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

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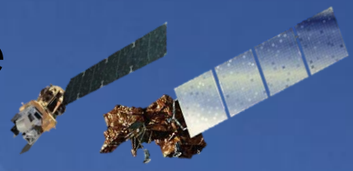
RadCalNet

Airborne Imaging spectrometer

Satellite sensors



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

Laboratory spectrometer

Portable field spectrometer

Calibrated field Diffuser reference

Red Lake Playa, Arizona 29 March 2013

Automated collections provide more opportunities

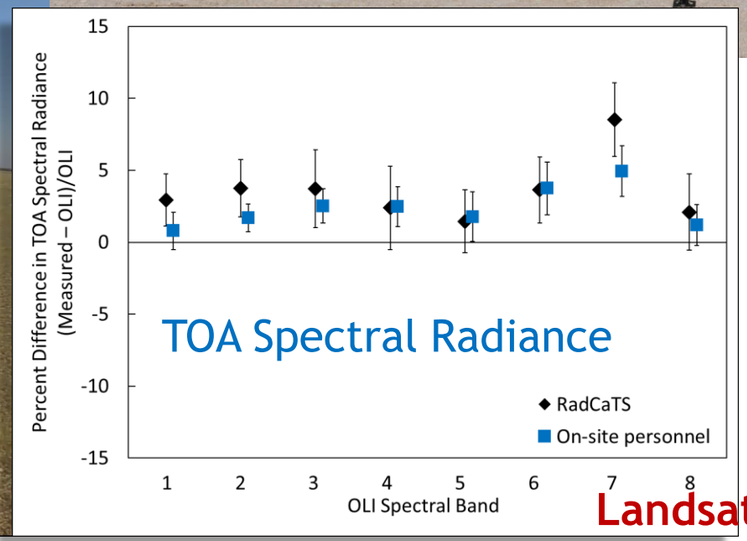
Greater number of calibrations for a given sensor

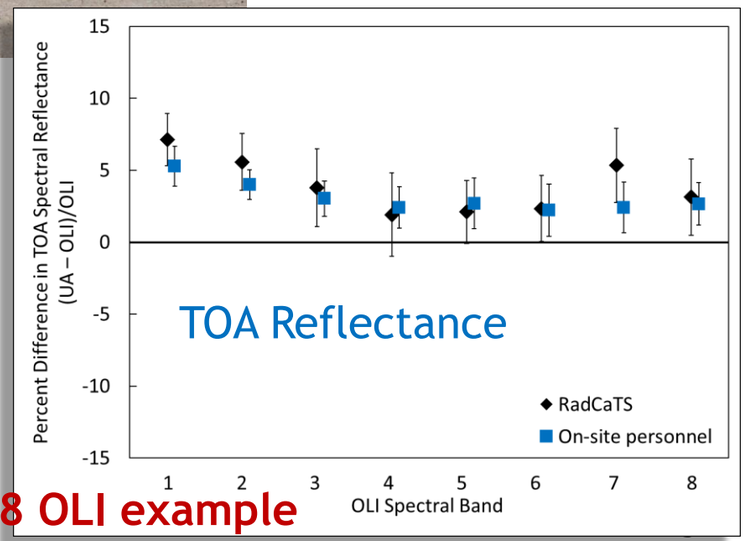
Easier to calibrate multiple sensors

ROSAS at La Crau, France

RadCaTS at Railroad Valley Playa, USA

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





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

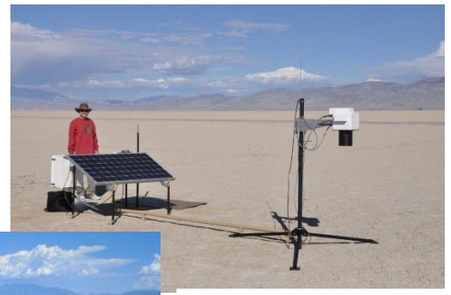
Committee on Earth Observation Satellites (CEOS)
Working Group on Calibration and Validation (WGCV)
Infrared Visible Optical Sensors (IVOS)

