Traceable Radiometry Underpinning Terrestrial- and Helio- Studies (TRUTHS)

– A 'gold standard' reference for an integrated space-based observing system for environment and climate action

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What is TRUTHS?

An under-development ESA Earth watch satellite mission, led by UK in partnership with Switzerland, Czech Republic, Greece and Romania conceived at NPL to explicitly establish high accuracy SI-Traceable measurements of the radiation state of the planet in the short-wave region of the spectrum. This will allow the establishment of 'benchmarks' from which change can be detected in as short a time as possible, facilitating timely evidence-based action to counter potential impacts and also monitor 'success' of mitigation strategies. In addition to its own observations, it will also become a 'gold standard' reference in space to recalibrate other Earth/solar viewing satellites and is a direct response to the recommendations of the 2010 BIPM/WMO workshop and other international bodies.

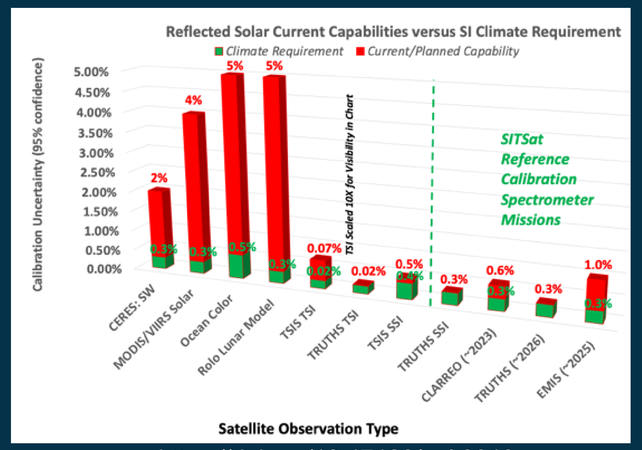
Satellites of this type are now being called SITSats (SI-Traceable Satellites)

What does TRUTHS measure?

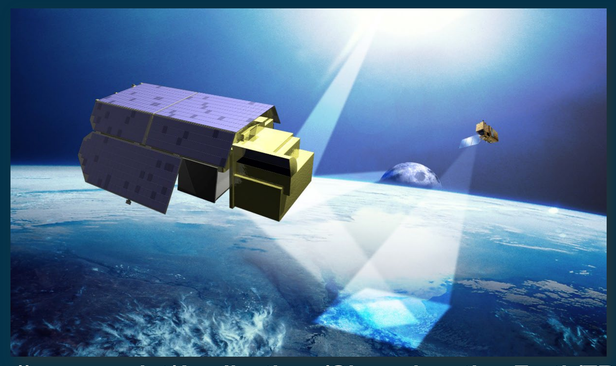
Total and spectrally resolved incoming and Earth/moon reflected solar radiation:

- **320 to 2400 nm** contiguously @ **~4 nm** bandwidth
- Global nadir @ **50 m** ground resolution with 100 km swath
- Target uncertainty of **0.3% (k=2)** @ top of atmosphere (~10X improvement on other Earth viewing sensors)
- Total integrated solar irradiance with target uncertainty of **<0.02% (k=2)**

Observations support many applications, although radiation balance most demanding. Measurement uncertainty optimised so that performance limit is natural variability i.e. enabling shortest time to detect a signal/trend.



https://doi.org/10.47120/npl.9319

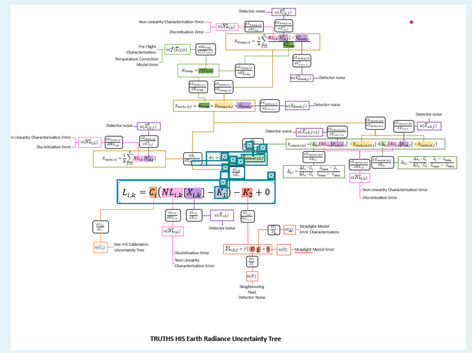


https://www.esa.int/Applications/Observing_the_Earth/TRUTHS

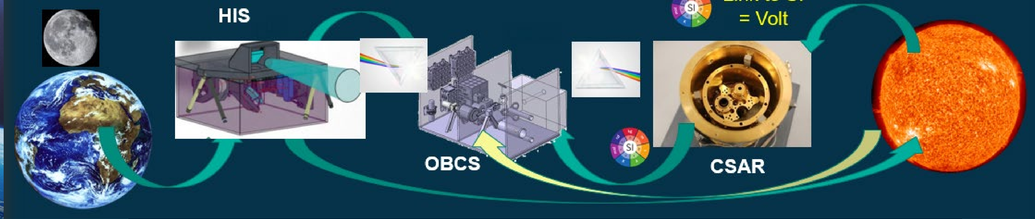
SI-Traceability 'in-flight'

Most optical satellites degrade on-launch and in-flight making it difficult to achieve and/or evidence SI-traceable uncertainties needed by climate.

