Traceable Radiometry Underpinning Terrestrial- and Helio- Studies (TRUTHS): Enabling a Space-based Climate and Calibration Observatory - An ESA Earth Watch mission.

Nigel Fox[1], Paul Green[1] Javier Gorron[1]

National Physical Laboratory (NPL), Teddington, United Kingdom
Corresponding e-mail address: nigel.fox@npl.co.uk

TRUTHS, will create a 'metrology laboratory in space'. Designed explicitly to meet the requirements of climate the mission establishes SI traceability on-board the space-craft through mimicking the ground-based radiometric calibration chain fully-linked to a space cryogenic radiometer. TRUTHS measures incoming and reflected radiation from the sun spectrally and spatially resolved with accuracy, typically an order of magnitude better than current satellites. This data will provide a benchmark of the radiation state of the planet from which change can be detected in <half time of existing sensors constraining climate forecasts. The data also allows an upgrade in performance of other sensors, ensuring their SI traceability through reference calibration from space.

INTRODUCTION

In November 2019 the TRUTHS mission [1, 2] was funded and adopted into the ESA Earth watch program. The mission is based on a concept conceived and prototyped by a UK team led by the National Physical Laboratory (NPL) the UK national metrology institute and selected by the UK space agency (UKSA) from a national competition. The first phase of implementation will be carried out by an industrial consortium drawn from subscribing member states: UK. Greece, Switzerland, Czech Republic and Romania with a view to a target launch date in 2026.

TRUTHS is a mission designed explicitly to meet the exacting needs of climate. Its primary goal is to establish a benchmark dataset of the radiation state of the planet, spectrally and spatially resolved with sufficient accuracy that trends can be detected limited only by natural variability, immune from biases and ambiguities of sensor performance and degradation. It measures incoming and reflected solar radiation from ~320 nm to 2450 nm with an uncertainty of 0.3% (k=2) (a factor ten improvement over existing sensors), globally sampled at 50 m spatial resolution and spectrally continuous with a bandwidth of 5-10 nm. This allows it not only to quantify change in radiation balance but also to attribute effects to key climate feedbacks such as Cloud and Albedo as well as account for potential variations in energy inputs total and spectral solar irradiance - facilitating testing of climate forecast models in the shortest time possible.

TRUTHS will be the scientific forerunner of a paradigm shift in how the Earth is observed, delivering data not constrained to a single discipline but deliberately specified to allow it to be configured to support applications in and at the boundaries of Land, Ocean and Atmosphere and meet the exacting needs of many Essential Climate Variables (ECVs) e.g. Land and Ocean Carbon cycle,

Additionally, it will be a 'metrology laboratory in space', providing and enabling SI-traceable measurements of improved and unequivocal accuracy from other sensors through in-flight calibration. TRUTHS will be an enabling element of the internationally requested 'space-based climate observatory', ideally in conjunction with other benchmark sensors such as NASA CLARREO [3].

MISSION CONCEPT

The TRUTHS payload comprises a hyperspectral imaging Spectrometer (HIS), which whilst of state-of-the-art performance is not significantly different than that flying or designed for other missions. The disruptive differentiator of TRUTHS is the on-board calibration system. This mimics the primary terrestrial traceability chain of a typical NMI – cryogenic radiometer – intensity stabilised lasers – Transfer Radiometers – Flat plate diffusers all implemented within in a small ~1 m^3 satellite.

This on-board calibration system facilitates a spectral radiance calibration of the HIS on a daily basis, removing not only effects of launch but also corrections for normal in-flight degradation of both the HIS and the calibration system. The space-based cryogenic radiometer of TRUTHS called CSAR (Cryogenic Solar Absolute Radiometer) not only serves as a primary SI standard but also measures incoming total solar irradiance with an uncertainty of

0.02% k=2. The CSAR for TRUTHS is based on an evolution of the first prototype currently serving as a terrestrial reference for solar irradiance at the World Radiation Centre in Davos for the last decade [4]. A CSAR v2, 1/3rd of the mass, was built and tested coupled to a space cooler as part of pre-development studies in 2016.

In addition to making high accuracy observations of the Earth for climate and other applications TRUTHS will improve the accuracy of other missions through reference calibration. The choice of a true non-sun-synchronous polar orbit allows TRUTHS to simultaneously view the same scene as other satellites on a regular basis. The high spatial and spectral resolution of TRUTHS facilitating a match to the footprint of other sensors and when viewing relatively uniform targets like deserts and snowfields calibrations can transferred in a traceable manner.

RESULTS

The paper will not only present the concept but also results of testing of the prototype calibration system under vacuum and simulations of cross-calibrations and performance improvements of other sensors such as Sentinel 2 where a factor 5 improvement in radiometric uncertainty has been demonstrated.

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