Radiometric calibration network for vicarious calibration of Earth observing imagers in the reflected solar

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Field test sites are regularly characterized to provide inflight and on-orbit calibration of aircraft and satellite sensors.

Red Lake Playa, Arizona 29 March 2013
Automated collections provide more opportunities

Greater number of calibrations for a given sensor

Easier to calibrate multiple sensors

RadCaTS at Railroad Valley Playa, USA

Automated approach provides results of similar accuracy as those with on-site personnel

ROSAS at La Crau, France

Landsat 8 OLI example
Community recognized the use of widely-available automated data

In 2013, CEOS/WGCV IVOS initiated a small group to develop a network making automated data widely available

- Discussions started well before this
- Landnet Working Group initial meeting at ESA ESTEC in January 2014
- Renamed the RadCalNet (Radiometric Calibration Network) Working Group
- Objectives were to
  - Define the detailed architecture of RadCalNet
  - Demonstrate RadCalNet operational concept with currently available infrastructure and resources
  - Provide recommendations to CEOS/WGCV/IVOS and CEOS/WGCV for an operational network
RadCalNet architecture overview

Architecture developed has three main parts:
1) Test sites provide data to RadCalNet
2) Centralized processing of data
3) Distribution of top-of-atmosphere reflectance

RadCalNet - Radiometric Calibration Network
RadCalNet relies on test sites pre-processing the input data.

RadCalNet does not standardize collection and processing schemes of sites.

Standardized input from RadCalNet sites.

Standardized RadCalNet processing stream.

Sites perform QA on their data.

Site-specific output.

L0: raw instrument data
L1: instrument data in physical unit
L2: surface or atmosphere parameters retrieved from L1.
Predict nadir-viewing top-of-atmosphere reflectance and uncertainties

**RadCalNet Inputs**
- Calibration & QC & Processing

**RadCalNet Outputs**
- TOA Reflectance with Uncertainties
  - 30 minute intervals
  - 9 am to 3 pm local standard time
  - Nadir view
  - 10 nm intervals from 400 nm to 1000 nm

**Surface Reflectance**
- 30 minute intervals
- 9 am to 3 pm local standard time
- Nadir view
- 10 nm intervals from 400 nm to 1000 nm

**Atmospheric Data**
- Pressure
- Temperature
- Aerosol
- Water Vapor
- Ozone

**Uncertainty**
Why nadir, 30 minutes, and 10 nm?

Moved RadCalNet development forward more quickly, provide a product that does not directly compete with how sites receive funding, and makes inclusion of additional sites more likely.

Spectral resolution sufficient to allow spectral band integration for sensors that would benefit from RadCalNet.

Providing reflectance means that temporal changes in TOA reflectance are either small or well behaved over 15 minute periods.

Typical sites are within a few percent of lambertian for views <10 degrees such that the absolute uncertainty is not dominated by directional reflectance effects.

Site evaluations show that choices do not dominate the uncertainty.
SI-traceable uncertainties more important than perfect site

- Sites have responsibility for their own quality assurance and providing uncertainties for inputs
- Relying on process outlined in NPL Uncertainty Analysis for Earth Observation course (www.meteoc.org/training.html)
- Uncertainty budgets include:
  - Instrumentation effects
  - Data sources
  - Spatial homogeneity of site
  - Radiative transfer code
  - Sampling
  - Processing assumptions

Analysis performed using a combination of literature, laboratory results, Monte Carlo analysis, image analyses
Uncertainty of TOA reflectance derived from test site uncertainties

- Monte Carlo approach relying on 100 variations of a given atmospheric and surface case
- Uncertainty in the input parameters used to derive the 100 cases
- TOA reflectance uncertainty is the standard deviation of the 100 cases
- Results below shows results from two cases
Monte Carlo results build a look-up table

Monte Carlo results based on input uncertainties to radiative transfer code modeling of predicted top-of-atmosphere radiance.

High aerosol loading with large sized aerosols for small solar zenith angle and six surface reflectance values.
Look up table resolution will rely on nearest neighbor to achieve 0.5%

Interesting features related to aerosol and surface coupling mean that interpolation approaches are problematic and LUT resolution is sufficient to achieve 0.5% goal.
SI-traceability with provided uncertainties is the key

Ensuring SI-traceability of automated data automatically provides comparable results

- Test sites have to demonstrate their traceability and uncertainties
- RadCalNet processing provides uncertainties for each data point
- Several well understood sensors were used to evaluate RadCalNet sites
- SI-traceability allows users to combine data from multiple sites with confidence
  - Larger number of possible calibrations
  - Evaluate temporal changes

Data here are for a single sensor in the blue part of the spectrum for two RadCalNet sites

