Metrology for Earth Observation and Climate Newsletter

www.meteoc.org September 2017

What is MetEOC-2?

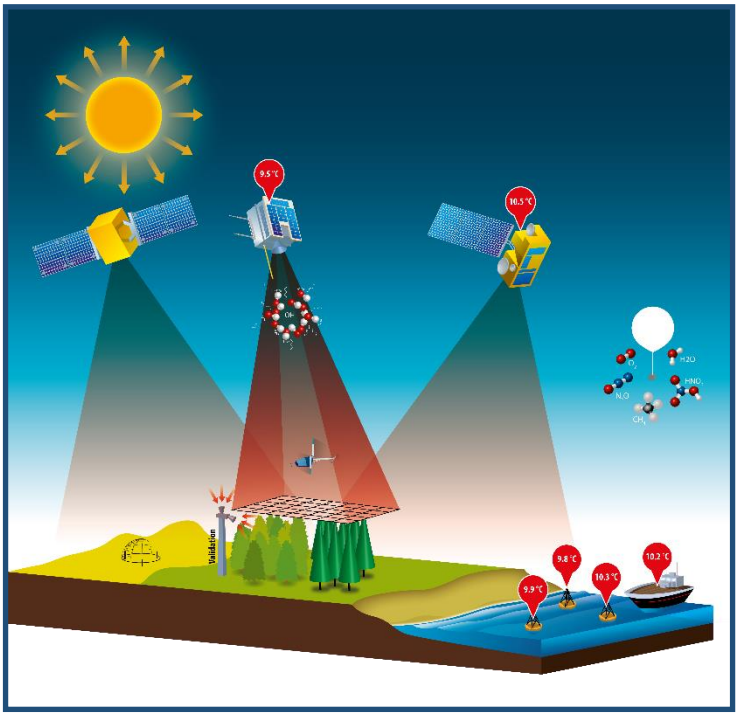
MetEOC-2 (Metrology for Earth Observation and Climate) is a joint research project that brings together a coordinated network of National Metrology Institutes (NMIs) across Europe, in collaboration with other international experts, to provide the underpinning metrology support to aid the improvement and assessment of Earth Observation (EO) datasets with a particular focus on climate applications. This is the second of a continuing series of projects, coordinated by Dr Nigel Fox of the UK National Physical Laboratory, and builds on previous expertise developed nationally. Within this project, four themes of work (outlined below) address the development of the tools, methods, and infrastructure required to enable trustable confidence levels to be assigned to data derived from Earth Observation satellites that is used for climate change monitoring.

The European Metrology Research Programme (EMRP) MetEOC-2 project is jointly funded by the EMRP participating countries within the European Association of National Metrology Institutes (EURAMET) and the European Union.

Project start: *September 2014*
Project end: *August 2017*
For more information: *www.meteoc.org*

MetEOC-2 Activities

Remote sensing of the Earth from space is the major means of obtaining the global data needed to underpin climate change research. Climate Data Records (CDRs) are the long term time-series of Essential Climate Variables (ECVs). Approximately 50 ECVs have been identified internationally as the key geophysical parameters necessary to systematically monitor and understand the drivers and impact of climate change. The CDRs of ECVs are the cornerstone of long term monitoring of climate, derived from a combination of data from multiple sources and sensors. ECVs such as, incoming radiation from the Sun, Sea Surface Temperature (SST) or the fraction of Photosynthetically Active Radiation absorbed by vegetation (fAPAR), are monitored using space assets in order to characterise the Earth system and its response to natural or human-induced changes.



The effective production of CDRs relies on robust knowledge of the data sources and their uncertainties. Despite progress in recent years, trustable, SI-traceable evidence for the quality of the retrieved EO datasets is lacking. In most cases, detection of small changes, aggregated over decades, are required to distinguish climate trends from data/environmental noise. Thus climate science relies on measurements that can be tied to invariant references with uncertainty levels currently only realisable in NMI's.

