RAILROAD VALLEY RADIOMETRIC CALIBRATION TEST SITE (RADCATS) AS PART OF A GLOBAL RADIOMETRIC CALIBRATION NETWORK (RADCALNET)

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ABSTRACT

The Radiometric Calibration Network (RadCalNet) is a coordinated multinational effort to provide in situ data that are suitable for the radiometric calibration and validation of Earth observation sensors that operate in the visible to shortwave infrared solar reflective spectral region (400 nm to 1000 nm). The main goals of RadCalNet are to provide top-of-atmosphere reflectance data to the scientific community, standardize data collection protocols for automated test sites, and to document the SI-traceable uncertainty budgets for each automated test site, of which there are currently four. The data available from RadCalNet are suitable for the calibration and validation of spaceborne imaging spectrometers. The work presented here provides a description of RadCalNet as well as a sample of the current results from the Radiometric Calibration Test Site (RadCaTS), which is located at Railroad Valley, Nevada, USA. Selected sensors for comparison include Terra and Aqua MODIS, SNPP and NOAA-20 VIIRS, and Sentinel-3A and -3B OLCI.

Index Terms— RadCalNet, RadCaTS, calibration, validation, imaging spectroscopy

1. INTRODUCTION

The methodologies used to perform the post-launch monitoring of Earth-observing sensors and onboard calibration systems have advanced to include in situ measurements by ground personnel, lunar observations, and invariant desert sites [1-3]. Future systems also include space-based instruments for on-orbit calibration, such as the Climate Absolute Radiance and Refractivity Observatory (CLARREO) [4, 5]. The ground-based radiometric calibration of satellite and airborne sensors has become mature and well-understood over the past thirty years. As the instruments and methodologies have become more sophisticated, the uncertainties associated with the determination of top-of-atmosphere (TOA) radiance (or reflectance) have decreased. The increasing number of satellite launches by national agencies and commercial companies has created a new challenge for the in situ measurement community. The challenge becomes even greater with the inclusion of very large constellations of satellites that generally do not have onboard calibration systems. A global network of instrumented sites is one solution that has gradually come in to fruition in the form of RadCalNet.

2. RADCALNET AND RADCATS

RadCalNet is a relatively new operational global network of radiometric calibration sites producing daily data that can be used to intercompare satellite sensors with different spectral, spatial, and orbital characteristics [6]. It is managed by the RadCalNet Working Group, which operates under the supervision of the Committee on Earth Observation Satellites (CEOS) Working Group on Calibration and Validation (WGCV) Infrared Visible Optical Sensors (IVOS) subgroup. RadCalNet is based on 20+ years of work by the international radiometric calibration community, and some of the current sites were part of the original CEOS Landnet sites [7]. After a prototyping phase using a select group of beta testers, data were made available to registered users at no cost beginning in June 2018. The historical data available to users varies from site to site, but in the case of RadCaTS at Railroad Valley, data are available from March 2013 to present [8-13].

As of January 2020, there are four operational RadCalNet sites located in the United States, France, China, and Namibia. It is anticipated that more sites will join in the future, and interested parties can find more information regarding the official procedure to join RadCalNet in the documentation section of the RadCalNet web portal.

Site	*Latitude*	*Longitude*	*Altitude (m)*
Railroad Valley USA	38.497° N	115.690° W	1435
La Crau France	43.559° N	4.864° E	18
Baotou China	40.852° N	109.629° E	1307
Gobabeb Namibia	23.600° S	15.120° E	510

The main data product produced by RadCalNet is the TOA reflectance from 400 nm to 1000 nm, sampled every 10 nm. The minimum spectral range required by RadCalNet site operators is 400 nm to 1000 nm, but some sites, including RadCaTS, include the full solar-reflective spectral range (400 nm to 2500 nm). The data are available from 09:00–15:00 local standard time, in 30-min intervals. Additional data such as the bottom-of-atmosphere (BOA) surface reflectance and atmospheric parameters (e.g. aerosol optical depth, aerosol Angstrom exponent, atmospheric temperature and pressure, water vapor, and columnar ozone) are also available on the web portal. The downloadable data have uncertainty estimates included in the data file.

