are looking to the metrology community to provide SI traceability and robust uncertainty budgets across the wide range of satellite applications. Although traceability of the measurand is a critical starting point, it is essential to pay attention to the retrieval and/or correction/transformation algorithms which allow the measurand to be transposed to a bio-geophysical variable and/or propagated through the atmosphere.

European missions (such as ESA Forum, TRUTHS and CLARREO-pf) need the appropriate infrastructure and methods to incorporate cost effective solutions into their climate observing systems. Many techniques have been developed in the past, however, full uptake requires further adaptation, in collaboration with these users, particularly if the full benefit of 'low-cost access to space' is to be realised. For example, the ESA Forum mission, needs to validate the extension of Spatial Heterodyne spectrometers developed in EMPIR project 16ENV07 MetEOC-4 in orbit to ensure it meets the challenging under-flight performance requirements. Similar, challenging under-flights are being considered for missions like TRUTHS and CLARREO-pf.

The concept of the CEOS - Fiducial Reference Measurements (FRM) has been developed to highlight the need for precise and well-characterised measurements tailored explicitly to the post-launch calibration and validation of Earth observation satellite missions. The CEOS-FRM will be utilised to determine optimal strategies for harmonisation and representativeness for current and future missions, whilst providing some insight to help create historical time series. In addition, there is need to characterise and transform, often point based surface observations of a direct SI quantity, e.g., spectral radiance to biomass or stored carbon and compare to one observed/computed by a satellite with an uncertainty metric. Metrology assessment of

algorithms, including extension of work in EMPIR project 16ENV07 MetEOC-4 to validate code, together with the utilisation of such algorithms to simulate and assess satellite performance is of increasing importance to the Earth Observation community. Automation of observations to create CEOS-FRM are a high priority and developing autonomous or remotely operated drones needs to be investigated as these bring opportunities to explore challenging areas in a cost-effective manner. The climate modelling community needs the ability to fully utilise observational uncertainties, for example, for the bio-geophysical parameters which are relevant to carbon and radiation cycles. in assimilation models. Coupled to this is the increasing challenge associated with 'big data' and how to optimise the uncertainty content to make it readily available to the users.

The Paris Agreement [1] details the need to monitor greenhouse gas (GHG) emissions and sinks from space in a trustable manner. Many space agencies and commercial providers are developing and launching satellites to address this issue, however, at present there is little quantitative evidence of achieved uncertainties of these missions. Work to further develop methods to establish traceability and evaluate associated uncertainties of the retrieved GHG inventories at all spatial scales, local to global, is urgently needed.

The artefact based WRR (World Radiometric Reference) is now replaced by an SI standard, CSAR (Cryogenic Solar Absolute Radiometer), having taken part in three WMO comparisons – however further optimisation work is needed. The World Infrared Standard Group (WISG) needs to understand and remove residual biases between some instruments when operated in different environments to improve confidence in observations of downwelling sky radiance. In addition, refinement of work carried out in EMPIR project 19ENV04 MAPP warrants further attention to ensure global acceptance.

## Objectives

Proposers should address the objectives stated below, which are based on the PRT submissions. Proposers may identify amendments to the objectives or choose to address a subset of them in order to maximise the overall impact, or address budgetary or scientific / technical constraints, but the reasons for this should be clearly stated in the protocol.

The proposal shall focus on the traceable measurement and characterisation of ECVs used for global climate observation systems.

The specific objectives are:

