Radiometric Calibration and Surface Reflectance Validation of MODIS and VIIRS

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THE UNIVERSITY OF ARIZONA
Wyant College of Optical Sciences

ARIZONA RadCaTS

Topics

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

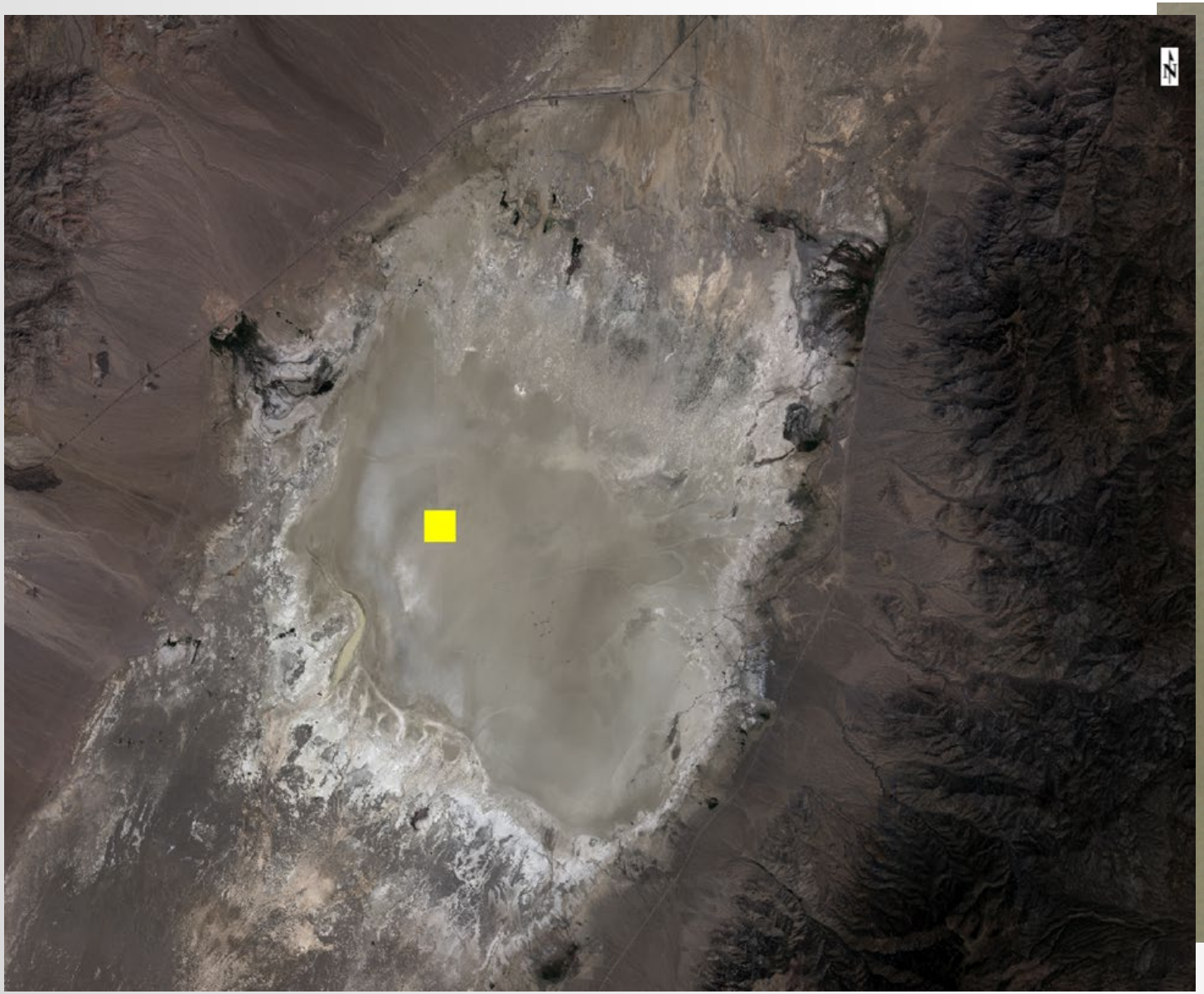
Introduction to RadCaTS

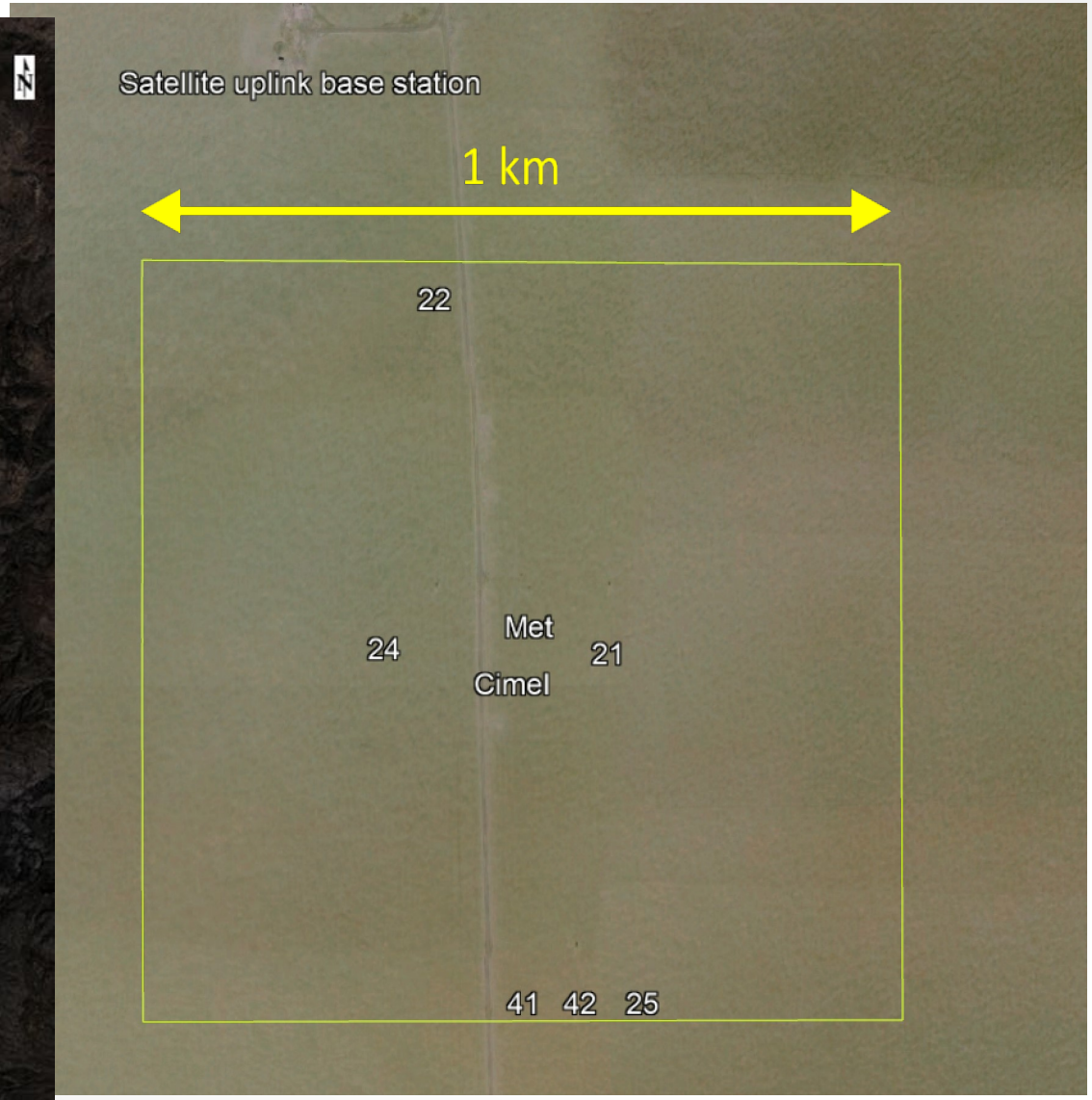
- Developed as an automated ground-based vicarious calibration system
