Development of a laser-based satellite sensor illumination system to advance the capabilities of Earth observing systems

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Abstract

An Earth observing satellite sensor's capability to robustly demonstrate SI traceability on-orbit at the uncertainty levels required by science data products is challenging. Dedicated on-orbit instrumentation and measurements of solar, lunar, and world reference calibration/validation sites established by the international Committee on Earth observation satellites (CEOS) are used to evaluate system performance and constrain measurement uncertainties. To meet future mission objectives such as climate quality observations by SI-traceable space-based reference observatories, for example the US Climate Absolute Radiance and Refractivity Observatory (CLARREO) [1] and EU Traceable Radiometry Underpinning Terrestrial and Heliostudies (TRUTHS) [2] instruments, the current state-of-the art satellite sensor measurement uncertainties need to be reduced by an order of magnitude. Clearly, advancement of current technologies for establishing SI traceability as well as development of new characterization and calibration capabilities will be necessary to achieve future mission uncertainty requirements.

The objective of the program is to develop a dynamic Ground-to-Space Laser Characterization (GSLC) system that advances the capabilities of Earth observing satellite sensors. SI-Traceable Space-based Climate Observing Systems (COS) have the lowest uncertainty requirements and illumination of sensors on these systems by the GSLC system would provide a robust evaluation of the concept. Possible COS sensors to illuminate would include the Reflected Solar spectrometer of the CLARREO Pathfinder Mission on the International Space Station starting in 2023 [1], and the hyperspectral imager for measurements of Earth reflected solar radiation of the TRUTHS mission. Both will be in Lower Earth Orbits (LEO orbits) and can point, a requirement for experiments using the GSLC system. The TRUTHS mission includes a Cryogenic Solar Absolute Radiometer (CSAR) that holds the scale for the TRUTHS mission and up to 10 lasers to transfer the scale to the hyperspectral instrument.

In this presentation, development of a Ground-to-Space Laser Characterization (GSLC) system that provides extensive on-orbit diagnostic capabilities for Earth remote sensing systems is discussed [3, 4]. In its simplest configuration, broadly tunable narrow-band lasers are introduced into the GSLC system, for example using NASA's GLAMR system [5] or NIST's SIRCUS system [6]. In this configuration, the GSLC can illuminate an instrument similar to TRUTHS and use its on-board SI-traceable reference instrument, for example the CSAR on TRUTHS, to transfer the scale and thus, absolute SI-traceable measurements by the satellite sensor is feasible. Demonstrating

additional capabilities, the GSLC system can project dynamic, user-defined calibration source distributions, in principle.

Previous demonstration studies include successful illumination of the Global Lightning Mapper on GOES-16 and 17 [7]. The GSLC system has leveraged advances in free-space optical communications technologies, including demonstrations such as the Lunar Laser Communications Demonstration [8], and laser beam transmittance through the atmosphere. The performance of illumination systems designed to reduce scintillation will be evaluated using sensors mounted on aircraft. Satellite sensor measurements of the GSLC illumination system, if successful, lay the foundation for an entirely new approach to *in situ* characterizations of satellite sensors.

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