Outcome of Workshop on SI-Traceable Space-based Climate Observing System (SITSCOS)

A CEOS and GSICS International Workshop held at the National Physical Laboratory London, UK, (September 2019)

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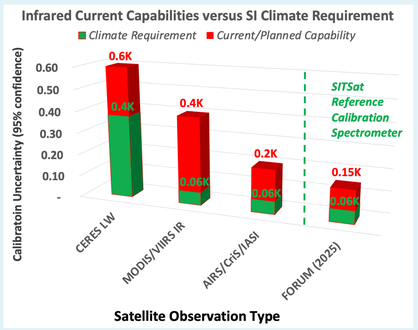
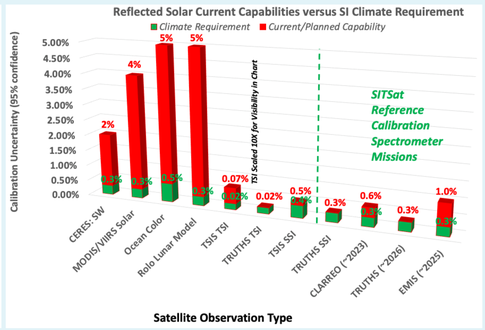
~100 international participants (EO/climate domain experts, instrument designers/builders; metrologists): 200 page report leading to recommendations available at https://doi.org/10.47120/npl.9319 together with presentations at http://calvalportal.ceos.org/sitscos-ws

Note: references for all figures and supporting information can be found in the report.

Limitation of observing system

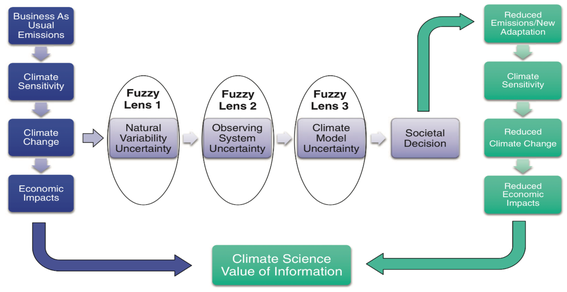




Workshop considered the observational needs for climate and the inadequacy of the current and planned observing system to address them, complimented by the benefits to be obtained from the emerging generation of SITSats (SI Traceable Satellites).

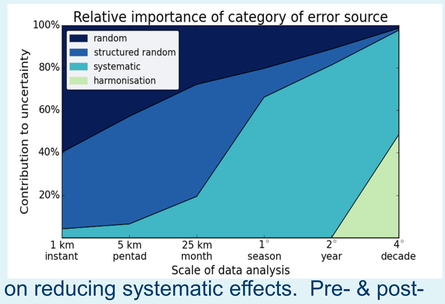
The economic impact of inadequate action as a result of uncertain information has been shown that it can lead to a cost to the global economy of $500B yr^{-1}. This can be contrasted to the estimated cost of a comprehensive SI-traceable climate observing system and associate research program of ~$8B yr^{-1}.

Value of Information Estimation Method

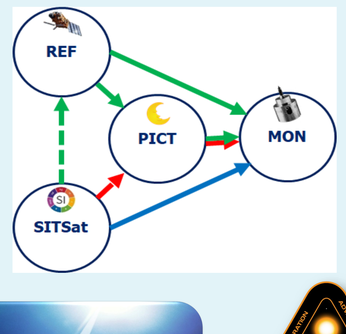


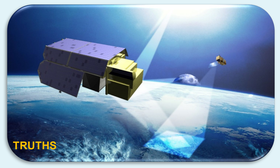
Metrology

The importance of rigorous transparent uncertainty assessment, traceable to international SI units is now embedded within much of the EO/climate community. However, achieving this for often complex bio-geophysical variables still needs significant research. It is noteworthy to recognise the relative importance of the nature of uncertainty when considering the large spatial and temporal scales typical of climate observations. This places the focus on reducing systematic effects. Pre- & post-deployment calibration to SI standards is thus a critical activity, but the uncertainty of the standards must also be 'fit for purpose'.



SI-Traceable references

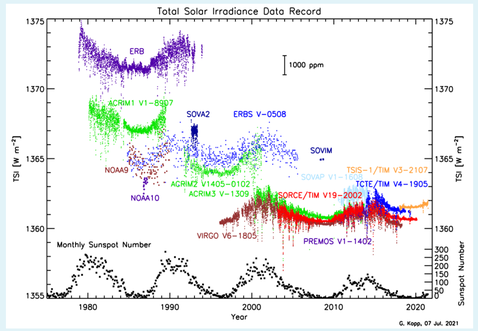


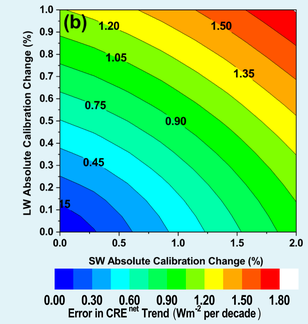


SITSats such as ESA TRUTHS and NASA CLARREO Pathfinder, can, in the future provide high accuracy SI-Traceability to other sensors from orbit. Achieved through direct, angle matched simultaneous observations of uniform natural targets with the sensor under test or through an intermediate secondary mission, uncertainties for some observations can be improved to be close to those desired in the ideal system. Not only do we need to ensure continuity of these fiducial reference observations for decades to come but also extend their spectral range and sensing method to cover all climate critical observations.

On-board and in-situ observations and standards must also be improved. The microwave domain, used for atmospheric water vapour, is identified as needing urgent action from the metrology community in addition to the IR in general and 'active' sensors.

Climate sensitivity





Long-term high accuracy measurements of incoming and outgoing radiation are critical to differentiate natural and anthropogenic impacts on radiation balance and Earth temperature. Historical biases in solar irradiance observations are now starting to reduce with improved sensors. However, subtle change in, for example, Cloud Radiative Effect, CRE (type and coverage) can have significant impact and is poorly understood. The observational uncertainty required depends on the size of the expected trend (see fig above right) but is expected to be <0.5% (k = 2).

Recommendations from report

- **Space agencies should plan a long-term operational SI-traceable climate observing system, building on the currently planned SITSats**
  - Overlapping continuity improves sensitivity monitoring climate change due to natural events
  - With SI traceability, gaps in observations may not compromise long-term data record
- **NASA should plan for CLARREO Pathfinder to intercalibrate additional sensors and surface sites**
  - Should also extend the mission operations plan to five years to enable overlap with the TRUTHS and CSRB SITSats
- **Encourage U.S. to add IR SITSat spectrometer**
  - to reach required goals from independent sensors through entire thermal-infrared spectrum
  - The complimentary FORUM mission covers the far-infrared
  - Chinese LIBRA mission aims to achieve those goals through improvement of multiple missions
- **Use the Moon to improve reflected-solar sensors' calibration accuracies and stabilities**
  - Lunar observations enable stabilities of < 0.1 %/decade
  - Further improvements in the accuracy of lunar irradiance models are required
- **Passive microwave instruments require further work on SI-traceability**
  - for climate-change accuracies of calibration references
  - to demonstrate reference calibration sensors in orbit
- **FRM (Fiducial Reference Measurements) of surface properties complement SITSats**
  - Integrate to further improve models and understanding of processes and Earth cycles
- **Plan follow-on SITSCOS workshop for 2026 to consider early results and status of SITSat missions**
  - Include progress and plans for SI traceability of microwave, polarimeter, and active satellite sensors