- Originally designed to supplement reflectance-based approach
  - Portable spectroradiometers, reference panels (surface reflectance)
  - Solar radiometers, ancillary weather equipment (atmospheric measurements)
  - Requirement: we 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

RadCaTS Instrument Locations

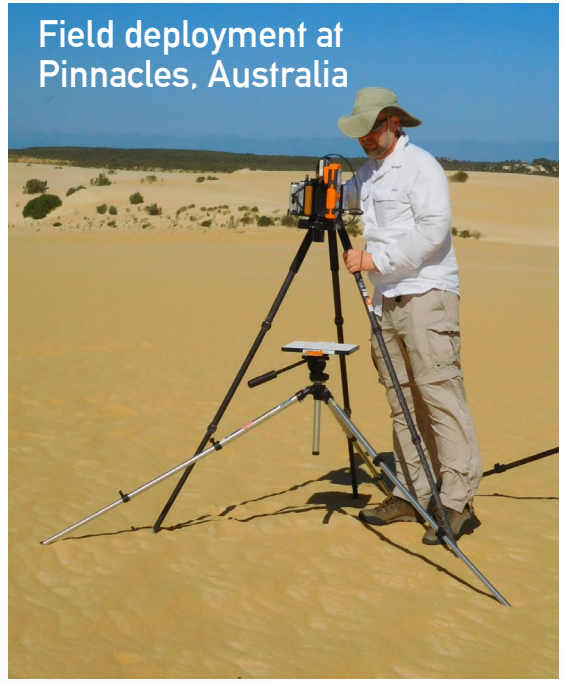


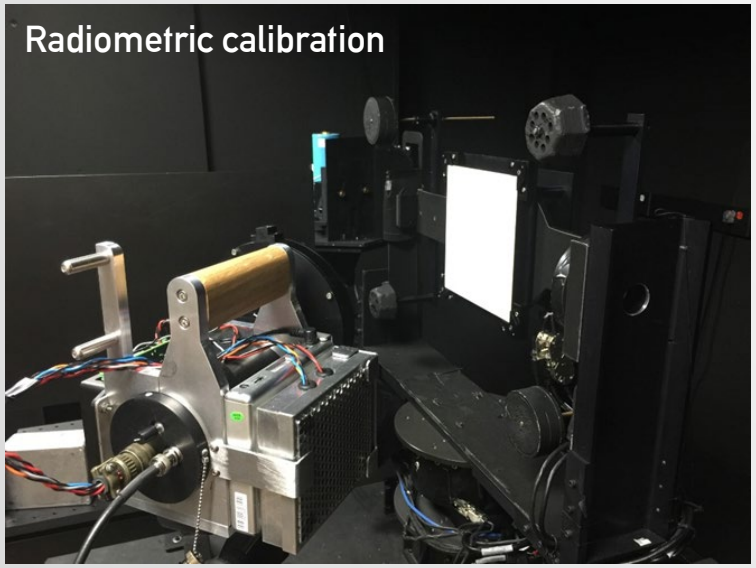


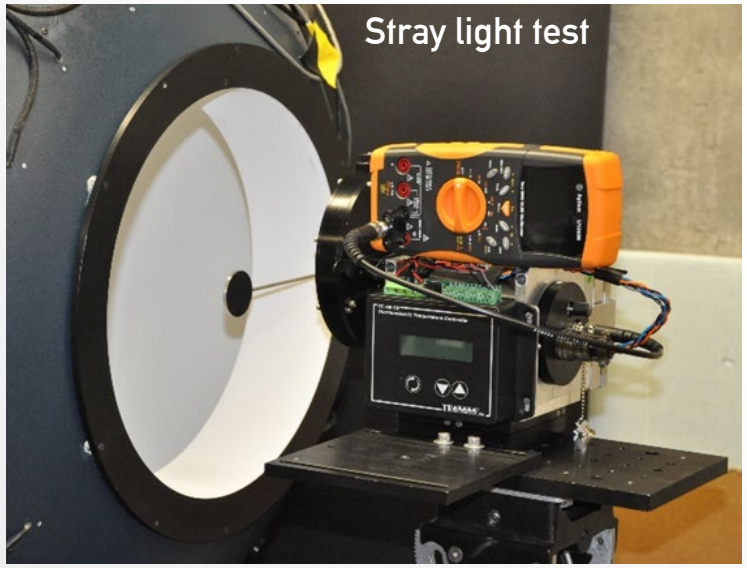
Field Radiometer for On-Site Calibration

