Radiometric Calibration and Surface Reflectance Validation of MODIS and VIIRS

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MODIS/VIIRS Science Team and Cal/Val Meeting
University of Maryland
College Park, MD, USA
18–21 Nov 2019
Topics

- Radiometric Calibration Test Site (RadCaTS)
- Current status of RadCaTS
- Radiometric calibration and surface reflectance validation results
- Summary and future work
Introduction to RadCaTS

• Developed as an automated ground-based vicarious calibration system

• Originally designed to supplement reflectance-based approach
  • Portable spectroradiometers, reference panels (surface reflectance)
  • Solar radiometers, ancillary weather equipment (atmospheric measurements)
  • Requirement: we have to be on site to deploy instruments

• RadCaTS uses a combination of custom and commercially-available instruments
  • GVR: ground-viewing radiometer (designed and built at U of Arizona)
  • Cimel CE318-T solar lunar photometer (AERONET)
  • Weather station
  • Wireless base station, connected to U of Arizona via satellite uplink
Current Status of RadCaTS

• Primary method for U of Arizona in situ data collection

• Instruments are combination of custom and commercially-available
  • GVR: ground-viewing radiometer (designed and built at U of Arizona)
  • Cimel CE318-T solar lunar photometer (AERONET)
  • Weather station
  • Wireless base station, connected to U of Arizona via satellite uplink
Field Radiometer for On-Site Calibration

- Calibration Test Site SI-Traceable Transfer Radiometer (CaTSSITTR)
- Same seven VNIR bands as RadCaTS ground-viewing radiometer
  - 400, 450, 500, 550, 650, 850, 1000 nm
- One-person operation, wireless data logging
- Temperature-controlled focal plane (35 °C)
- Travelling transfer radiometer for test site intercomparison and uncertainty analysis (e.g. RadCalNet)
Support Instrumentation

- Commercial UAS for spatial uniformity analysis (SPIE 2017)
Other Instrumentation

- Web camera (Campbell Scientific CCFC)
  - Installed in May 2018, views south
  - Images collected at 09:00–15:00 local standard time (17:00–23:00 UTC)
  - Every 30 minutes
  - Images are now available on RadCalNet data portal

- Images currently stored on site with option to download to U of Arizona

- Dust storm (29 Jul 2018)
- Clear (11 Jun 2019)
- Snow (17 Feb 2019)
- Rain (22 May 2019)
CEOS WGCV Radiometric Calibration Network (RadCalNet)

- Online data portal went live in Jul 2018: www.radcalnet.org
  - TOA reflectance from 09:00–15:00 local standard time
  - 400 nm to 2500 nm, $\Delta \lambda = 10$ nm
  - Surface reflectance and atmospheric data are also available

- RadCalNet forum: forum.radcalnet.org (announcements, FAQs, documentation, etc.)
Surface Reflectance Determination at RadCaTS

- For a given time of interest:
  - Determine surface reflectance in each of GVR’s 8 spectral bands
  - Determine the average for each of the 8 bands
  - Convert the multispectral results to hyperspectral by fitting to library of data collected from ~2000–present using portable spectroradiometer (e.g. ASD)
RadCaTS Surface Reflectance QA

• ‘Good–Bad Day’ QA Criterion (old method)
  • If 0.9 < Angstrom exponent < 1.5: good day
  • Else: bad day
  • Problem: too many good days were excluded

• New criteria (current method)
  • Developed for use with Railroad Valley results for RadCalNet
  • If \( \text{AOD}_{550\ nm} < 0.16 \) and \( \text{BRF}_{\text{GVRs}} \) is within \( \pm 1\sigma \) of the 2014–2019 average: good day
  • Else: bad day

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MODIS and VIIRS Cal/Val Imagery

Source
• LAADS DAAC

Radiometric Calibration

Surface Reflectance Validation
• Terra & Aqua MODIS: Collection 6 (2013–2019)
• NOAA-20 VIIRS: no imagery
MODIS Results
Current MODIS Radiometric Calibration Results