TRUTHS flies a primary standard cryogenic radiometer (CSAR) and with the OBCS largely mimics methods used on the ground at metrology institutes to calibrate the imaging spectrometer (HIS) utilising sunlight dispersed by a monochromator to provide spectrally tuneable radiation. CSAR compares the heating effect of this optical power with that of electrical- anchoring to the SI Volt in-orbit.

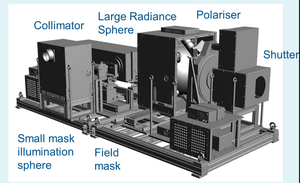


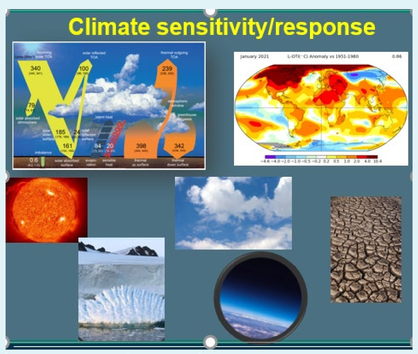
As a metrology mission, 'SI in space', it is also critical the mission provides an exemplar to the community of evidencing uncertainty evaluation and SI-traceability. The use of Fiduceo like diagrams and full tables and descriptors of sources of uncertainty and correlations will be provided.



Pre-flight characterisation & comparison

Although TRUTHS has an SI-traceable on-board calibration system (OBCS) & CSAR, it still requires comprehensive characterisation pre-flight to assess design compliance. Similarly, comparison of primary standards (CSAR and NPL laboratory cryogenic radiometer) together with an end-to-end comparison of the in-flight system with an independent facility is an essential element of evidencing SI-traceability. The NPL Spectroscopically Tuneable Absolute Radiometric (STAR) facility is designed to achieve this whilst TRUTHS is in vacuum, utilising a tuneable CW laser (260 – 2600 nm) . The bottom figure on the right shows STAR being used to calibrate the MicroCARB satellite.





Change in balance of Earth's radiation (incoming solar vs reflected & emitted infrared) results in temperature change. Effects, such as cloud and albedo can be non-linear. **Forecasts of climate models need constraint & testing.**

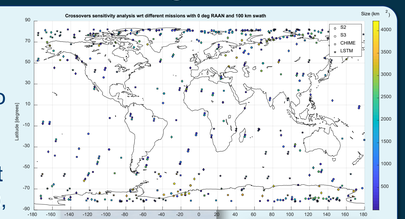
Policy makers require unequivocal evidence upon which to take timely/costly decisions

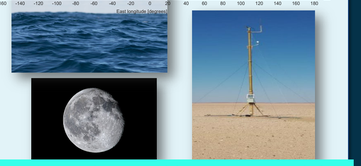
Results of societal action to mitigate impact of the climate emergency require robust high accuracy trustworthy benchmark references from which to monitor change and improvement. **Traceability to SI provides this trust**

Gold standard reference

TRUTHS has a 90° pole to pole orbit allowing simultaneous overlap with other missions on different parts of the globe (see fig),

This allows the calibration of TRUTHS to be transferred to other satellites through simultaneous, angle matched observations of these natural targets. High spectral & spatial resolution of TRUTHS allows convolution with that of the sensor under test.





All targets can be used however spatial uniformity is a preference: deserts, snow, ocean, cloud and even the moon. Some have local instruments to account for drifts reducing the simultaneity constraint

Recommendations

- The development and use of SITSats for all observations of the Earth should be encouraged, aiming for an international SI-Traceable climate & calibration observatory.
- Robust assessment and accessible documentation of uncertainty for all satellite observations should be encouraged, but mandatory for climate applications.
- New science needs to be established in readiness to fully exploit the high accuracy reference quality observations that SITSats will provide and enable.