- 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)


Field deployment at RadCaTS

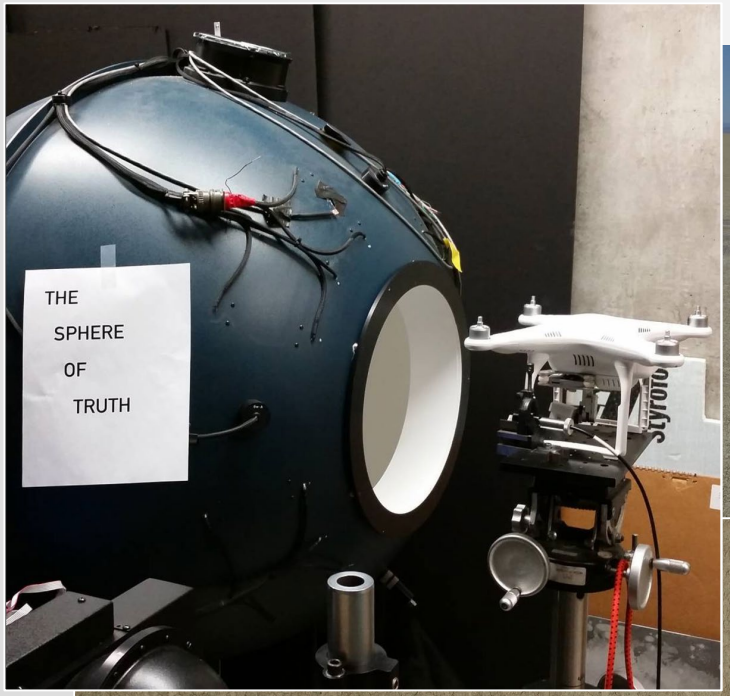

Field deployment at Pinnacles, Australia


Radiometric calibration


Stray light test

Support Instrumentation

- Commercial UAS for spatial uniformity analysis (SPIE 2017)

