Title: Metrology for Earth observation and climate

Abstract

Remote sensing of the Earth from space, utilising the full EM spectrum, is the major means of obtaining the global data needed to underpin climate change research and provide the knowledge to enable policy makers to adopt appropriate mitigation and adaptation strategies. In some cases changes of a few tenths of a per cent per decade are required, relying on measurands currently only realisable in laboratories of NMIs at similar levels of uncertainty. Earth Observation (EO) traceability is needed to develop calibration and validation standards and techniques, pre & post launch for land, ocean and atmosphere. Metrology techniques are also required to extend the concept of traceability through to the bio-geo physical parameters used by end user communities particularly those leading to long term climate data records. This will extend the capabilities of the SI to meet the needs of climate. The long-term goal is direct traceability in flight at uncertainty levels required for decadal climate monitoring and the establishment of a virtual centre of excellence of metrology for EO and climate.

Conformity with the Work Programme

This Call for JRPs conforms to the EMRP Outline 2008, section on “Grand Challenges” related to Energy and Environment on pages 8/9 and 23/24/25.

Keywords

Remote-sensing, Climate, Calibration, Validation, Radiometry, Satellites, Traceability, Earth Observation

Background to the Metrological Challenges

Remote monitoring of the Earth system is crucial to enable better stewardship of the environment and most importantly to provide the necessary information to aid policy makers in the development of appropriate mitigation and adaptation strategies to respond to climate change. This must be tackled through global observations which can only be made from space. Although such observations have and are being made, the harsh and challenging environment of space limits the uncertainty currently attainable. In the specific case of climate this is often a factor 10 larger than required by the community. This drive for reduced uncertainty together with the need to synergistically combine data from a variety of sources (space and in-situ) has placed “traceability” and its reliable quantification at the top of the agenda of space agencies and wider GEO community. In the case of satellites, improvements are needed throughout all stages of data production: pre-flight and post-launch calibration and validation and all the intermediate processing steps leading to a retrieved bio-geo-physical parameter. The technical scope 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. It also expands the scope of metrology beyond instrument calibration towards addressing the need for full end to end traceable uncertainty budgets for Essential Climate Variables (ECVs) and subsequent long term climate data records.

There are many examples demonstrating inconsistencies and biases between in-flight sensors and where normalisation has been used to enable long-term records to be established. The most commonly used example is that of Total Solar Irradiance, others exist e.g. the NOAA series of satellites show an apparent “greening” of the deserts as the sensors drift with time, for air temperature - observations between sondes and microwave sounders have led to significant debate on the nature of global warming. The work-plans of the international coordinating bodies on Earth observation satellites are focussed on the development of improved traceability strategies and comparisons to evaluate biases. Such activities are particularly prevalent in the optical domain, where efforts are underway to establish networks of SI traceable post-launch reference standards in preparation to underpin the needs of virtual constellations of sensors. Significant research is needed to ensure that these can maintain SI traceability in the long-term in a cost effective manner.

It is of course essential that the primary SI measurements made by space instrumentation e.g. reflectance, radiance etc are made with an appropriate uncertainty and that this is a core NMI responsibility. However, it is equally important to the users of EO derived information (e.g. carbon stored in a forest, change in land cover, aerosol size and distribution) particularly policy makers in the case of climate, that these bio-geophysical parameters retrieved from the primary measurements also have metrologically robust uncertainties assigned to them.

The long-term goal for the metrology community is to establish the capability to make SI traceable measurements from space at uncertainties commensurate with those obtained in the laboratory through direct use of a primary standard, in effect transferring an "NMI into orbit". This challenge has been placed on the community to meet the exacting needs of climate and in particular to constrain and improve the accuracy of forecast models to decadal rather than multi-decadal timescales. The US is carrying out studies and prototyping a mission called CLARREO to address this topic, which in part follows on from a European Mission concept called TRUTHS, the latter has been reviewed by ESA and was considered worthy of further study to refine the methodology to facilitate as early an implementation as possible, including its ability to provide reference calibrations of other sensors from space.

Scientific and Technological 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 JRP-Protocol.

The JRP shall focus on the traceable measurement and characterisation of Earth Observations.

The specific objectives are

1. To develop new transfer standards and techniques for traceability of pre- and in-flight spectral radiance and irradiance of satellite/airborne remote sensing instrumentation and associated in-field instruments to meet the needs of climate applications in land, ocean or atmosphere.
2. To establish, in conjunction with the existing international EO community, autonomous "SI traceable" global networks of test-sites for post-launch calibration and validation of remote sensing instruments. This is likely to include transfer radiometers to establish global networks of surface reflectance (<1 %). IR radiometers for ship borne sea surface temperature validation (<0.05 K) and robust methods and statistics to ensure representativeness for satellite pixels and climate quality data sets.
3. To establish and apply metrologically robust methods in order to establish full end to end traceable uncertainty budgets on a bio/geo physical parameter typical of ECVs and long term climate data records, for example sea surface temperature and albedo. This will include not only an assessment of traceability of pre-flight calibration and post launch validation but also methods to link multiple satellites/observing systems over long timescales and validation of retrieval algorithms.
4. To develop methods to enable direct routes to SI traceability for instrumentation (ideally laboratory based) and measurements of importance to climate which are currently dependent on community based scales e.g. Atmospheric Optical Thickness, World Radiometric Reference for solar irradiance.
5. To demonstrate methods and techniques needed to facilitate the early deployment of missions to establish a high accuracy (<0.3 % Earth reflected spectral radiances) SI traceable satellite sensor in-orbit, capable of making benchmark measurements for climate and enable reference calibration of other sensors.

For objective 1, proposers should prioritise the activities using the outputs of the MetEOC study identifying the metrological requirements for future European Earth Observation missions with a likely focus to include extensions of capabilities into the UV and IR for pre-flight and improvements to on-board references standards for satellites such as solar-diffusers and blackbodies.

Proposers are expected to select specific case studies from within each objective based on an assessment of stakeholder priority needs.

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 project ENV04 “Towards a European Metrology Centre for Earth Observation and Climate” and how their proposal will build on those.

EURAMET expects the average size of JRPs in this call to be between 3.0 to 3.5 M€, and has defined an upper limit of 5 M€ for any project. The available budget for integral Research Excellence Grants is 30 months of effort.

Potential Impact

Proposals must demonstrate adequate and appropriate participation/links to the “end user” community. This may be through the inclusion of unfunded JRP-Partners or collaborators, or by including links to industrial/policy advisory committees, standards committees or other bodies. Evidence of support from the “end user” community (eg letters of support) is encouraged.

You should detail how your JRP results are going to:

- feed into the development of urgent documentary standards through appropriate standards bodies
- transfer knowledge to the earth observation and climate sectors.

You should detail other impacts of your proposed JRP as detailed in the document “Guide 4: Writing a Joint Research Project”

You should also detail how your approach to realising the objectives will further the aim of the EMRP to develop a coherent approach at the European level in the field of metrology and includes 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 Member States and countries associated with the Seventh Framework Programme whose metrology programmes are at an early stage of development to be increased
- outside researchers & research organisations other than NMIs and DIs to be involved in the work

Time-scale

The project should be of up to 3 years duration.