RadCaTS was originally developed as a supplemental data source for the traditional vicarious calibration work conducted by the Remote Sensing Group of the Wyant College of Optical Sciences at the University of Arizona (UArizona) [3, 14-20]. The ever-increasing number of sensors on orbit made it clear that performing vicarious radiometric calibration using on-site personnel would become too logistically difficult and also too cost prohibitive. Work began in the early 2000s with a prototype system that was developed in order to test the data processing algorithms. All-weather custom ground-viewing radiometers were created to measure the radiance reflected from the test site surface, and the AERONET sun photometer that was already deployed to Railroad Valley continued to be used for atmospheric measurements [21-23]. The current suite of RadCaTS instruments includes four ground-viewing radiometers (GVRs) in a nadir-viewing configuration, one GVR in the GOES-West viewing configuration, one GVR in the GOES-East viewing configuration, a Cimel CE318-T solar lunar photometer, a meteorological station, and a satellite uplink base station with an all-weather camera to document site conditions throughout the day. The GVRs make measurements every two minutes throughout the day, while the Cimel collects data using the AERONET collection protocol. The data are uploaded daily to the UArizona for processing. The region of interest at RadCaTS is 1 km × 1 km, which was the original site used with the reflectance-based approach for large-footprint sensors such as MODIS and AVHRR [24, 25].

The GVRs are radiometrically and spectrally calibrated and geometrically characterized at UArizona before deployment to RadCaTS. They have been shown to be temporally stable, which is critical since the ambient temperature at Railroad Valley typically varies from –20 °C to 40 °C throughout the year [22]. The Calibration Test Site SI-Traceable Transfer Radiometer (CaTSSITTR) was developed in order to validate the radiometric calibration of field radiometers on site, which greatly reduces the amount of down time required to return the GVRs to the UArizona laboratory for calibration [23, 26]. There are currently two CaTSSITTR instruments: -A (Arizona), and -G (Goddard), which have been used recently to validate the radiometric calibration of the RadCaTS GVRs as well as perform independent measurements during round-robin field campaigns [27].

3. DATA

This work presents the results from a recent comparison between RadCaTS and the moderate-resolution sensors Terra and Aqua MODIS, SNPP and NOAA-20 VIIRS, and Sentinel-3A and -3B OLCI. The period of study and the number of RadCaTS dates for each sensor are shown below. It should also be noted that the results are restricted to near-nadir overpasses (<12°) since the GVRs are viewing the site in a nadir configuration.

Satellite and Sensor	*Period*	*RadCaTS Data*
Terra MODIS	2013–2019	N = 118
Aqua MODIS	2013–2019	N = 84
SNPP VIIRS	2013–2019	N = 70
NOAA-20 VIIRS	2018–2019	N = 18
Sentinel-3A OLCI	2016–2019	N = 66
Sentinel-3B OLCI	2018–2019	N = 17

The MODIS and VIIRS imagery are downloaded from the NASA LAADS DAAC, while the Sentinel-3 OLCI data are downloaded from the ESA Copernicus Open Access Hub. In all cases, the RadCaTS results are compared to the at-sensor spectral radiance.

4. RESULTS

A summary of the TOA spectral radiance results for MODIS and VIIRS is shown in Fig. 1 (VNIR) and Fig. 2 (SWIR) as a ratio of the TOA spectral radiance (Sensor/RadCaTS). The uncertainty bars are ±4 % (1σ) estimate of the RadCaTS TOA product. The results for Sentinel-3A and -3B OLCI are shown in Fig. 3 and Fig. 4, respectively. The OLCI water vapor band

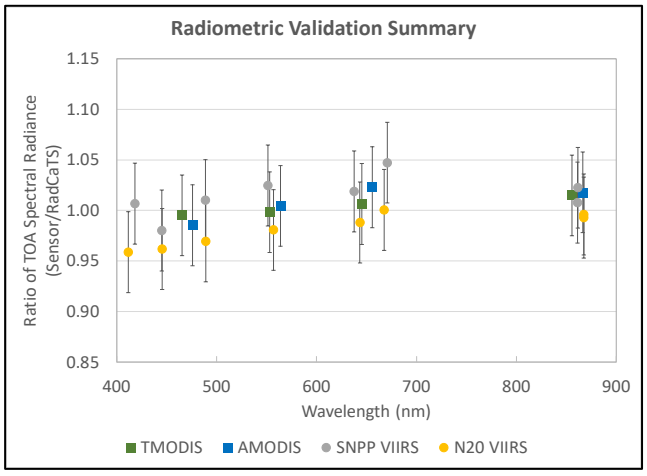

Fig. 1. MODIS (bands 1–4) and VIIRS (bands I1, I2, M1–M5) comparison with RadCaTS.