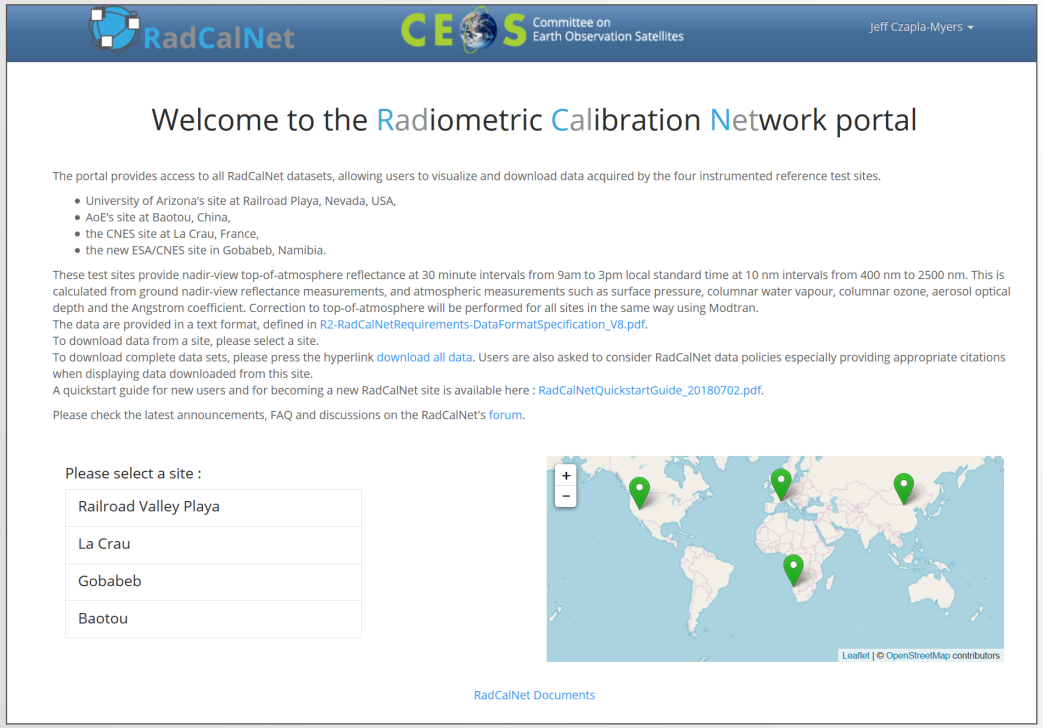


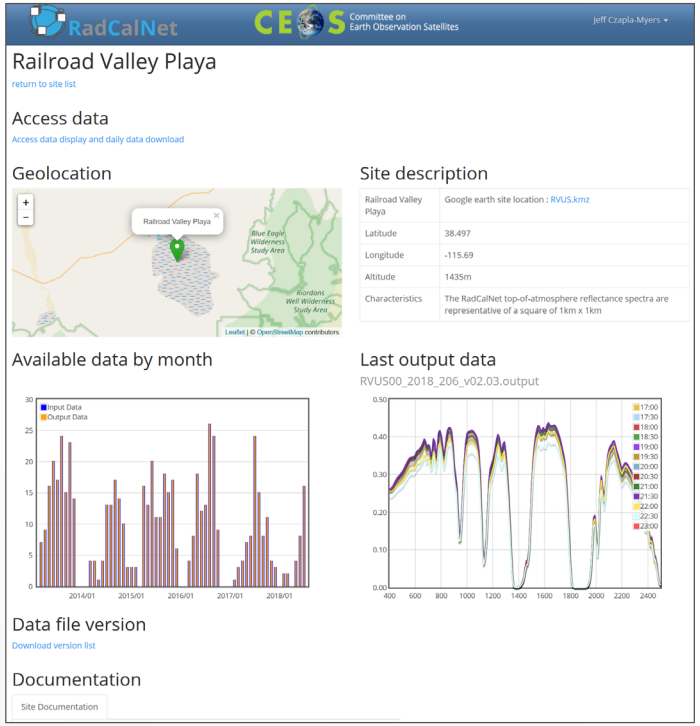
Other Instrumentation

- 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

CEOS WGCV Radiometric Calibration Network (RadCalNet)

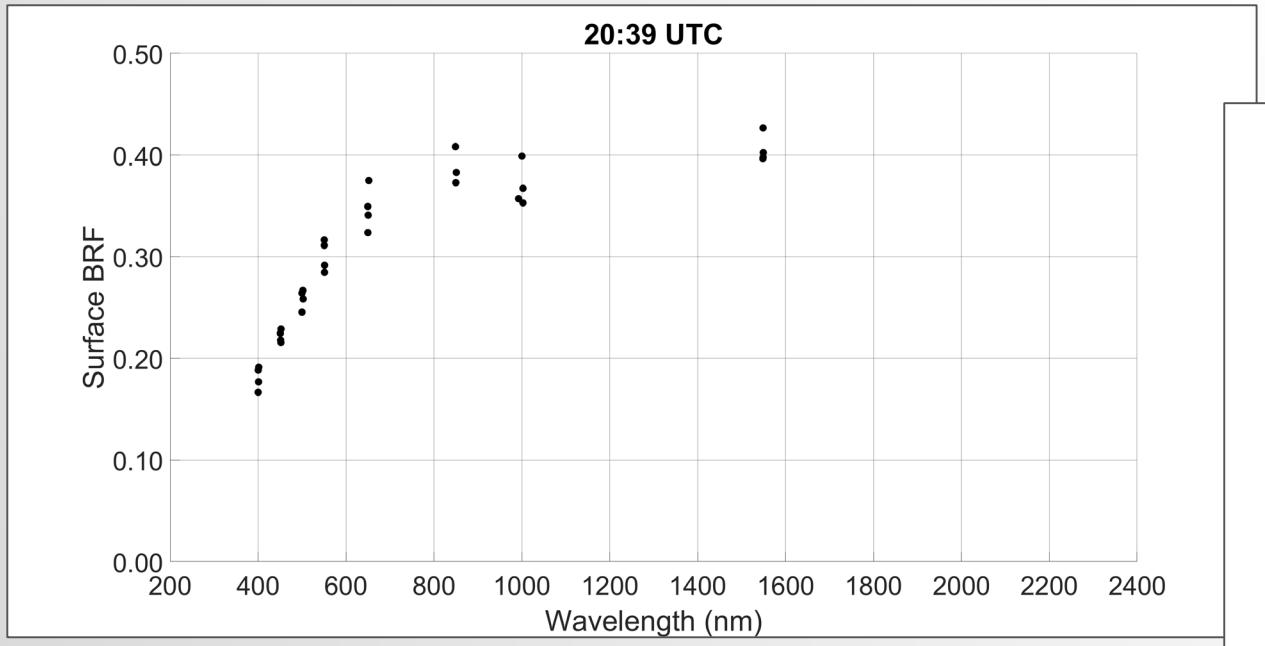
- **Online data portal went live in Jul 2018: www.radcalnet.org**
  - TOA reflectance from 09:00–15:00 local standard time
  - 400 nm to 2500 nm, $\Delta\lambda$ = 10 nm
  - Surface reflectance and atmospheric data are also available
- **RadCalNet forum: forum.radcalnet.org** (announcements, FAQs, documentation,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