1. To develop methods for the incorporation of highly accurate sensors and lower cost sensors into an integrated SI-traceable space-based climate observing system, suitable for pre- and in-flight measurements, prioritising the needs from current European mission studies (e.g., ESA Forum, TRUTHS and CLARREO-pf) as well as from other stakeholders (e.g., WMO, BIPM) related to radiation and carbon cycles. An improvement of the uncertainty of satellite-based sea-surface-temperature measurement to 0.1 K is expected.
2. To develop SI-traceable measurement methods with associated uncertainties for transformed bio-geophysical parameters, relevant to radiation and carbon cycles, and to create historical climate time series. These methods should be representative and provide the assimilation of observations into models, retrieval algorithms (including machine learning (ML)) and harmonisation to link satellite observed digital counts to climate parameters.
3. To develop satellite derived SI-traceable measurement methods with associated uncertainties (from, e.g., spectral radiance) for emissions, biomass and stored carbon (e.g., land and ocean carbon sinks) to underpin 'NetZero' climate action and future carbon accounting systems (e.g., international stock takes and sophisticated carbon financial metrics). This should include simulation studies using radiative transfer models as well as ML techniques and consider the use of drones for on site characterisation.
4. To develop instrumentation and standards for traceable climate quality non-satellite derived remote sensing measurements. This should include harmonisation and interpretation of representativeness for networks related to the radiation cycle such as assessing unexplained variances observed between primary pyrgeometer designs impacting observations of downwelling IR radiation in the World Infrared Standard Group (WISG), ongoing refinements to the World Radiometric Reference (WRR) and traceability for Aerosol optical depth.
5. To facilitate the take up of the technology and measurement infrastructure developed in the project by the EMN for Climate and Ocean Observation, the measurement supply chain (satellite organisations, instrument manufacturers), standards developing organisations and end users (environmental monitoring and regulation bodies such as the World Meteorological Organisation (WMO), policy makers and climate data providers).

These objectives will require large-scale approaches that are beyond the capabilities of single National Metrology Institutes and Designated Institutes. Proposers shall give priority to work that meets documented needs, in particular those supporting the European Green Deal. To enhance the impact of the research, the involvement of the appropriate user community such as industry, standardisation and regulatory bodies is strongly recommended, both prior to and during methodology development.

Proposers should establish the current state of the art and explain how their proposed project goes beyond this. In particular, proposers should outline the achievements of the EMRP projects ENV04 MetEOC and ENV53 MetEOC-2 and EMPIR projects 16ENV03 MetEOC-3, 19ENV07 MetEOC-4 and 19ENV04 MAPP, and how their proposal will build on those.

Proposers should note that the programme funds the activity of researchers to develop the capability, not the required infrastructure and capital equipment, which must be provided from other sources.

EURAMET expects the average EU Contribution for the selected JRPs in this TP to be 2.8 M€ and has defined an upper limit of 3.5 M€ for this proposal.

EURAMET also expects the EU Contribution to the external funded beneficiaries to not exceed 35 % of the total EU Contribution across all selected projects in this TP.

Any industrial beneficiaries that will receive significant benefit from the results of the proposed project are expected to be beneficiaries without receiving funding or associated partners.

## Potential Impact

Proposals must demonstrate adequate and appropriate participation/links to the 'end user' community, describing how the project partners will engage with relevant communities during the project to facilitate knowledge transfer and accelerate the uptake of project outputs. Evidence of support from the "end user" community (e.g. letters of support) is also encouraged.

You should detail how your proposal's results are going to:

- Address the SRT objectives and deliver solutions to the documented needs,
- Feed into the development of urgent documentary standards through appropriate standards bodies,
- Facilitate improved industrial capability, or improved quality of life for European citizens in terms of personal health, protection of the environment and the climate, or energy security,
- Transfer knowledge to the environmental, climate change and space agency sectors.

You should detail other impacts of your proposed JRP as specified in the document "Guide 4: Writing Joint Research Projects (JRPs)"

You should also detail how your approach to realising the objectives will further the aim of the Metrology Partnership to develop a coherent approach at the European level in the field of metrology and include the best available contributions from across the metrology community. Specifically, the opportunities for:

- improvement of the efficiency of use of available resources to better meet metrological needs and to assure the traceability of national standards
- the metrology capacity of EURAMET Member States whose metrology programmes are at an early stage of development to be increased
- organisations other than NMIs and DIs to be involved in the work.

## Timescale

The project should be of up to 3 years duration.

## Additional information

The links provided in this section are only correct at the time of publication up until the end of the Call year.

These references have been provided by EURAMET.

[1] *The Paris Agreement*  
[https://unfccc.int/sites/default/files/resource/parisagreement\\_publication.pdf](https://unfccc.int/sites/default/files/resource/parisagreement_publication.pdf)

[2] *EMN Climate and Ocean Observation Strategic Research Agenda*  
<https://www.euramet.org/research-innovation/metrology-partnership/strategic-research-and-innovation-agendas>