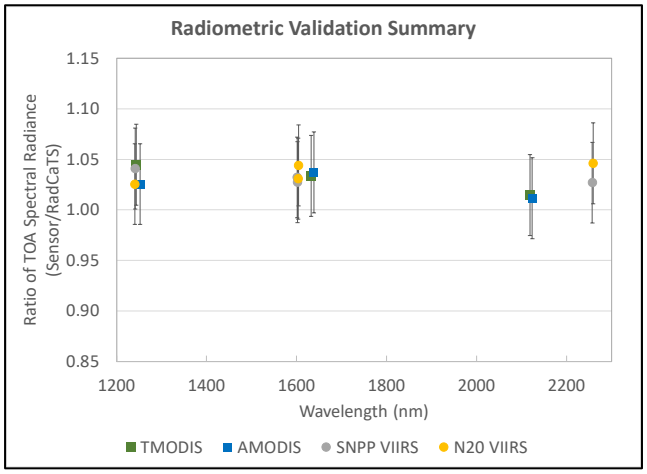

Fig. 2. MODIS (bands 5–7) and VIIRS (bands I3, M7, M8, M10, and M11) comparison with RadCaTS.

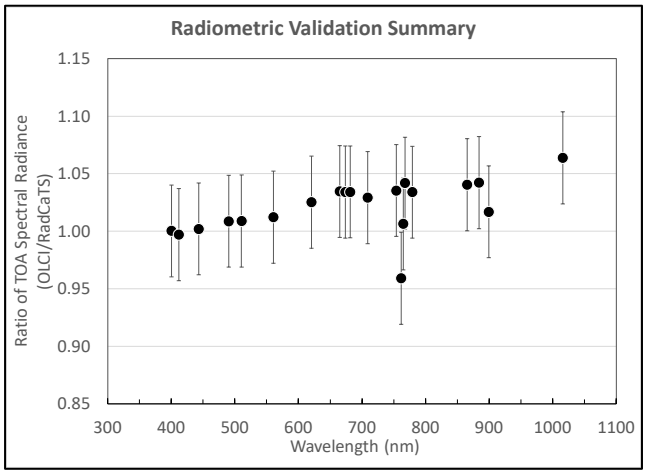

Fig. 3. Sentinel-3A OLCI comparison with RadCaTS.

20 is excluded due to the low signal-to-noise ratio of the RadCaTS data.

5. CONCLUSION

RadCaTS is one of the four operational sites that make up RadCalNet, and this work presents an example of the radiometric validation of moderate-resolution sensors that operate in the solar-reflective region. The results for MODIS and VIIRS show excellent consistency between the four instruments. The results for Sentinel-3A OLCI are in reasonably good agreement with RadCaTS in the lower VNIR range, but show a higher bias at wavelengths >750 nm. Sentinel-3B OLCI shows a slightly greater offset from the RadCaTS results at wavelengths <600 nm. Sentinel-3B is the newest platform in this study, so additional data will assist with further assessment of the current results.

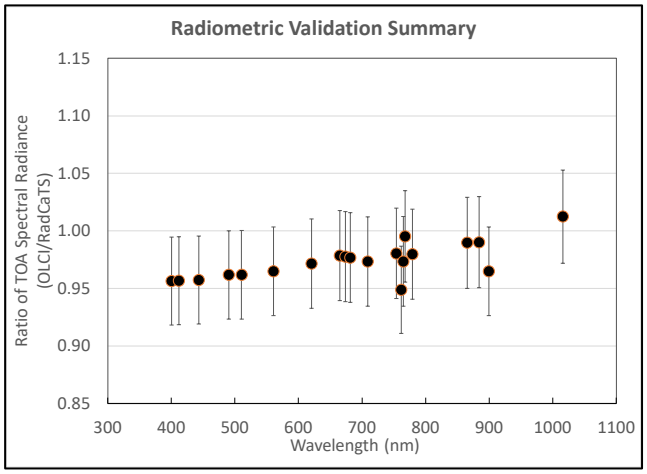

Fig. 4. Sentinel-3B OLCI comparison with RadCaTS.

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