The four themes of work within MetEOC-2:

1) Underpinning requirements for Earth Observation **sensor traceability**:
   - Develop Level 1 satellite optical products to be consistent with each other and, in the long term, to make them fully SI-traceable;
   - Develop mathematical tools for propagating uncertainty and assess traceability through data processing chains.
2) Improve traceability to determine and reduce the measurement uncertainties of **atmospheric ECVs**.
3) Establishing traceability for satellite-derived **biophysical ECVs** through modelling, reference measurements and test-site characterisation.
4) SI-traceability and uncertainty analysis of **radiation balance ECVs**, and the creation of reliable multi-decadal CDRs.

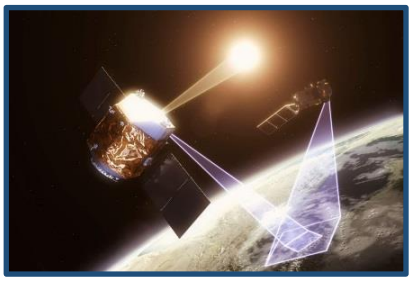
Global network of satellite radiometric test sites nears fully operational status

Spatially uniform, bright and ideally stable land based targets typified by deserts are used to provide post-launch radiometric calibration/validation of Earth viewing satellite optical imagers. CEOS is developing a network of sites called RadCalNet, which have been instrumented with autonomous sensors to monitor surface reflectance change and associated atmospheric properties to allow satellites to compare their measurements against. NPL, in part supported by MetEOC-2, is helping to create a test site in Gobabeb, Namibia as a European contribution to RadCalNet in partnership with CNES and ESA. NPL is also helping to evaluate traceability and uncertainty of all the individual member test sites and their consistency with each other.

The MetEOC-2 project has been instrumental in developing the tools to improve SI-traceability of the sites and in developing mathematical techniques to understand site effects (such as viewing and solar angles, spectral effects and inhomogeneity of the sites). This provides space agencies and small commercial satellite operators with valuable calibration information without the need for dedicated field campaigns or expensive on-board calibration systems. It helps to improve interoperability between sensors – allowing scientists to combine different sources of data to provide a more holistic understanding of long term climate change, and enables more accurate and more valuable climate services.

For more information about RadCalNet, see here

Proposed satellite mission TRUTHS moves a step closer to launch

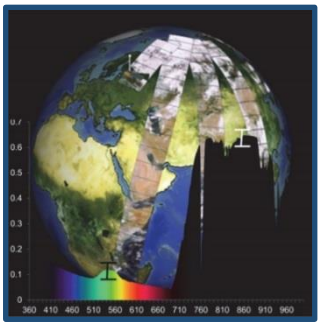


TRUTHS is a metrology institute led satellite mission designed to provide climate data ten times more accurately than is currently possible and upgrade the performance of the global Earth Observation system. This step-change in satellite capability is made possible through the development of a novel calibration concept, which will effectively put a 'national measurement laboratory' into orbit.

The calibration system has been experimentally proven in a vacuum through MetEOC-2, in conjunction with UKSA and Airbus Defence and Space, overcoming previous technical hurdles such as those related to speckle on the diffuser, utilising very few movements. This has raised the Technology Readiness Level of the state-of-the-art TRUTHS calibration system to Level 5/6, as well as enabling it to have sufficient maturity to be proposed as a candidate mission to ESA's Earth Explorer programme.

Find out more about TRUTHS here

MetEOC delivers training to thousands on uncertainties in Earth Observation



Through both MetEOC 1 and 2, a training course has been developed that provides a structured approach to uncertainty analysis applied to the radiometric and spectral calibration of instruments used in Earth observation applications. The course focuses on how to apply uncertainty analysis, taking users through a step-by-step application of concepts to real laboratory and field examples.

A comprehensive understanding of uncertainty underpins the usefulness and value of Earth observation. This course has been designed to be accessible to the community, and has also been presented at multiple workshops and the International Ocean-Colour Coordinating Group summer school.

The course text book and presentations are freely available for download here. An e-Learning programme has also been developed, which can be accessed here.

MetEOC-2 provides traceability for the NDMC

The Network for Detection of Mesospheric Change (NDMC) is an international network of 55 ground-based experiments which monitor temperature and atomic oxygen concentration at the mesopause region, the area of the atmosphere that forms the boundary between the mesosphere and thermosphere, at around 85 km above the Earth. Temperature changes in the mesopause are a very sensitive indicator for predominantly CO_2 induced global warming. This project provided a new radiance source traceable to SI to give traceability to measurements of mesospheric temperature with a sufficiently low uncertainty to enable identification of temperature changes at the level of 1 K per decade.