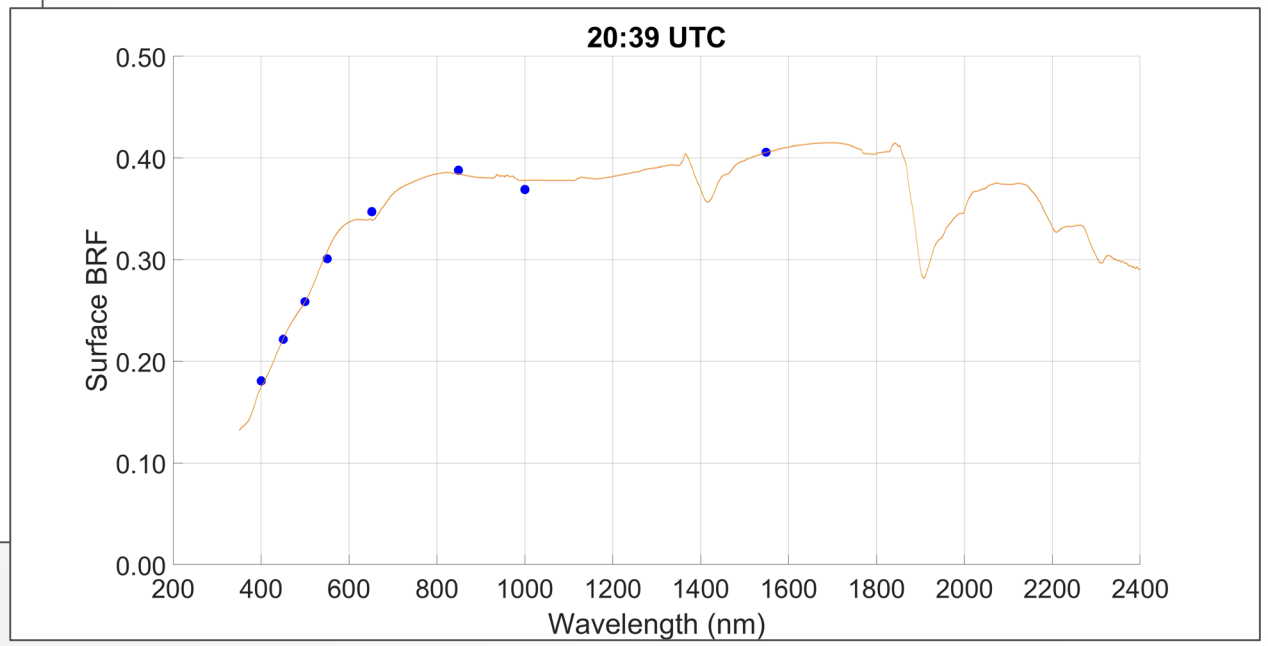




Surface Reflectance Determination at RadCaTS

- 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)





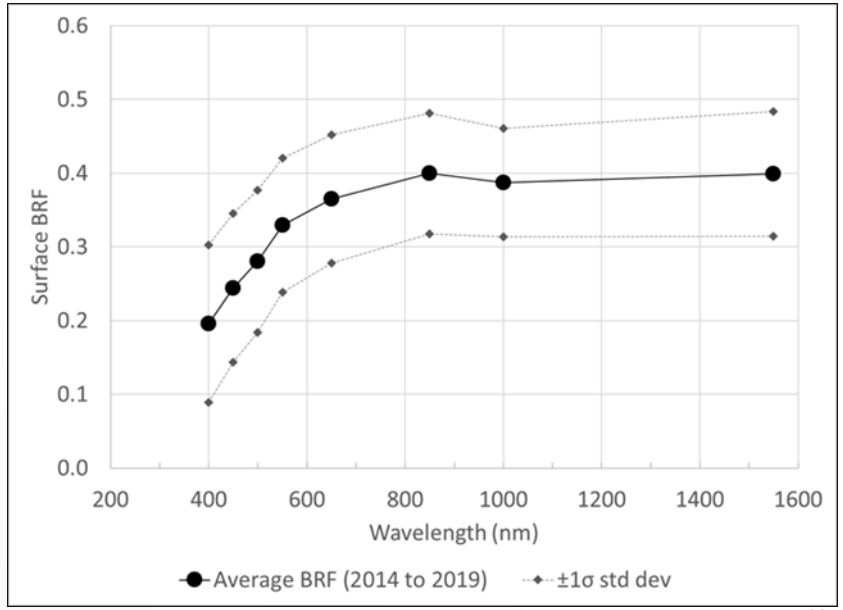
RadCaTS Surface Reflectance QA

- '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

Site	2013	2014	2015	2016	2017	2018	2019	Total
RVUS	145	83	133	114	88	149	18	730

- New criteria (current method)
  - Developed for use with Railroad Valley results for RadCalNet
  - If $AOD_{550\ nm} < 0.16$
    and BRF_{GVRs} is within ±1σ of the 2014–2019 average: good day
  - Else: bad day

Site	2013	2014	2015	2016	2017	2018	2019	Total
RVUS	193	234	222	221	262	230	65	1427



MODIS and VIIRS Cal/Val Imagery

Source

- LAADS DAAC

Radiometric Calibration

• Terra & Aqua MODIS:	Collection 6.1	(2013–2019)
• SNPP VIIRS:	Collection 1 (Archive 5110)	(2013–2019)
• NOAA-20 VIIRS:	Collection 2 (Archive 5200)	(2018–2019)

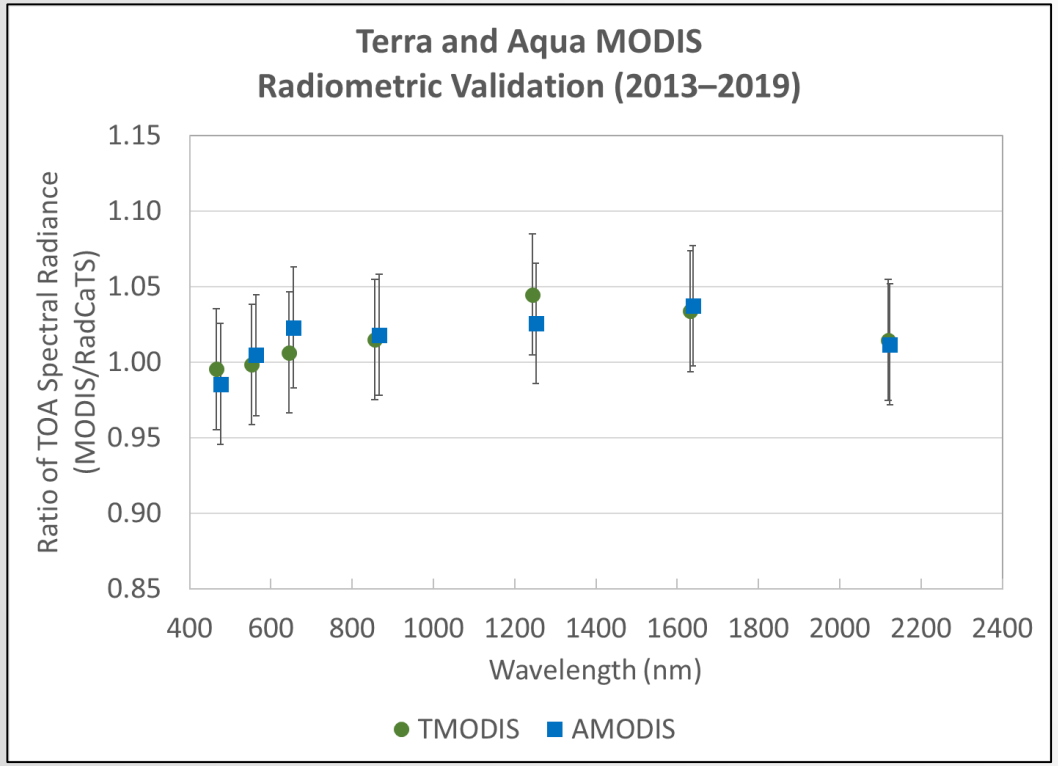
Surface Reflectance Validation

• Terra & Aqua MODIS:	Collection 6	(2013–2019)
• SNPP VIIRS:	Collection 1 (Archive 5000)	(2013–2019)
• NOAA-20 VIIRS:	no imagery	

