SI Traceability, Uncertainty Analysis and Comparison for RadCalNet

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RadCalNet provides nadir-view ground and top-of-atmosphere spectral reflectance values (10 nm steps, 400 nm – 1000 nm / 2500 nm) every 30 minutes from four instrumented reference sites in China, Namibia, USA and France. NPL has been the metrology partner for this initiative and is responsible for ensuring the SI-traceability of the network. In this presentation we describe the metrological processes introduced to ensure SI-traceability to the network.

RADCALNET

The increased use of satellite-derived data in climate and earth monitoring, requires robust and traceable radiometric and spectral calibration of satellite sensors. Vicarious calibration sites play a vital part in ensuring the stability and interoperability of satellite sensor data post-launch for both traditional satellites and the smaller, often commercial satellites which do not have onboard calibration capability.

RadCalNet [1], the Radiometric Calibration Network established through the Committee on Earth Observation Satellites Working Group on Calibration and Validation (CEOS-WGCV), provides a network of instrumented ground reference sites providing users with bottom and top-of-atmosphere (BOA and TOA) reflectance measurements every 30 minutes in 10 nm spectral intervals (for 400 nm to 1000 nm or to 2500 nm) and for nadir view. (For all sites, more detailed spectral information and off-nadir reflectances can be obtained from site owners). Each RadCalNet site provides ground reflectance values that are propagated to TOA through a centralised processing system. RadCalNet has over 300 users.

It is a key aspect of RadCalNet that the sites document their traceability to the International System of Units (SI) and that they provide associated uncertainties for each observation.

RADCALNET WORKING GROUP AND MEMBERSHIP PROCESSES

RadCalNet was established under CEOS-WGCV by the RadCalNet working group (WG). The RadCalNet WG comprises the owners of RadCalNet member sites (currently AOE, China, CNES, France, University of Arizona, USA and ESA, Europe), the organisation which provides processing of site data to TOA reflectance (NASA, USA), the organisation which operates the RadCalNet data servers and portal (Magellium, France) and NPL as the metrology partner (NPL also operates the Namibian site on behalf of ESA). Additionally, CEOS-WGCV has appointed a "Test site admissions panel" that has the authority to approve sites to join RadCalNet.

New RadCalNet sites must provide 45 days' data from their site, show that they can provide data operationally (within two weeks of measurement) and provide a questionnaire detailing information about their site (instrumentation, location, climatology) along with a detailed uncertainty statement. These documents are peer reviewed by the RadCalNet WG, which also performs a comparison of the site with others using satellite sensors. Once the documents have been updated, the RadCalNet WG writes a report to the CEOS-WGCV test site admissions panel which formally approves the site.

To support site owners to establish sites, the RadCalNet WG to maintain and monitor the performance of sites and users to understand the data and its limitations, NPL has produced guidance documents on site selection, site instrumentation, uncertainty budgets and comparisons [2] along with document templates and procedures for peer reviewing sites. These guidelines and procedures are based on metrological approaches used by national metrology institutes for the mutual recognition arrangement. NPL also carries out four-monthly comparisons of all sites to ensure ongoing data quality.

RADCALNET REFLECTANCE UNCERTAINTIES

Each site's uncertainty budget documents the traceability to SI for the field measurements (including laboratory comparison and transfer to field as well) and for any auxiliary information required, e.g. the solar and sky irradiance required to convert measured ground radiance into ground reflectance. Because satellite sensors are not compared with

RadCalNet on a single overpass but through an averaging of multiple overpasses, it is also important to identify which sources of uncertainty have a common (unknown) error for different days and which are due to transient effects that will have different (unknown) errors on different overpasses.

RadCalNet ground reflectances and atmospheric observations, which are provided by site operators with associated uncertainties (that may vary from measurement to measurement), are propagated to TOA through a common RadCalNet processor operated by NASA. Uncertainties associated with TOA reflectances are obtained using look up tables based on ~80k atmospheric, altitude and solar angle conditions. For each condition a 100-sample Monte Carlo run was used to obtain the uncertainty associated with the propagation to TOA.

SITE COMPARISONS

At present, comparisons between the sites are performed using the ESA Multi Spectral Instruments (MSI) on board the Sentinel-2A and -2B satellites as references. These are high quality sensors with onboard calibration capability, which are regularly compared to each other and to other similar sensors (e.g. NASA's Operational Land Imager (OLI) on Landsat 8) over a large variety of vicarious targets.

Every four months NPL performs comparisons between the sites' RadCalNet products and Sentinel-2A/B for every valid matchup. These data (e.g. fig. 1) are provided to the RadCalNet WG for monitoring.

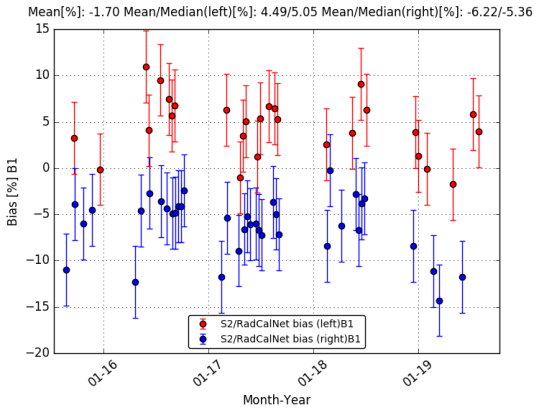

Figure 1 Example comparison results for one of the RadCalNet sites.

Currently comparisons between sites is performed using satellite observations as a reference. During MetEOC-2, the Czech Metrology Institute (CMI) developed an instrument, called MuSTR [2], to act as a travelling standard for in situ site comparisons. Work is ongoing to develop procedures and analysis methods for such comparisons.

SUPPORTING USERS

RadCalNet provides, at no cost, data for nadir view observations. Most satellites do not observe the sites at nadir view. Satellite sensor spectral response functions are also not represented by data provided in 10 nm spectral steps and satellites do not go over the sites exactly on the half hour. Most sites will provide off-nadir, higher spectral and temporal resolution data as a commercial service, but users need guidance on when RadCalNet data are fit for purpose and what additional uncertainties are to be considered when the RadCalNet conditions are not met.

Figure 1 shows the comparison to Sentinel-2 over one of the RadCalNet sites for one spectral band. There, the red data represent an orbit where the site was imaged on the left-side of the swath, and the blue data where the site was imaged on the right-side. The observed bias from the nadir reflectance values is due to the bi-directional reflectance factors of the surface. NPL is developing site-specific models to understand and quantify such differences.

As a founder member of the RadCalNet WG, NPL has been developing procedures, guidance and protocols for site owners and data users, has performed scientific analysis to develop comparison and uncertainty methods and provides routine quality control on the data provided by RadCalNet.

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