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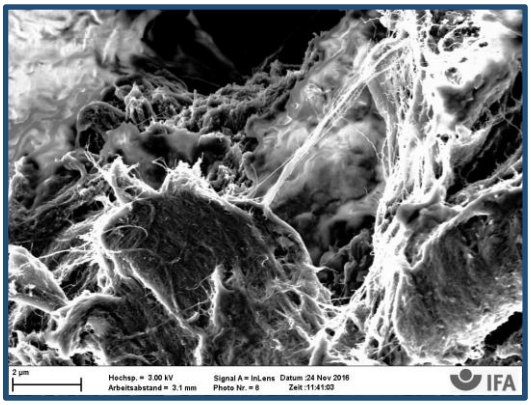
First SI-traceable, large-area blackbody developed for calibrating infrared limb sounding interferometers on-board long duration stratospheric balloons

Limb sounding imaging FT interferometers provide height and spatially resolved measurements of a range of atmospheric molecules - indicators of climate change and anthropogenic induced emissions. Following the successful development of large area traceable black bodies for the airborne GLORIA instrument, this project has extended the capability to long duration stratospheric balloon borne instruments. Here the challenge was to maintain (and in part improve) performance but with a lower weight.

In addition to evolutionary upgrades, the blackbody targets the introduction of innovative commercial 'phase change material' thermal packs to control temperature rather than complex and massive conventional electrical power. Temperature spatial non-uniformity of <100 mk was achieved and temperature stabilities of >300 hrs.

Carbon nanotubes tested and qualified for use in scientific instruments

Carbon nanotubes (CNTs) are lattices of carbon atoms that are tube-shaped, providing a material with a diameter on the nanometer scale, or a one-billionth of a meter. CNTs have exciting applications for science, being at least 100 times stronger than steel but only one-sixth as heavy, as well as excellent conductors of heat and electricity. If arranged as vertically-aligned 'forests', CNTs can possess a remarkably high emissivity (close to 1 – a perfect blackbody), making them extremely useful for radiometry. However, nano-particles have the potential to be hazardous to human health particularly if ingested into the lungs.

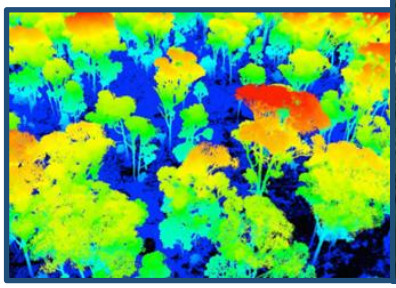


This project investigated the 'release rate' of CNTs under different handling conditions to ensure their safe use in scientific instrumentation.

Wytham Woods mapped in a virtual model

Covering about 30% of global land area, forests play a significant role in the delivery of ecosystem services including climate regulation, carbon storage, biodiversity, prevention of soil erosion and flood mitigation. However, uncertainties of the amount of above-ground biomass estimates (which are also a surrogate for carbon storage) are very high, as it's very hard to estimate without destructive sampling (i.e. cutting a tree down and weighing the wood and leaves).

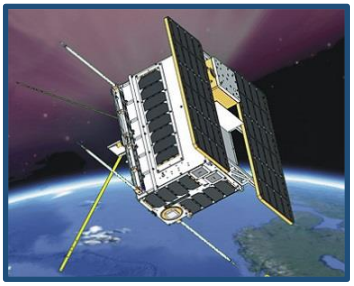
To reduce that uncertainty and avoid destructive sampling, Terrestrial Laser Scanner data has been collected and used by NPL in collaboration with UCL to measure each tree's volume of a test site in Wytham Woods, Oxfordshire. Sophisticated mathematical modelling and remote-sensing methods are applied to the data to make accurate estimates of biomass. This data has been used to produce a highly realistic virtual 3D representation of Wytham Woods, which can be used to improve vegetation monitoring, calculation of biomass carbon storage, and improve satellite product validation activities.