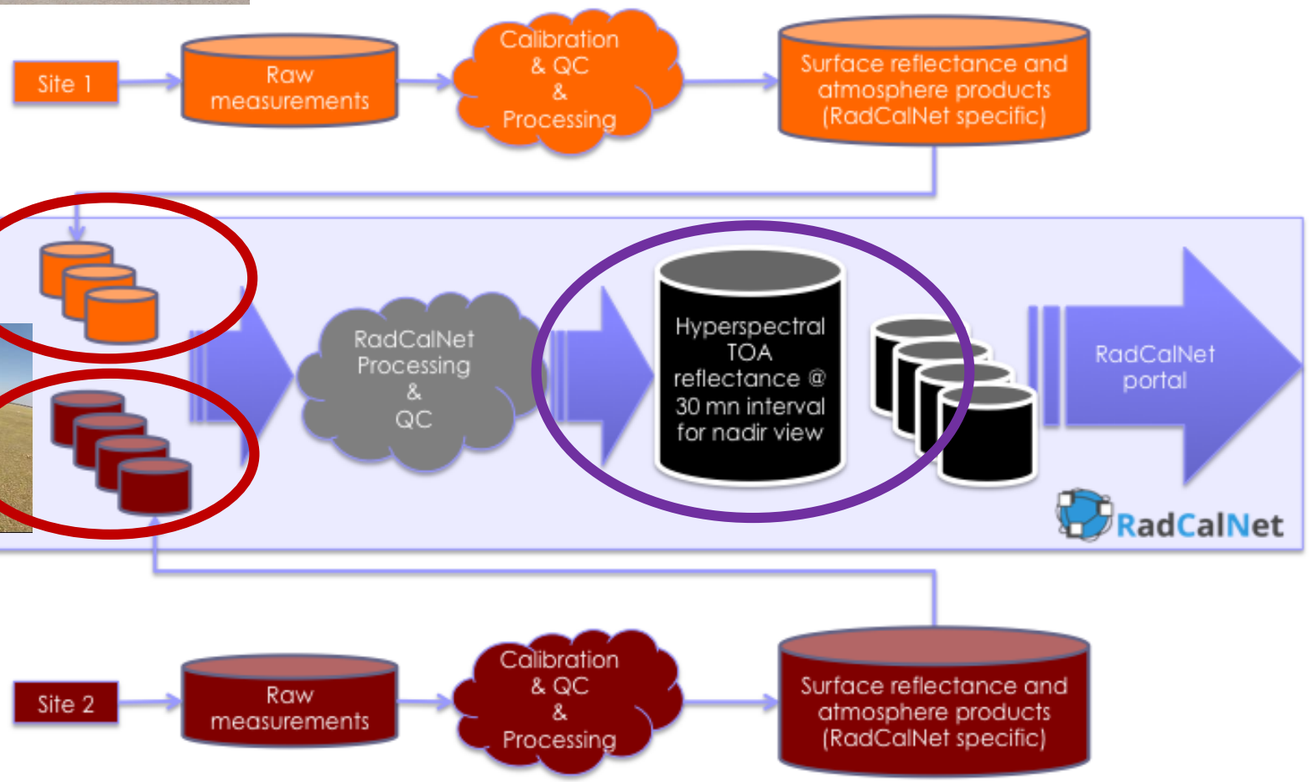
RadCalNet

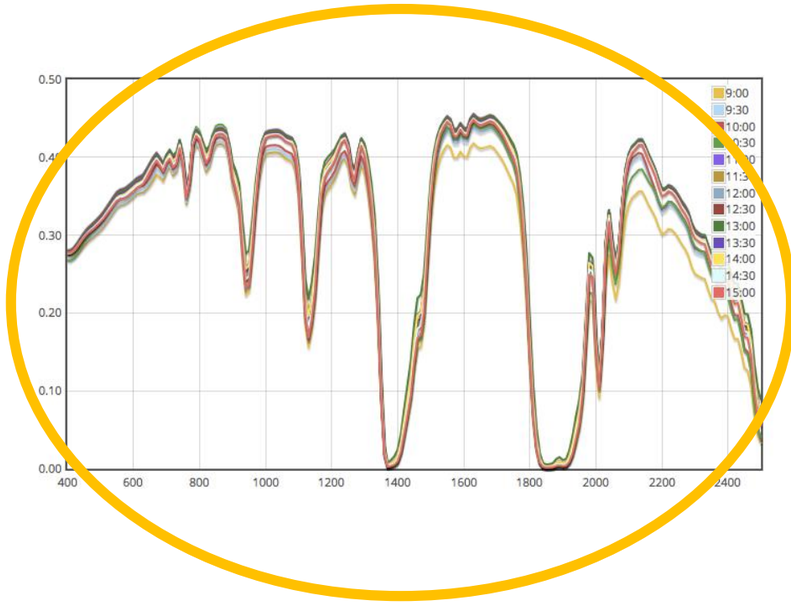
RadCalNet architecture overview

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





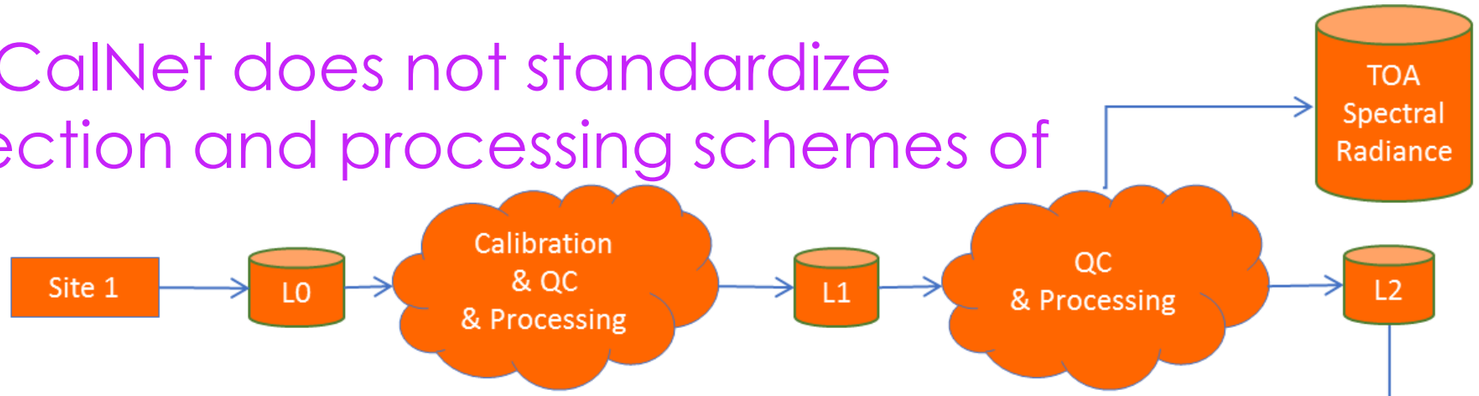


RadCalNet - Radiometric Calibration Network

RadCalNet

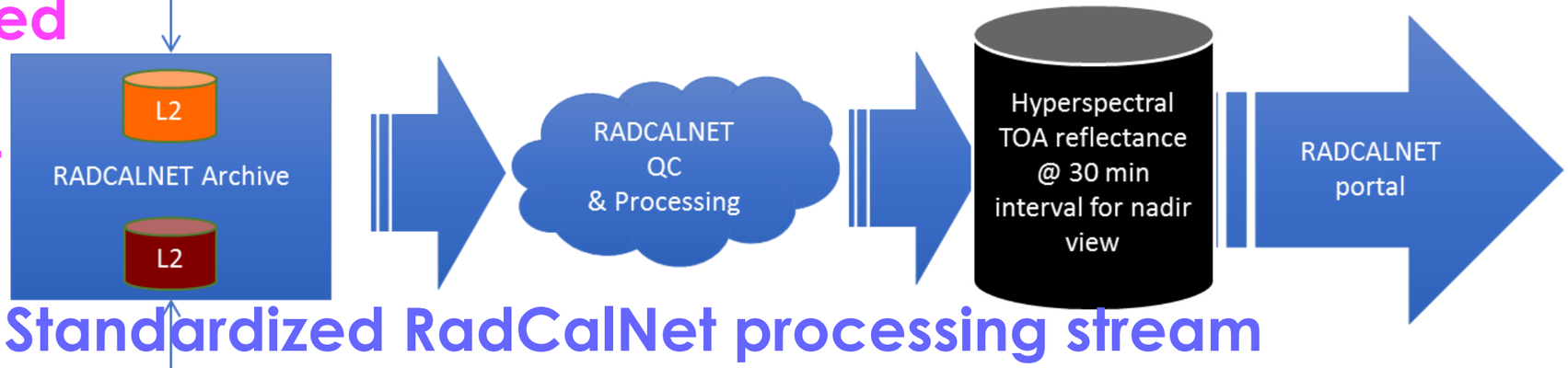
RadCalNet relies on test sites pre-processing the input data

