On measuring the radiant properties of objects of observations for the Global Earth Observation System of Systems (GEOSS)

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Abstract. The report describes major radiometric calibration tasks arising in connection with the upcoming implementation of the GEOSS programs, including the unity of measurements and their traceability to national and international standards. The new stringent requirements for the accuracy and repeatability of radiometric observations within the GEOSS program and in other areas call for new approaches to both ground and space calibration of radiometric instruments some of which are described in this report.

The task of developing the GEOSS to support a stable development of the world community has been advanced at the beginning of this century at the highest political level by representatives of more than 50 countries and more than 30 international organizations. The GEOSS program plan defines major areas of GEOSS data application, implementation milestones and organizational structure, and involves extensive observations within the optical spectral bandwidth.

In addition to providing imagery data, planned GEOSS instruments can measure radiance, reflective properties, and radiant temperature of objects of observations. Such measurements require complete metrological support for the instruments. In general, the data supplied by various GEOSS subsystems will be used by different participants of the program under the condition of their unified standard presentation (formats, geolocation, etc.). Also, the unity of data acquired by different subsystems (traceability to national and international standards) is required for many applications such as climatology, meteorology, and environmental monitoring. This important task has not yet been adequately included into the 10-yr plan; therefore, measures need to be taken by the national metrological organizations to advance the idea and implement it at a proper international level.

The instrument designers are required to supply the program with instruments that are capable of providing high-quality data. Within the wide spectrum of the GEOSS program applications, the highest requirements for the long-term repeatability and accuracy of the optical instrumentation are imposed by climatology, which uses data accumulated over the time spans on the order of decades. According to the recently documented requirements for instrument calibrations [NISTIR 7047], the required values are, respectively:

- 0.02% per decade and 0.1% within the spectral band from 0.2 μm to 3 μm, and
- 0.01K per decade and 0.1K within the spectral band from 3 μm to 15 μm.

A necessary condition for meeting these requirements and ensuring the unity of observations is a high-level support for the methodology basis and the equipment used for both ground and space-borne radiometric calibrations. The methodology basis includes such components as unified proper terminology, common definitions of measurands and respective physical units, calibration techniques and estimation of measurement accuracy as a part of the calibration procedure.

The ground calibration tasks presented in this report include better calibration standards, techniques and means to transfer radiometric quantity dimension from standard sources to the instruments that are being calibrated, calibration installations, and international inter-comparisons of radiometric standards. These activities should result in universal, stable and highly accurate scales of radiometric quantities. The report describes the efforts that are being undertaken at

- the All-Russian Research Institute for Opto-Physical Measurements (VNIIOFI), with

the purpose of creating highly stable and highly accurate blackbodies built on the basis of phase transitions of pure metals or eutectic alloys, and

- the Space Dynamics Laboratory (SDL), with the purpose of designing high-accuracy thermo-vacuum installation for calibration of the thermal band IR sensors.

Two cryogenic vacuum chambers have been designed at SDL. The chambers are multi-functional and allow one not only to transfer the unit dimension but also to measure all the necessary output radiometric and other optical properties of the instrument that is being calibrated.

The unique reproducibility of radiometric properties of the blackbodies designed at VNIIOFI is based upon the phase transition of eutectic alloys (at 0.2 μm to 3 μm) or pure metals (at 3 μm to 15 μm); therefore, such blackbodies can be widely used to implement uniform and stable radiometric scales for GEOSS and for other programs involving radiometric observations from space.

The current and prospective techniques of in-flight radiometric calibration discussed in the report include an international radiometric standard space-borne facility as discussed earlier within the Russian/American Space Metrology Working Group. We believe that a unification of all GEOSS subsystems into a single high-quality universal data-producing system can be achieved if the problems that have been discussed in this report are solved by the joint efforts of all participants of the program.

References

NISTIR 7047. Satellite Instrument Calibration for Measuring Global Climate Change. *US Department of Commerce.* 2004.