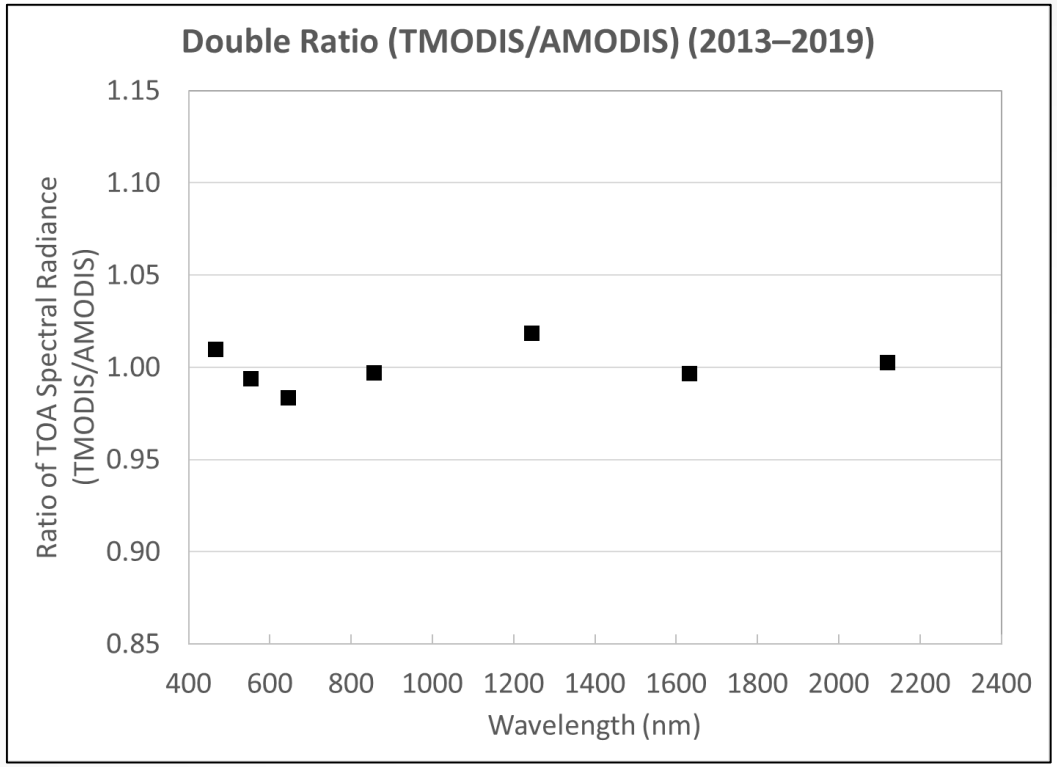
MODIS Results

Current MODIS Radiometric Calibration Results

- 2013–2019
- TMODIS: N=118, AMODIS: N=84



Double ratio to remove RadCaTS

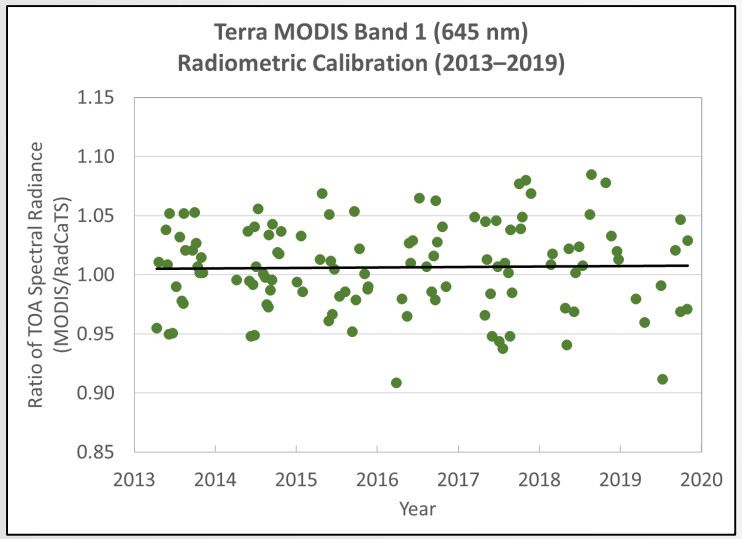


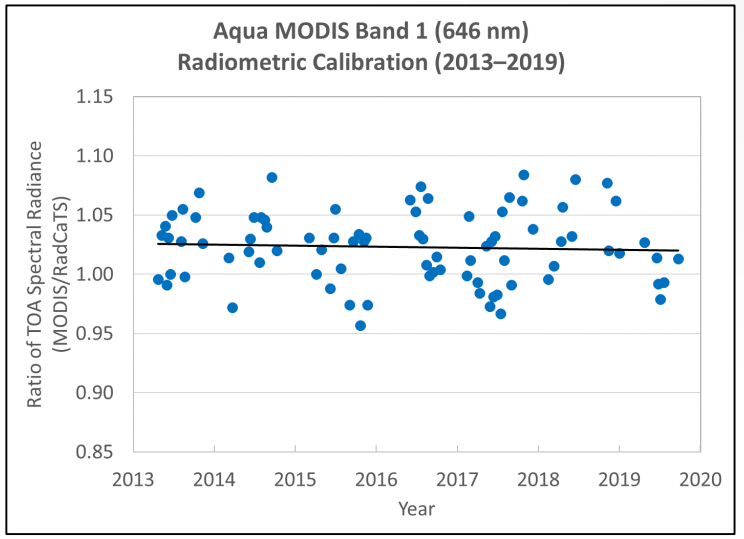
- MODIS Bands 1–7
- Double ratio: (TMODIS/RadCaTS)/(AMODIS/RadCaTS) = TMODIS/AMODIS

