Metrology for Earth Observation and Climate

Newsletter

www.meteoc.org February 2016

What is MetEOC-2?

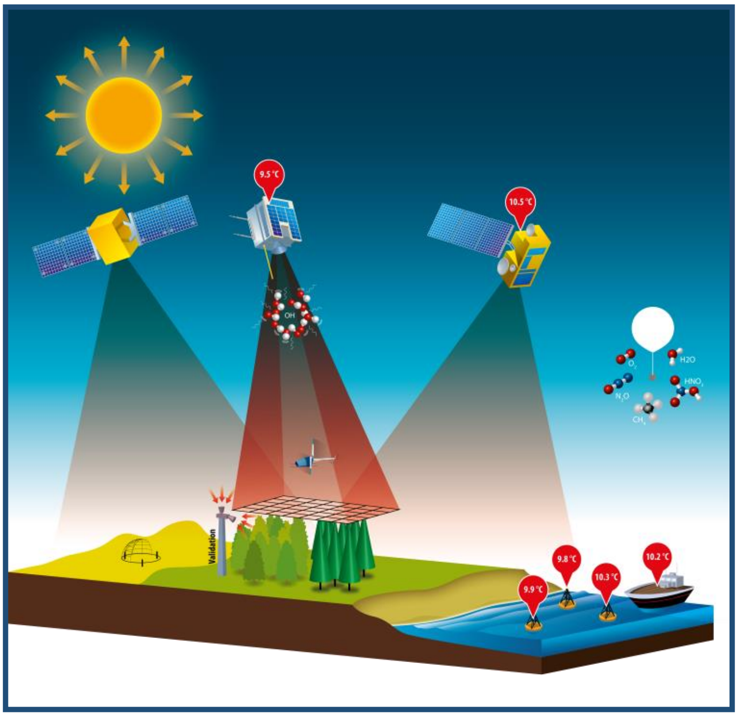
MetEOC-2 (**M**etrology for **E**arth **O**bservation and **C**limate) is a joint research project (JRP) that brings together a coordinated network of National Metrology Institutes (NMIs) across Europe, in collaboration with other international experts, to progress towards establishing a European centre of excellence to provide 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 and builds on previous expertise developed nationally. Within this current JRP, 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 are required to distinguish climate trends from data noise. Thus climate science relies on measurements 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, the goal to make 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.

3D forest reconstruction to improve forest monitoring techniques

Field measurements at Wytham Woods will provide a framework for quantifying end-to-end traceability of in situ Plant Area Index (PAI) sensors through estimates of gap fraction.




Forest monitoring programmes can assess the impact of natural and anthropogenic processes on forest resources. NPL aims to provide traceability for terrestrial and satellite measurements of key biophysical climate variables, including forest cover, to provide quality-assured data which decision-makers can act on with confidence.

Using NPL's expertise in traditional field surveys, as well as novel imaging techniques, the *TREES Group at NPL* undertook two successful measurement campaigns (Summer & Winter 2016) at a six hectare site in Wytham Woods, Oxfordshire, UK. The field team consisted of; Kim Calders, Ally Barker, Niall Origo, Joanne Nightingale and Mat Disney (UCL), with support from Tobias Jackson (Oxford University) and Daniel Fox (NPL summer student).

A range of optical devices were used to estimate forest structure, canopy area and the spectral properties of individual foliage elements, bark and understory. Measurements were carried out using: a hemispherical camera, LAI-2200, Trac and ASD Spectrometer, and using 20m-grid sampling for collecting 3D terrestrial LiDAR data. The sampling strategy will enable us to address spatial variance and quantify the effect of sampling designs on inferred ECVs.

LiDAR measurements (of position and reflectance) were used in computational tree models to produce a 3D reconstruction of the site for leaf on and leaf off conditions. This can be used: in 3D radiative transfer models; provide traceable uncertainty from ground measurements through to satellite observations; and validation of other sensors.

During the summer campaign, NPL was joined by Teemu Hakala and Olli Nevalainen from the Finnish Geospatial Research Institute (FGI) in National Land Survey of Finland. Their work used hyperspectral techniques as part of the Research Excellence Grant ENV53-REG2 to investigate the aspects of generating hyperspectral reflectance point clouds with hyperspectral instrumentation, including; an unmanned airborne vehicle (UAV)-based hyperspectral imaging system, terrestrial hyperspectral passive imaging system, and an active hyperspectral LiDAR (HSL).

Find out more

Field site characterisation in the Gobabeb Desert, Namibia

A new reference calibration site in the Gobabeb Desert has been selected as the European (ESA / CNES) contribution to the CEOS WGCV, RadCalNet network.