RadCalNet does not standardize collection and processing schemes of sites

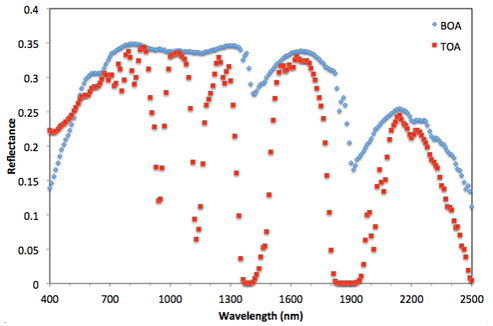


Site-specific output

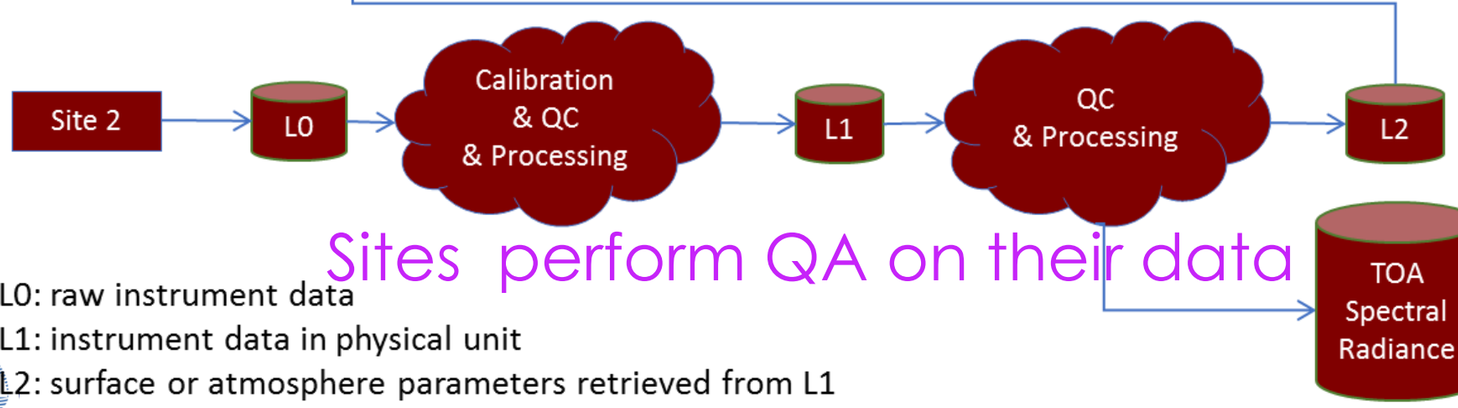
Standardized input from RadCalNet sites



Standardized output



Standardized RadCalNet processing stream



Sites have developed additional RadCalNet dedicated processing

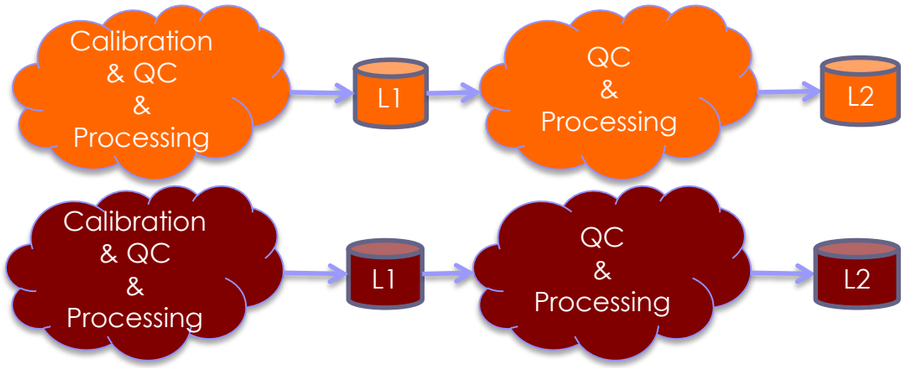
Sites perform QA on their data

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



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

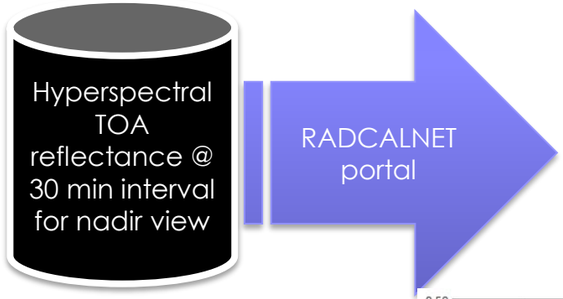
- Pressure
- Temperature
- Aerosol
- Water Vapor
- Ozone