Radiometric Calibration Results (Temporal Example)

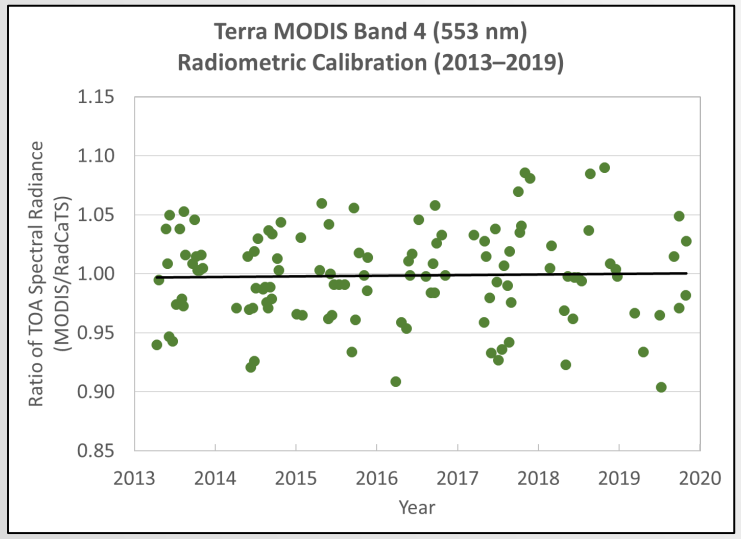
Terra MODIS

Aqua MODIS

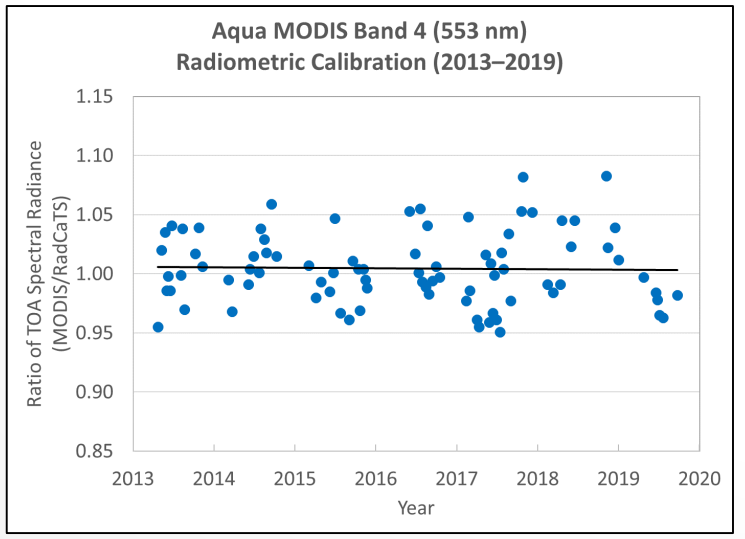




Band 1 (645 nm)

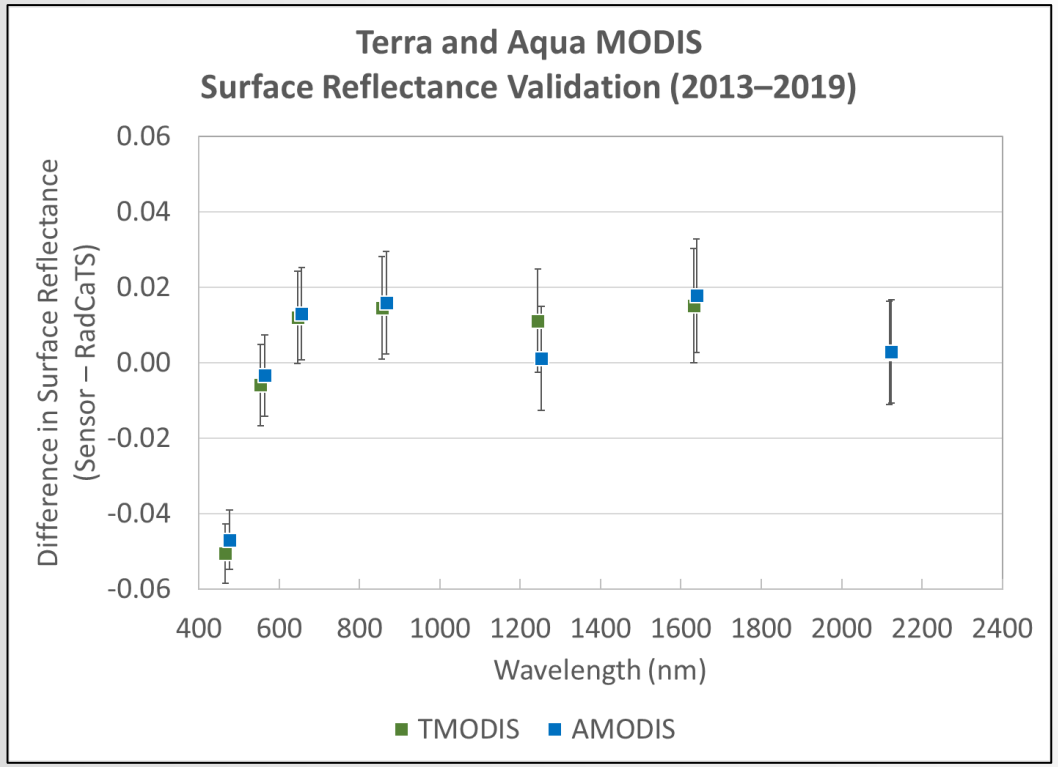


Band 4 (553 nm)