Vicarious calibration and validation using ground reference sites is a key technique in Earth Observation, both for the cross comparison of sensors, and for monitoring long-term drift. It is common to use accessible desert sites for field campaign measurements that are made to coincide with a satellite overpass.

Staff from NPL in collaboration with CNES and with financial support from ESA successfully completed a field campaign in Namib Desert in November 2015. The NPL team comprised of Claire Greenwell, Aga Bialek and Maxim Lamare, and the CNES team of Aimé Meygret, Sebastien Marcq and Sophie Lachérade. The purpose was to undertake site characterisation in order to find a location for a permanent measurement site that will be installed in 2016 (including a CIMEL sun photometer) to continuously monitor the atmosphere and surface reflectance. Prior to the field campaign, the instruments were characterised at NPL with full traceability to SI standards.

Initial tests involved a visual assessment of the candidate test sites' surfaces, GSM coverage tests, and a detailed characterisation study of the spectral reflectance and homogeneity of the chosen test site.

ASD measurements being taken at the Gobabeb site

ASD spectrometers were used to assess the uniformity of the site over a wide area; small scale and large scale areas were covered, and long transects measured. Tests of the change in ground radiance over a day and the change in downwelling irradiance were also done. Large calibrated tarpaulins were also used for comparison experiments.

GRASS deployed at the Gobabeb site

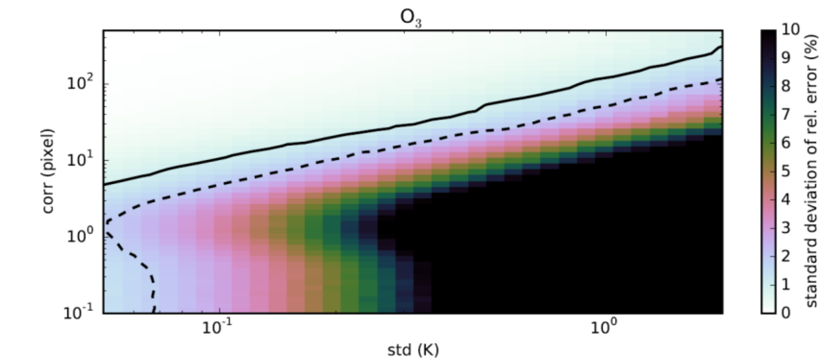
Ground-based measurements of the hemispherical directional reflectance factor (HDRF) of the site were carried out with GRASS. GRASS is designed to record quasi-simultaneous, multi-angle, hyperspectral measurements of the Earth's surface reflectance. During the campaign, measurements were made under clear sky conditions over viewing zenith angles from 0° to 50°, and azimuths from 0° to 360°. Changes in illumination were monitored with an integrating sphere mounted on the instrument and a reference measurement was recorded at nadir over a Spectralon panel.

Find out more

Uncertainty budget for reference sources

For the first time the propagation of uncertainties of reference sources through atmospheric limb imaging retrieval algorithms was determined providing the missing link in a true end-to-end uncertainty budget.

Reference sources play a key role in the radiometric calibration of atmospheric remote sensing instruments. The calibration concept of the airborne instrument *GLORIA* (Gimballed Limb Observer for Radiance Imaging of the Atmosphere) combines deep space measurements with black body measurements. Propagation of the uncertainties of these black bodies through the highly non-linear retrieval algorithm of GLORIA has been investigated using a Monte Carlo approach by Isabell Krisch, Jörn Ungermann and Peter Preusse from *the Institute of Energy and Climate Research of Research Center Jülich*. A retrieval has been performed for different random deviations of the black body radiation temperature. The figure shows the result of this study for the ozone retrieval. The influence of the temperature deviations depends on their correlation length and standard deviation. Almost uncorrelated temperature deviations influence the result more than completely correlated deviations. The higher the standard deviations of the black body inhomogeneities, the more severe the error of the retrieval result. To keep the errors in the Ozone retrieval below 1 % (solid black line in the figure) the black body temperature deviations should be below 300 mK for correlation lengths of around 30 detector pixels. These values are in the range of the measured temperature variations of the blackbodies used for the calibration of GLORIA which were determined by the BUW-PTB team; Friedhelm Olschewski, Bernd Gutschwager, Albert Adibekyan, Marco Schulz, Max Reiniger and Christian Monte, and were confirmed by the analysis of recent in-flight measurements by Anne Kleinert of the Institute for Meteorology & Climate Research, Karlsruhe Institute of Technology (KIT).



Standard deviations of the retrieval error distributions for different standard deviations (x-axis) and correlation lengths (y-axis) of the black body uncertainties. The black solid (dashed) line indicates 1% (2%) retrieval error.