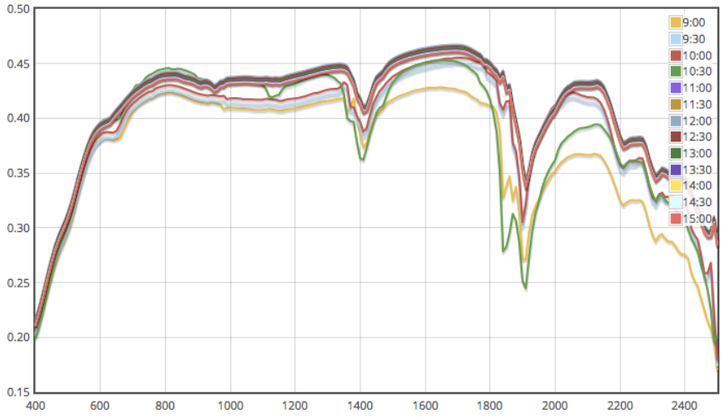
Uncertainty

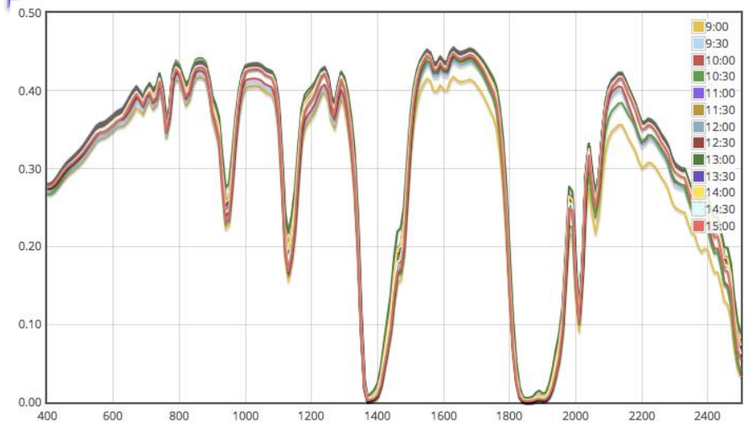
RadCalNet Outputs

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

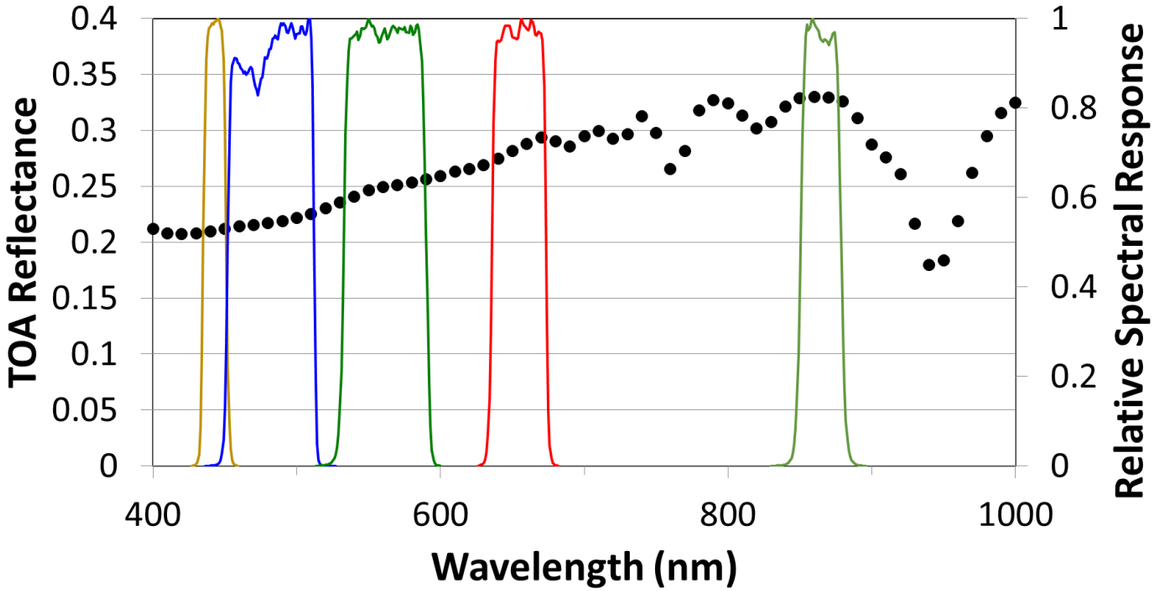




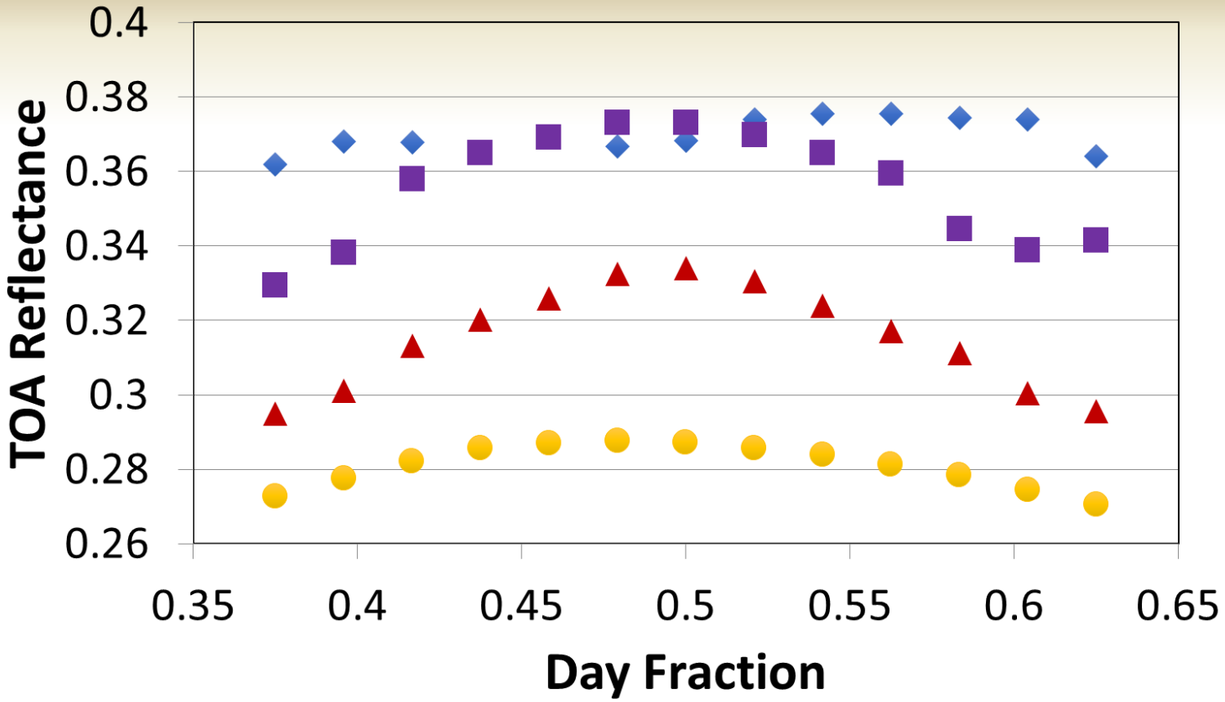


Why nadir, 30 minutes, and 10 nm?

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



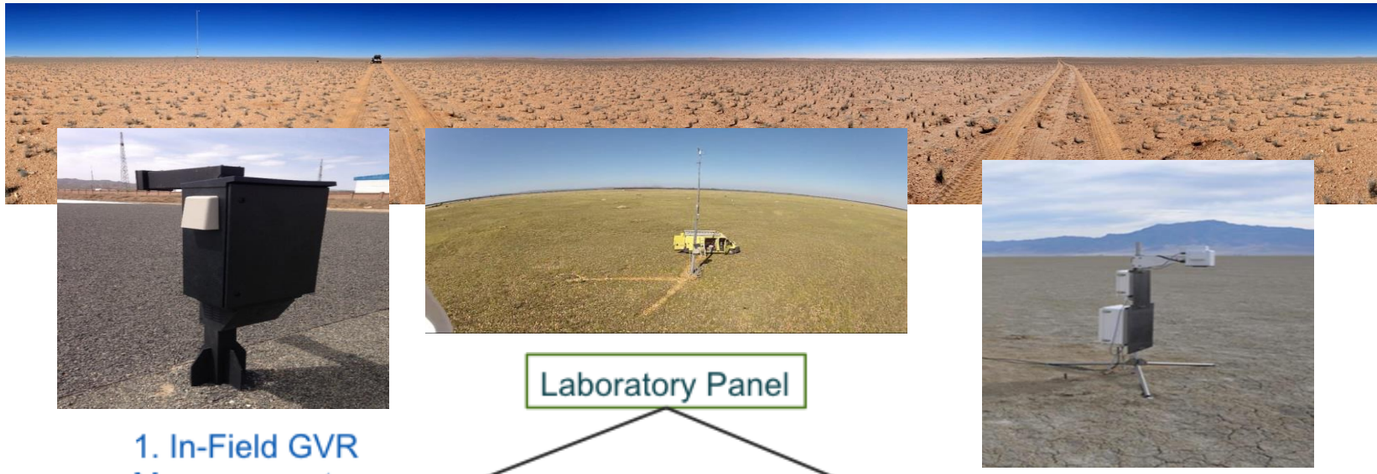
Providing reflectance means that temporal changes in TOA reflectance are either small or well behaved over 15 minute periods

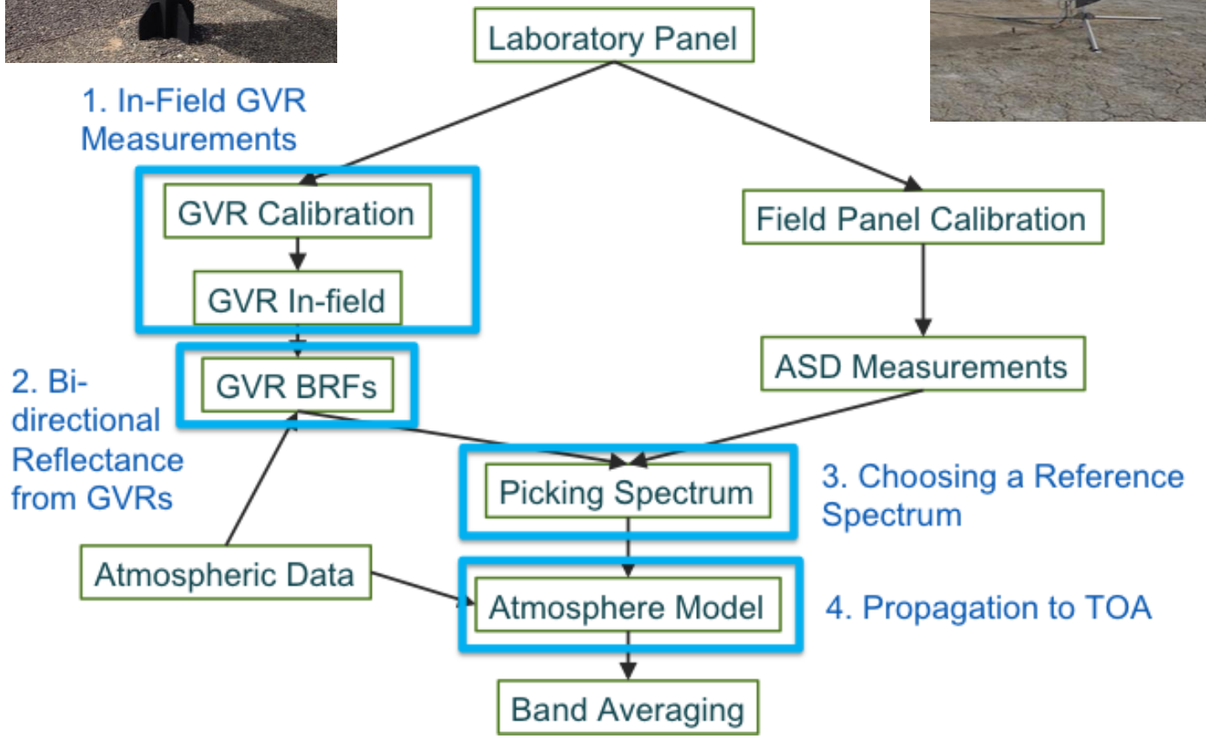
Typical sites are within a few percent of lambertian for views <10 degrees such that the absolute uncertainty is not dominated by directional reflectance effects

Site evaluations show that choices do <u>not</u> 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