No significant temporal change

No significant difference in calibration average from the two sites
RadCalNet data became openly available in Summer 2018

- 20 Beta testers evaluated RadCalNet in 2016/2017
  - Demonstrated utility of RadCalNet data sets
  - Feedback was extremely positive and productive
  - Improvements to portal were implemented
- Currently 345 users with numbers continuing to increase
- Global distribution

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<tr>
<td>Total</td>
<td>308</td>
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Four RadCalNet Sites so far

**La Crau, France**
- CIMEL photometer (12 bands)
- Pebbles and low vegetation
- Site used since 1987 for calibration and instrumented since 1997

**Baotou, China**
- Three automated spectrometers + sun photometer
- Artificial target (white, black, and gray)
- Operational since 2015

**Railroad Valley Playa, USA**
- >20 years working experience on site
- 4 radiometers, sun photometer, met station
- Dry lakebed

**Gobabeb, Namibia**
- Sun photometer similar to La Crau and met station
- Sparse dry grass and gravel/sand
Example usage

- Results here are for two sensors using two sites
  - Total number of calibration points are similar for both sensors
  - No significant temporal degradation
- No overlapping data sets for the two sensors
- Data points are for the sensor band centers with band averaging of the RadCalNet TOA reflectance

Both sensors are meeting their absolute radiometric uncertainties

No significant band-to-band differences for either sensor

Sensor 1 band 1 is **significantly different** from Sensor 2 band 7
RadCalNet website opened in summer 2018

Four test sites currently providing data with historical results dating to 2015 for some sites

- Procedures are in place for adding new sites
- Beta testing process greatly improved the RadCalNet site
- Number of users continues to increase
- Use of RadCalNet has expanded beyond absolute radiometric calibration
  - Intercomparisons of sensors
  - Evaluation of radiative transfer codes
  - Surface reflectance validation
- Feedback from users has led to reprocessing with an improved spectral resolution, inclusion of additional metadata, and updated uncertainties
- Development of RadCalNet is an incredible example of generosity of the test sites as well as cooperation across multiple agencies, countries, and study areas
Many thanks to

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and
https://www.radcalnet.org

Welcome to the Radiometric Calibration Network portal

RadCalNet is an initiative of the Working Group on Calibration and Validation of the Committee on Earth Observation Satellites. The RadCalNet service provides satellite operators with Si-traceable Top-of-Atmosphere (TOA) spectrally-resolved reflectances to aid in the post-launch radiometric calibration of optical imaging sensor data. The free and open access service provides a continuously updated archive of TOA reflectances derived over a network of sites, with associated uncertainties, at a 10 nm spectral sampling interval, in the spectral range from 380 nm to 2500 nm and at 30 minute intervals. Each individual site is equipped with automated ground instrumentation in order to provide continuous measurements of both surface reflectance and local environmental/atmospheric conditions needed for the derivation of TOA reflectance values. TOA reflectances provided on this portal are derived from the individual sites surface and atmospheric measurements using a common method through a central processing system. Each member site takes responsibility for the quality assurance of the surface/ atmosphere measurements provided and is subject to peer review and rigorous comparison to ensure site-to-site consistency and Si traceability.

Abstract: Vicarious calibration approaches using in situ measurements saw first use in the early 1980s and have since improved to keep pace with the evolution of the radiometric requirements of the sensors that are being calibrated. The advantage of in situ measurements for vicarious calibration is that they can be carried out with traceable and quantifiable accuracy, making them ideal for intercalibration studies of co-orbiting sensors. The development of automated sites to collect in situ data has led to an increase in the available number of datasets for sensor calibration. The current work describes the Radiometric Calibration Network (RadCalNet) that is an effort to provide automated surface and atmospheric in situ data as part of a network including multiple sites for the purpose of optical/imagery radiometric calibration in the visible to shortwave infrared spectral range. The key goals of RadCalNet are to standardize protocols for collecting data, process to top-of-atmosphere reflectance, and provide uncertainty budgets for automated sites traceable to the international system of units. RadCalNet is the result of efforts by the RadCalNet Working Group under the umbrella of the Committee on Earth Observation Satellites (CEOS) Working Group on Calibration and Validation (WCGV) and the Infrared Visible Optical Sensors (IVOS). Four radiometric calibration instrumentation sites located in the USA, France, China, and Namibia are presented here that were used as initial sites for prototyping and demonstrating RadCalNet. All four sites rely on collection of data for assessing the surface reflectance as well as atmospheric data over that site. The data are converted to top-of-atmosphere reflectance within RadCalNet and provided through a web portal to allow users to either radiometrically calibrate or verify the calibration of their sensors of interest. Top-of-atmosphere reflectance data with associated