For more information, see here

CLARA TSI radiometer successfully launched into orbit

On the 14th July 2017, the NORSAT-1 microsatellite was successfully launched into orbit. This satellite is designed to investigate solar radiation, space weather and detect ship traffic, and contains a Compact Lightweight Absolute Radiometer (CLARA). This radiometer will help ensure continuity of Total Solar Irradiance (TSI) measurements, which is a measure of the amount of solar energy reaching the Earth's upper atmosphere. It is an essential climate variable and this instrument will reduce ambiguities due to existing instrumental biases and support long term (>30 year) monitoring of TSI in space. During MetEOC-2, partners at SFI Davos characterised and SI-traceably calibrated the CLARA radiometer.



A video of the NORSAT-1 launch can be viewed here.

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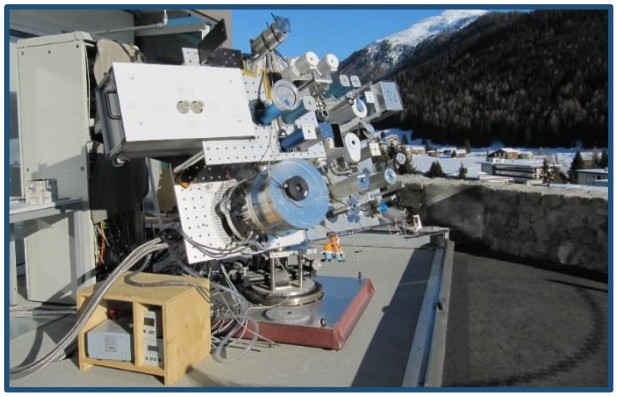
Bidirectional Reflectance Distribution Function retrieved using UAV's

Understanding the directional scattering properties of light in an open forest canopy is essential to verify the end-to-end traceability between field measurements at a given test-site and concur recently acquired satellite observations of the same target. However, this is inherently complex, and previous efforts have assumed either constant illumination conditions or perfectly uniform reflectance (Lambertian properties). By developing techniques for SI-traceable spectroscopy on Unmanned Aerial Vehicle's (UAVs), this project was able to extract reliable BRDF information from multiple flight paths, delivering a rapid and robust background information of directional scattering properties for open canopy vegetation sites for the first time.

Towards a new World Radiometric Reference for Direct Solar Irradiance

The World Radiometric Reference (WRR) is the measurement standard of the World Meteorological Organisation (WMO) corresponding to the SI unit of irradiance, but tailored to the Sun. It was introduced in order to ensure world-wide homogeneity of solar radiation measurements and has been in use since 1980, and is based on the mean of a set of, now ageing, radiometers. Every five years, a global intercomparison exercise takes place to ensure consistency between ground-based TSI measurements. This project has upgraded the Cryogenic Solar Absolute Radiometer (CSAR), developed in-part during MetEOC-1. This upgrade allows it to perform continuous sequences of fully automated solar irradiance measurements, incorporate improved cavity absorbance to reach near 100%, reduce the uncertainty of window transmittance measurement and reduce residual noise to allow measurements at close to 0.01% uncertainty level. This work enables CSAR to be a prime candidate for replacement as the new WRR.



Looking ahead to MetEOC-3

MetEOC-2 has been wide-reaching in its aim to improve the measurement accuracy and traceability for space-measured optical Essential Climate Variables. As of September 2017, MetEOC-2 has ended and MetEOC-3 has started. This new project aims to build on the successes of the previous 6-years of work, and continue to contribute to the establishment of a European metrology 'centre of excellence' network; helping to facilitate uncertainties at levels needed to monitor ECVs and climate change mitigation.

Funded partners:

NPL National Physical Laboratory; le cnam; INRiM Istituto Nazionale di Ricerca Metrologica; CSIC; MIKES; PTB; LNE Sharing a passion for progress; Aalto University; SFI; JRC European Commission; MI; VSL Dutch Metrology Institute

Unfunded partners:

Science & Technology Facilities Council; UCL; DLR; Geodeettinen Laitos; Jülich Forschungszentrum; Bergische Universität Wuppertal

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