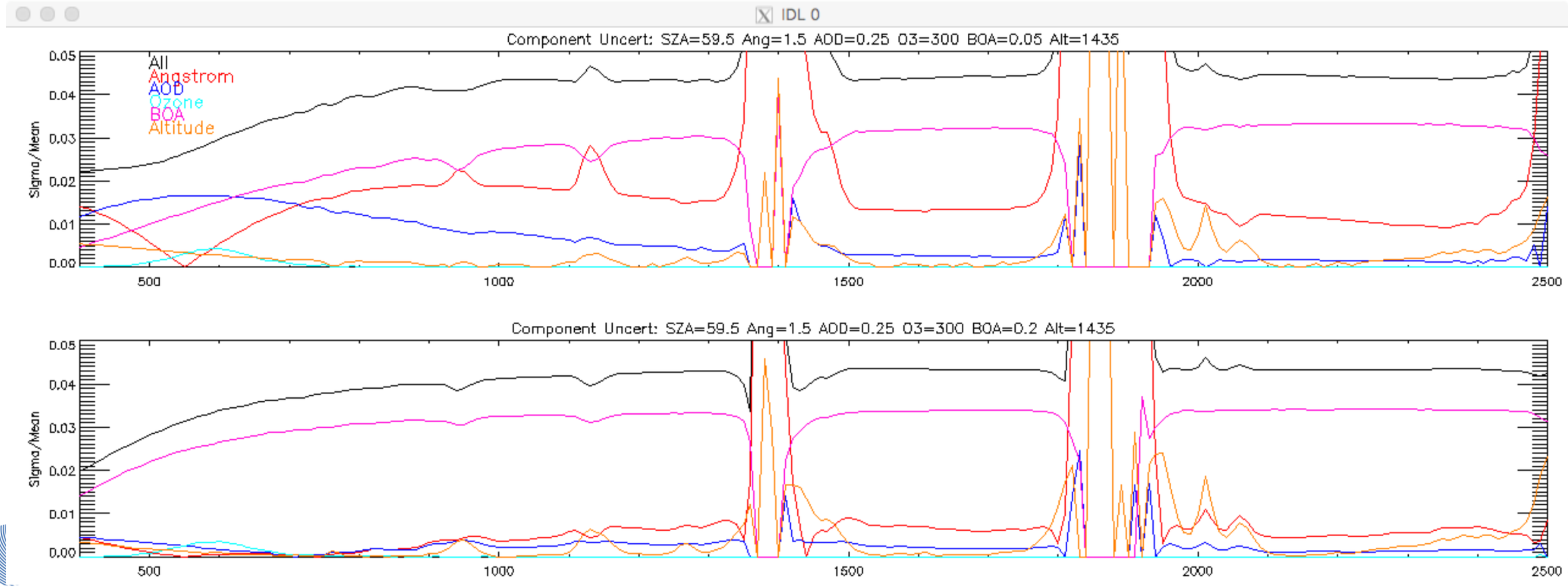




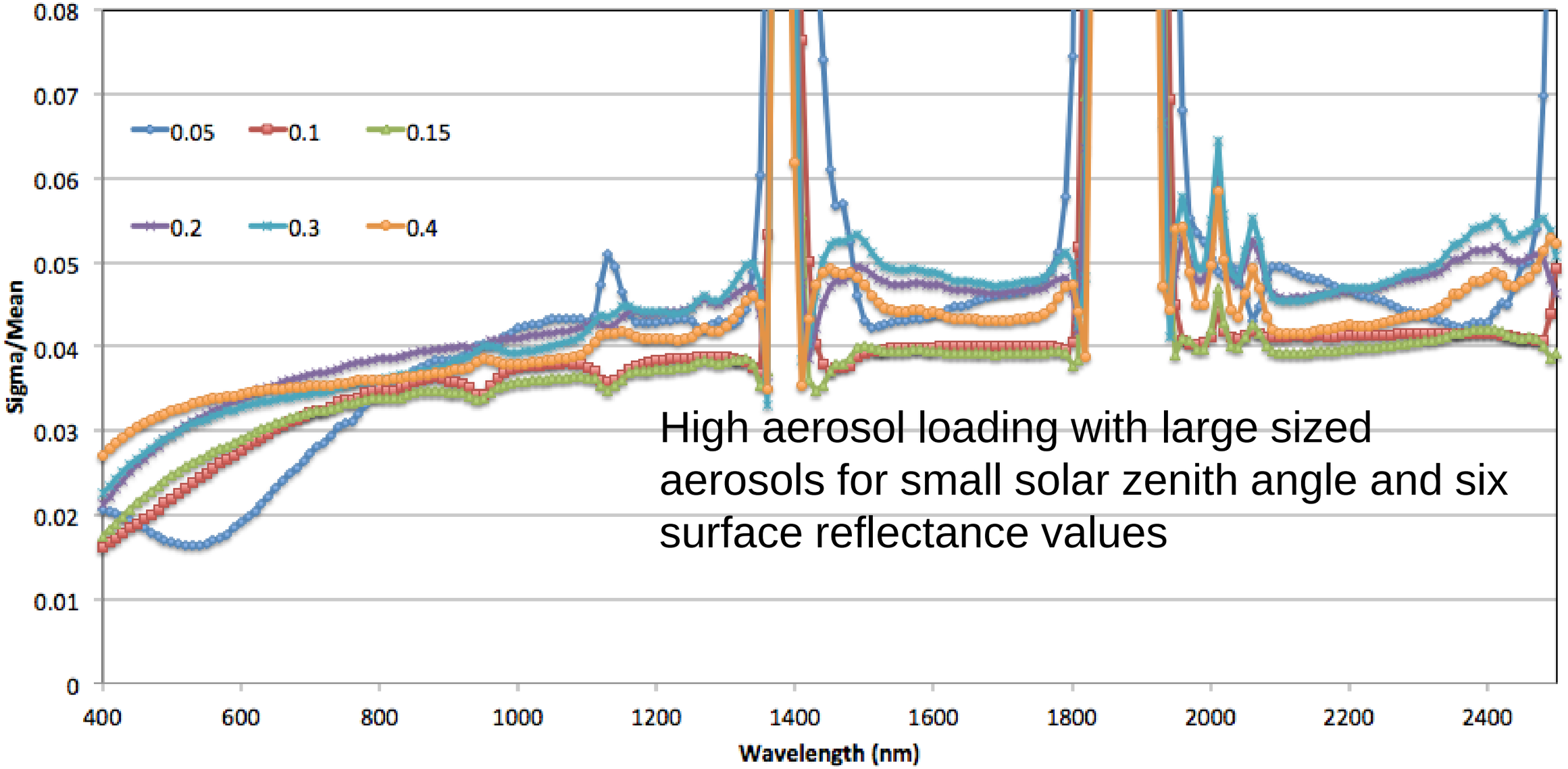
Analysis performed using a combination of literature, laboratory results, Monte Carlo analysis, image analyses