- 2013–2019
- **TMODIS**: N=118,  **AMODIS**: N=84
  - Double ratio to remove RadCaTS
  - **MODIS Bands 1–7**
  - **Double ratio**: \( \frac{\text{TMODIS}}{\text{RadCaTS}} / \frac{\text{AMODIS}}{\text{RadCaTS}} = \frac{\text{TMODIS}}{\text{AMODIS}} \)
Radiometric Calibration Results (Temporal Example)

**Terra MODIS**

**Band 1 (645 nm)**

**Band 4 (553 nm)**

**Aqua MODIS**

**Band 1 (646 nm)**

**Band 4 (553 nm)**
Current MODIS Surface Reflectance Validation Results

- 2013–2019
- **TMODIS**: N=118, **AMODIS**: N=84
  - Double difference to remove RadCaTS

MODIS Bands 1–7
- Double difference: \((\text{TMODIS}−\text{RadCaTS})−(\text{AMODIS}−\text{RadCaTS}) = \text{TMODIS}−\text{AMODIS}\)
Surface Reflectance Validation Results (Temporal Example)

**Terra MODIS**

Terra MODIS Band 1 (645 nm)
Surface Reflectance Validation (2013–2019)

```
Reflectance  0.03  0.04  0.05  0.06  0.07  0.08  0.09  0.10
```

**Aqua MODIS**

Aqua MODIS Band 1 (645 nm)
Surface Reflectance Validation (2013–2019)

```
Reflectance  0.03  0.04  0.05  0.06  0.07  0.08  0.09  0.10
```

**Terra MODIS**

Terra MODIS Band 4 (553 nm)
Surface Reflectance Validation (2013–2019)

```
Reflectance  0.03  0.04  0.05  0.06  0.07  0.08  0.09  0.10
```

**Aqua MODIS**

Aqua MODIS Band 4 (553 nm)
Surface Reflectance Validation (2013–2019)

```
Reflectance  0.03  0.04  0.05  0.06  0.07  0.08  0.09  0.10
```
VIIRS Results
Current SNPP and NOAA-20 VIIRS Radiometric Calibration Results

- SNPP VIIRS: N=70, NOAA-20 VIIRS: N=18

SNPP VIIRS

NOAA-20 VIIRS

Double Ratio to Remove RadCaTS

- VIIRS Bands: I1–I3, M1–M5, M7, M8, M10, M11
- Double ratio: \( \frac{\text{SNPP/RadCaTS}}{\text{N20/RadCaTS}} = \text{SNPP/N20} \)
Radiometric Calibration Results (Temporal Example)

SNPP VIIRS

Band I1 (638 nm)

NOAA-20 VIIRS

Band I1 (638 nm)

Band M4 (552 nm)
Current SNPP VIIRS Surface Reflectance Validation Results

- 2013–2019
- N=70

**SNPP VIIRS Surface Reflectance Validation (2013–2019)**

- **Band I1 (638 nm)**
- **Band M4 (552 nm)**

**Temporal Examples**

- SNPP VIIRS Band I1 (638 nm)
- SNPP VIIRS Band M4 (552 nm)
Recap
Summary of All Radiometric Calibration Results

VNIR

SWIR
Summary of All Surface Reflectance Validation Results

**VNIR**

Surface Reflectance Validation (2013–2019)

**SWIR**

Surface Reflectance Validation (2013–2019)
Summary

- RadCaTS continues to be operational, with daily data collection
- Surface reflectance results are uploaded to NASA GSFC for further processing to TOA reflectance for RadCalNet
- One new ground-viewing radiometer will be deployed in 2020
  - 5 nadir viewing configuration
  - 1 GOES-East
  - 1 GOES-West
- BRDF correction will continue to be developed and integrated in processing code
- Headwall UAS will be deployed at RadCaTS for spatial and BRDF studies
- GVR head translation stage continuing to be developed
- Analysis will be updated to include NOAA-20 VIIRS surface reflectance when available
Thanks!

• The authors would like to thank NASA for funding this work (NASA Research Grant 80NSSC18K0614), and AERONET for processing and distributing the Cimel data.

• We would also like to thank the Bureau of Land Management (BLM), Tonopah, Nevada office, for assistance and access to Railroad Valley.