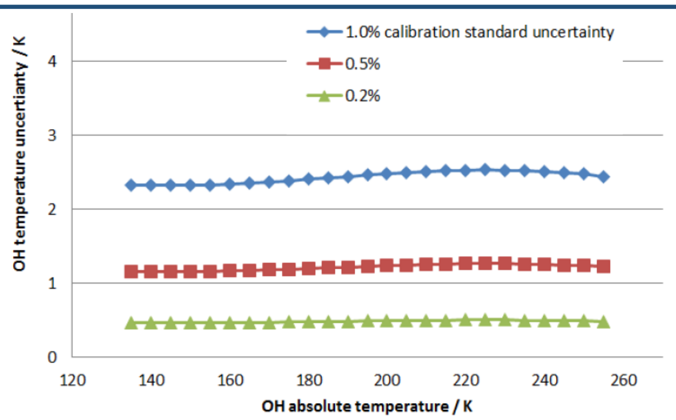
Traceability for the Mesopause Region

Determining calibration requirements for the reliable identification of temperature trends of up to 1K/decade in the Mesopause region – a sensitive indicator for climate change

The Network for the Detection of Mesospheric Change (*NDMC*) is a global program with the mission to promote international cooperation among research groups investigating the Mesopause region (80 km to 100 km) with the goal of early identification of changing climate signals. Therefore, one of the main objectives is the early identification and quantification of long-term changes by monitoring key parameters in this region, e.g. temperature and airglow brightness.

The main source of airglow is a thin layer (on average <10 km) of chemically excited hydroxyl molecules (OH) at 87 km. The molecular emissions can be used to determine temperature at the respective emission heights. Observations are usually performed with infrared spectrometers. Recent advances in detector technology led to the application of InGaAs focal plane arrays, aimed at the observation of the brightest emissions around 1.5 µm to 1.6 µm. However, since emission intensities are small and expected temperature trends are only on the order of 1 K per decade, precise instrument calibration is required.

Within MetEOC-2 the initial emphasis was therefore laid on determining the calibration requirements. Elaborate Monte-Carlo-simulations were performed by the DLR team, Carsten Schmidt and Sabine Wüst with input from PTB, to determine the propagation of uncertainty from calibration over observation to final analysis procedures. The results indicate that for an uncertainty of 1 K of the final OH-temperature, the uncertainty of the calibration must be below 0.5 %. This constitutes high demands on calibration sources (black body operated at around 115 °C and observed at 1.5 µm), instrument stability and signal-to-noise ratio. To achieve these requirements a traceability concept is proposed for the NDMC by PTB, DLR and VSL, which is based on a radiometrically well characterized Traveling Radiance SOurce (TRSO) and Traveling Reference SPectrometer (TRSP). Two suitable instruments were identified will now undergo a thorough characterisation at PTB by Max Reiniger and Bernd Gutschwager. The TRSP and TRSO will be linked to the primary standards of the radiation temperature scale of PTB via a very sensitive NIR radiometer (NIRTR) designed and built by Paul Dekker and Steven van den Berg of VSL.



Monte-Carlo simulation of OH rotational temperature uncertainty as a function of absolute OH temperatures, commonly observed over the year at NDMC sites. To achieve an uncertainty of 1 K in rotational temperature, the uncertainty of the radiance calibration should be ~0.5

Events

The MetEOC-2 project will be exhibiting at:

Cheltenham Science Festival, 7-12 June 2016

New Scientist Live, London, 22-25 September 2016

Uncertainty for Earth Observation Training Course

This course was run in July 2014 and February 2015. The course text book can be freely downloaded *here*

The course presentations are available for download *here*:

1. Introduction
2. Political Framework
3. Law of Propagation of Uncertainties
4. Steps to a Budget
5. The Measurement Equation
6. Validating Uncertainties
7. Example - The APEX imager
8. Pre-flight Calibration

Competition

European Climate Science Poster Challenge 2016

Design a poster relating to the cause, monitoring/measuring, or mitigation of climate change and WIN the opportunity to join a team of climate scientists in a field campaign experiment. Applicants must be over 18 years. *Find out more*

A proposal for a follow-on phase of this project (MetEOC-3) is currently being planned. Ideas from the community relating to priority needs, particularly where metrology support to an existing international project is desired, are welcome. Responses need to be sent to:

Dr Nigel Fox, Head of Earth Observation and Climate, NPL (nigel.fox@npl.co.uk) by **20th February.**

Funded partners:

Unfunded partners:

For more information visit: *www.meteoc.org*

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