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

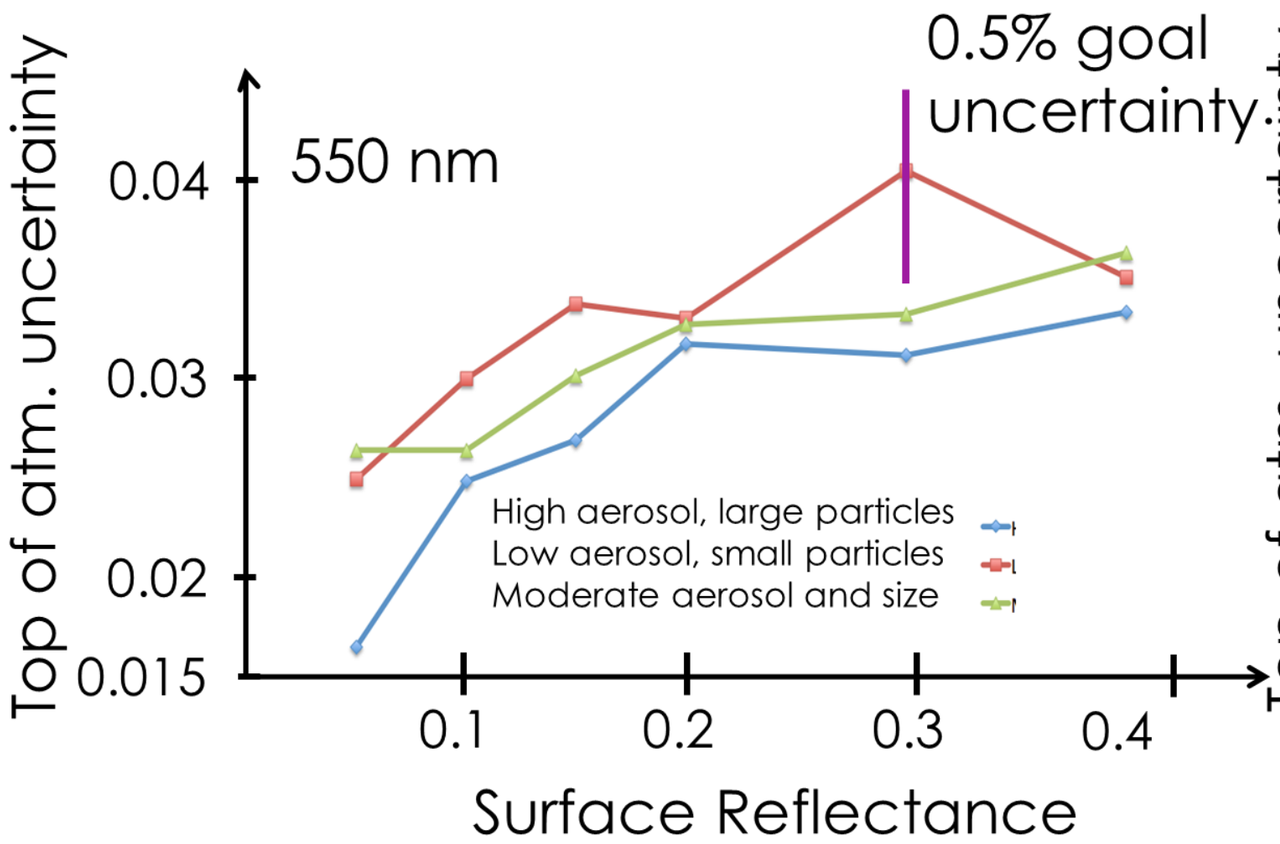


High aerosol loading with large sized aerosols for small solar zenith angle and six surface reflectance values

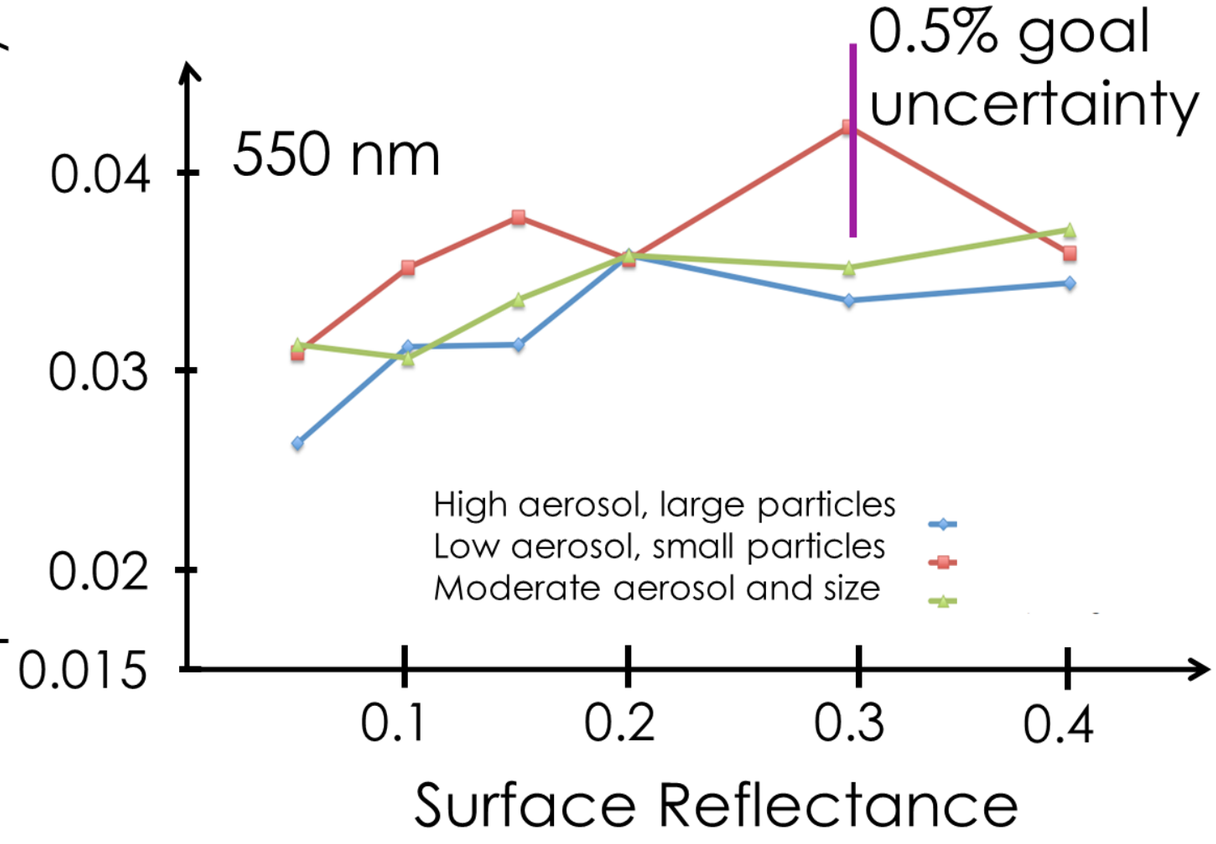
Monte Carlo results based on input uncertainties to radiative transfer code modeling of predicted top-of-atmosphere radiance

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



High sun

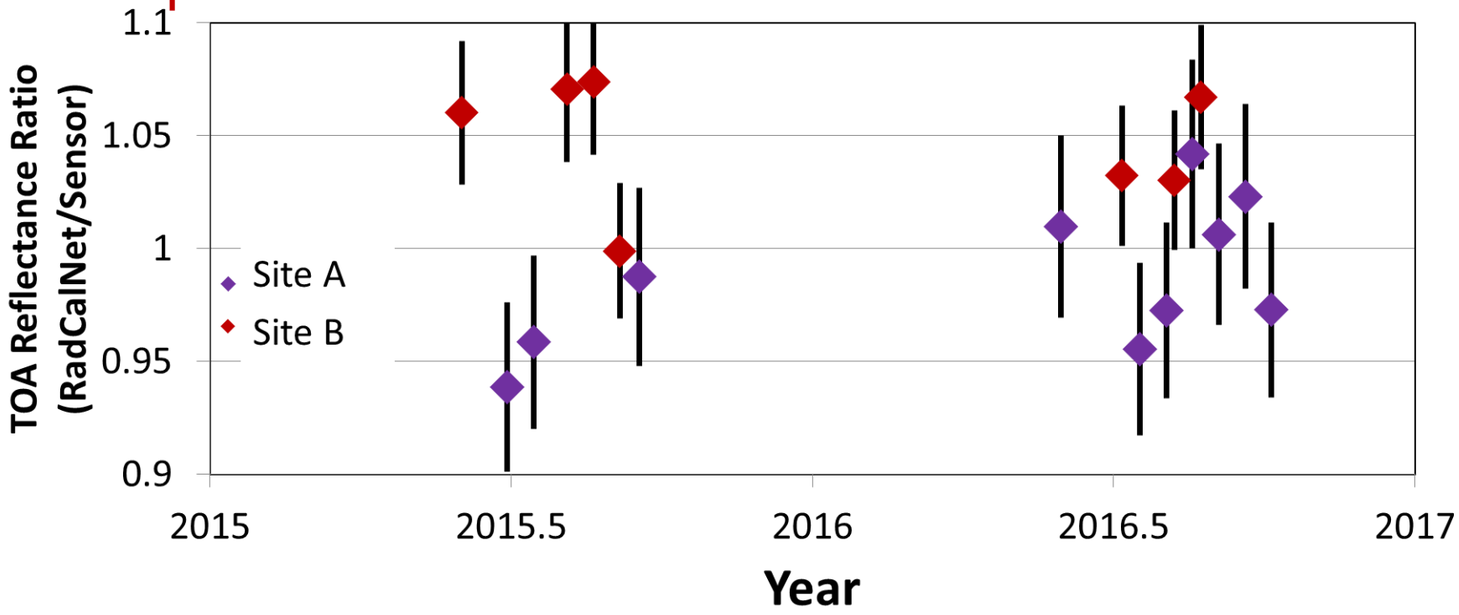


Low sun

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



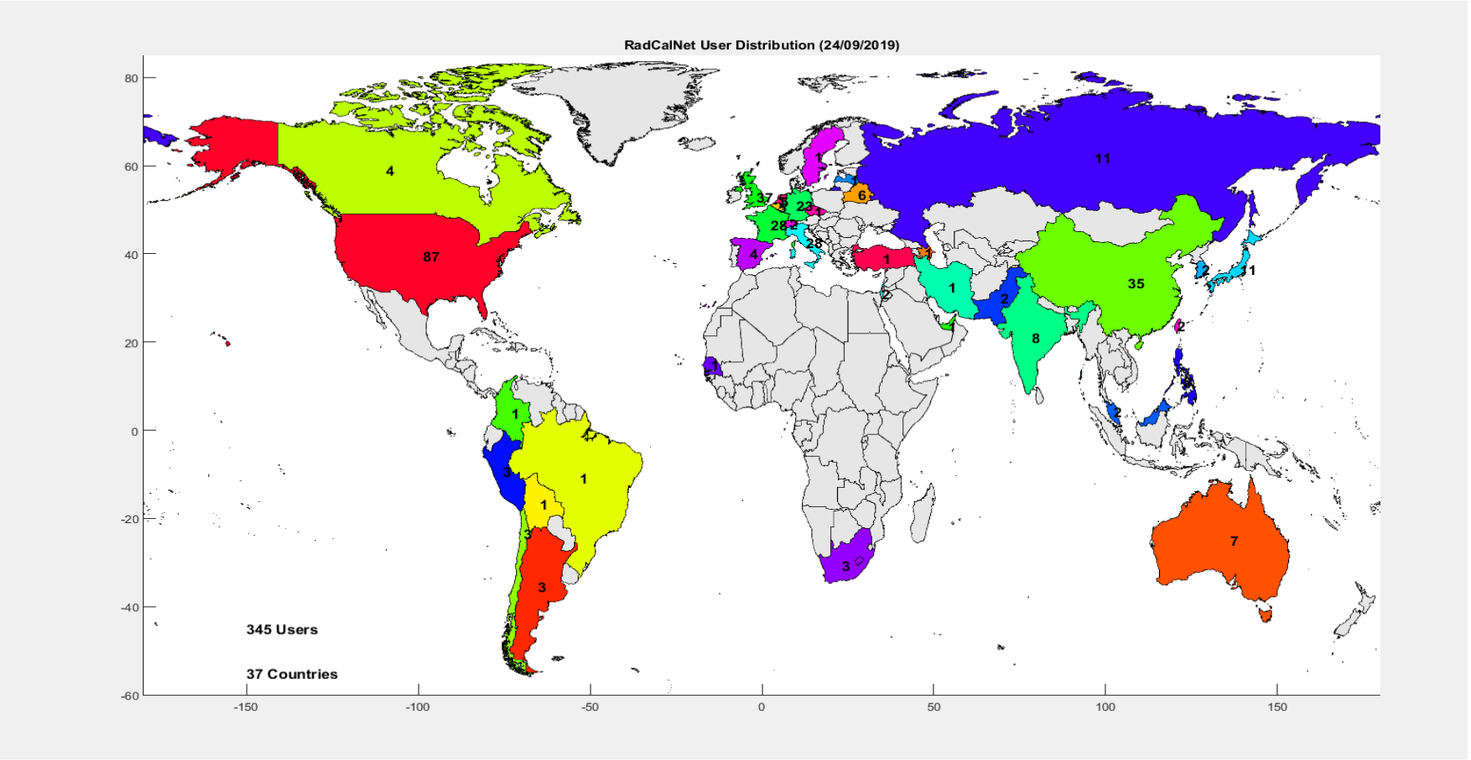
Data here are for a single sensor in the blue part of the spectrum for two RadCalNet sites

No significant temporal change

No significant difference in calibration average from the two sites

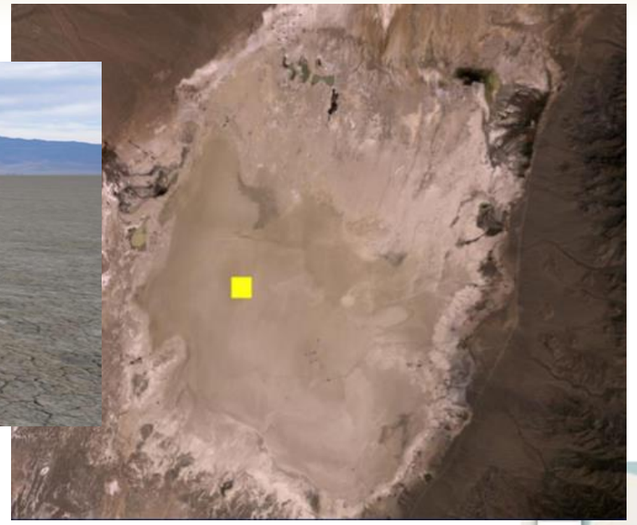
RadCalNet data became openly available in Summer 2018

- 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



	Public users	Beta users	RadCalNet working Group
Before the opening	126	20	17
Between 24/07/2018 to 07/09/2018	32		
Between 08/09/2018 to 20/01/2019	45		
Between 21/01/2019 to 20/05/2019	52		
Between 21/05/2019 to 24/09/2019	53		
Total	308	20	17

Four RadCalNet Sites so far

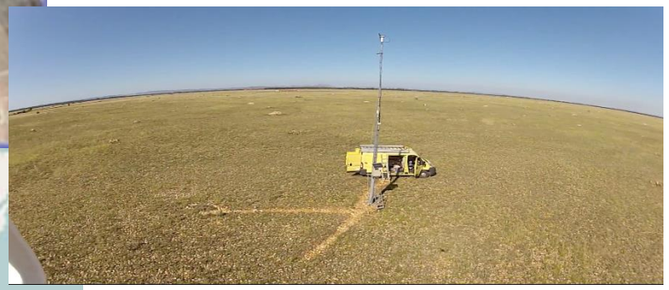


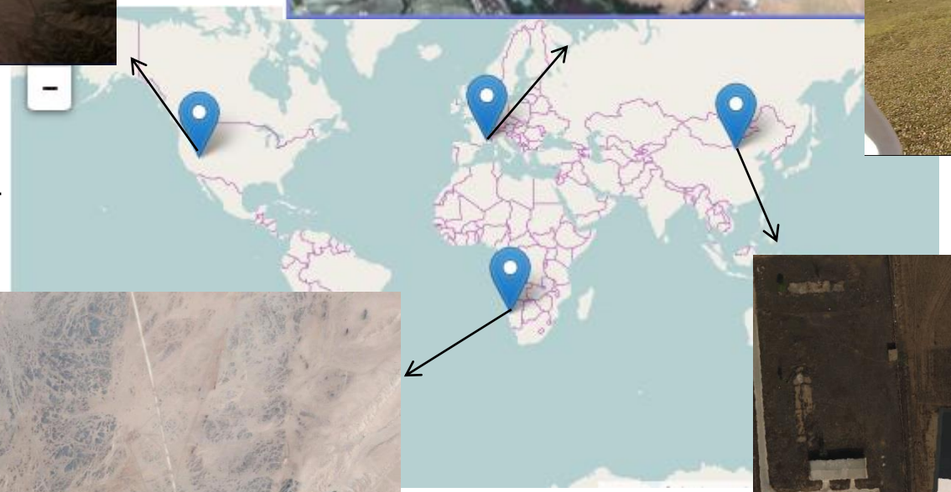
Railroad Valley Playa, USA

- >20 years working experience on site
- 4 radiometers, sun photometer, met station
- Dry lakebed

La Crau, France

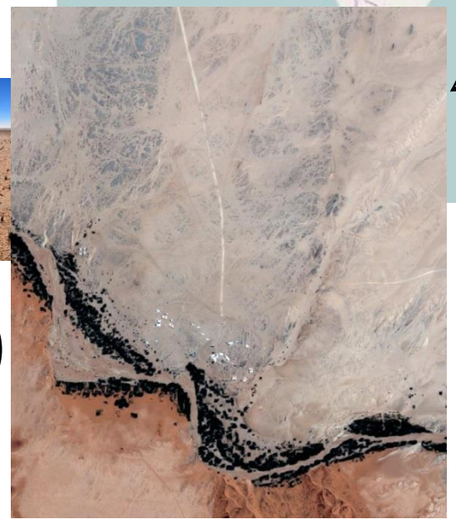
- CIMEL photometer (12 bands)
- Pebbles and low vegetation
- Site used since 1987 for calibration and instrumented since 1997





Gobabeb, Namibia

- Sun photometer similar to La Crau) and met station
- Sparse dry grass and gravel/sand

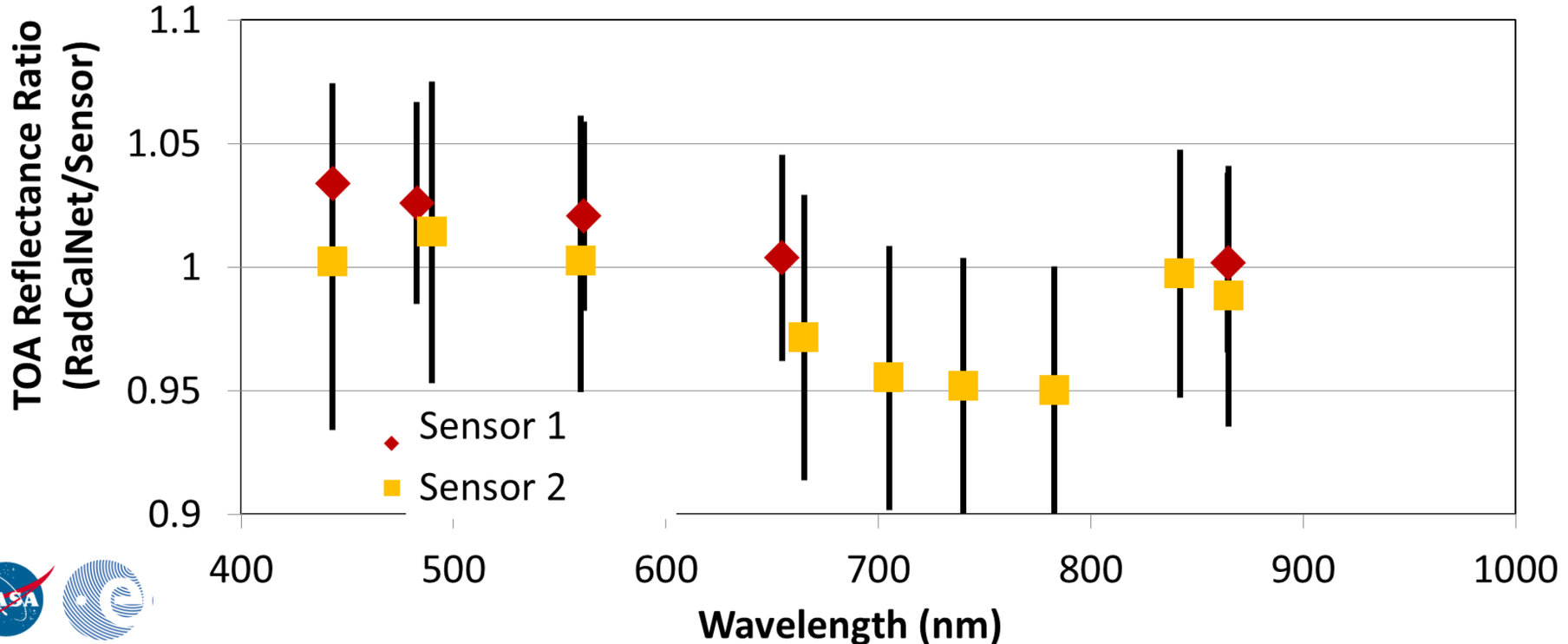


Baotou, China

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

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

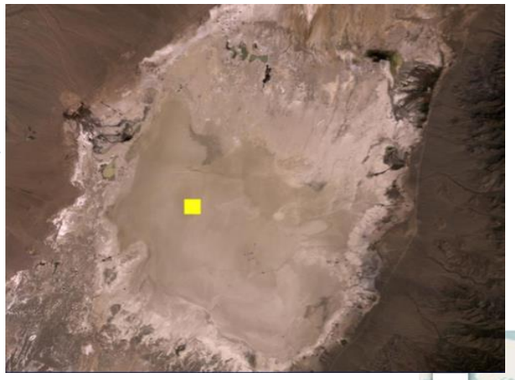
Sensor 1 band 1 is **significantly different** from Sensor 2 band 7

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



Aime Meygret,
Patrice Henry,
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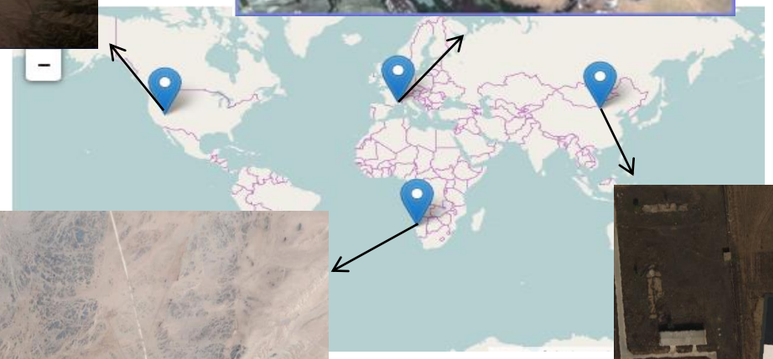
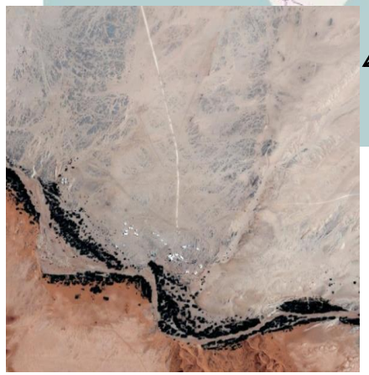


RadCalNet



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More information available from

Remote Sens. **2019**, *11*(20), 2401;

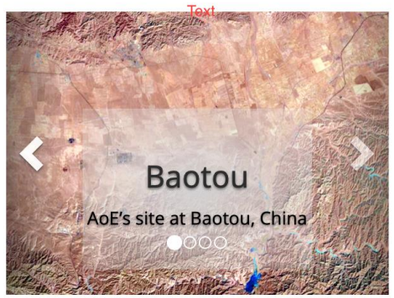
https://doi.org/10.3390/rs11202401

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 and validation 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 atmosphere 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.



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remote sensing

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Communication

RadCalNet: A Radiometric Calibration Network for Earth Observing Imagers Operating in the Visible to Shortwave Infrared Spectral Range

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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 interconsistency studies of on-orbit sensors. The recent development of automated sites to collect the 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 atmosphere in situ data as part of a network including multiple sites for the purpose of optical imager 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 (WGCV) and the Infrared Visible Optical Sensors (IVOS). Four radiometric calibration instrumented 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