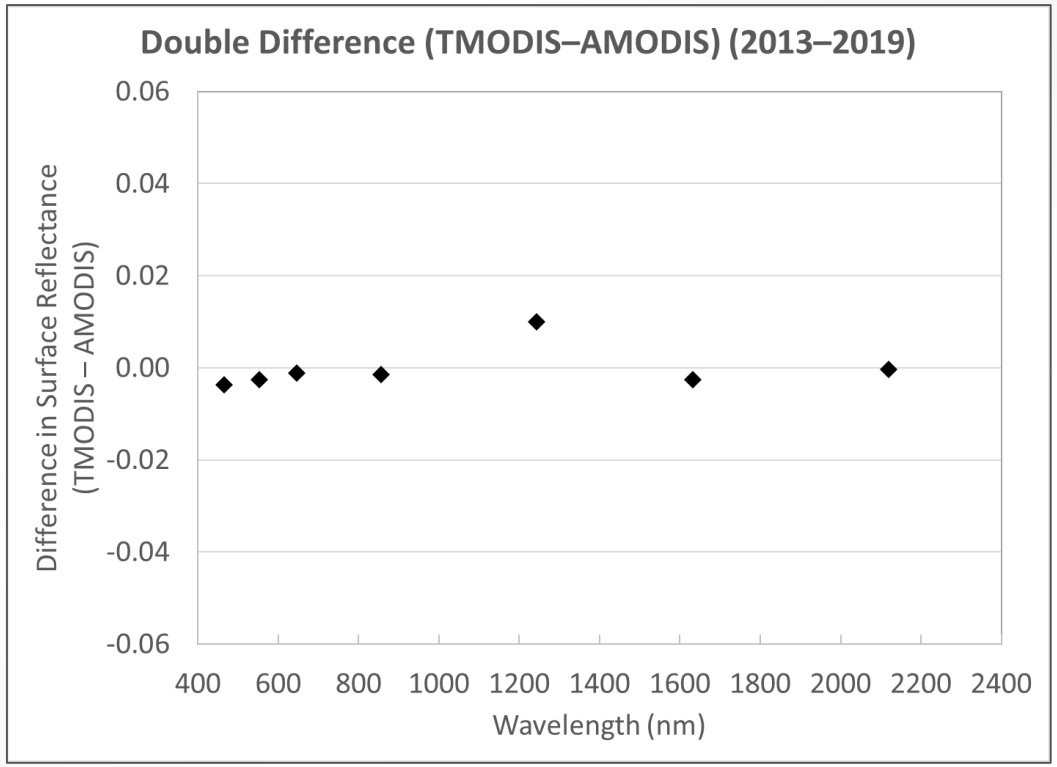


Current MODIS Surface Reflectance Validation Results

- 2013–2019
- TMODIS: N=118, AMODIS: N=84



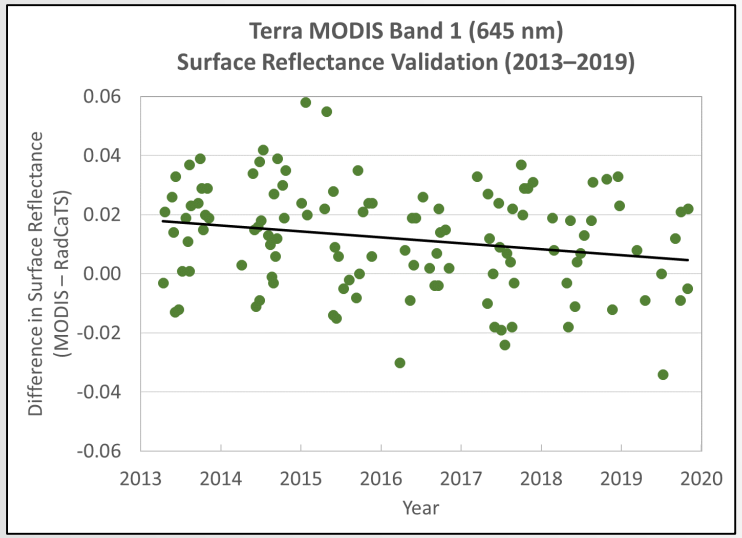
Double difference to remove RadCaTS



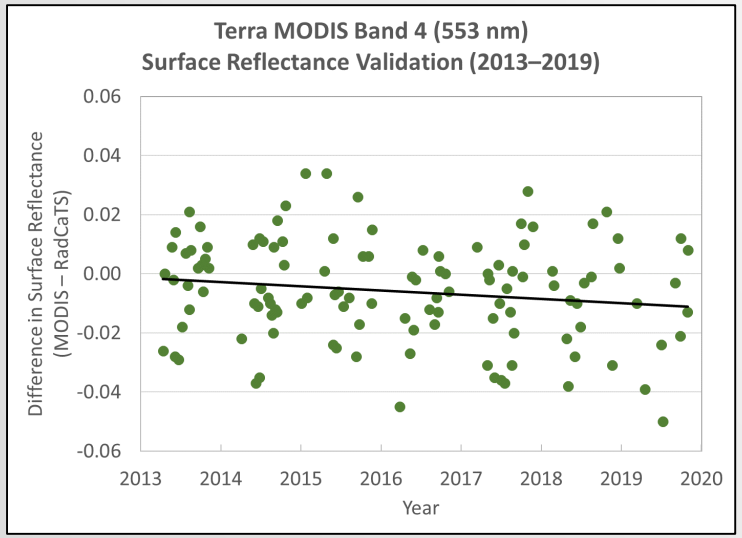
- MODIS Bands 1–7
- Double difference: (TMODIS–RadCaTS)–(AMODIS–RadCaTS) = TMODIS–AMODIS

Surface Reflectance Validation Results (Temporal Example)

Terra MODIS

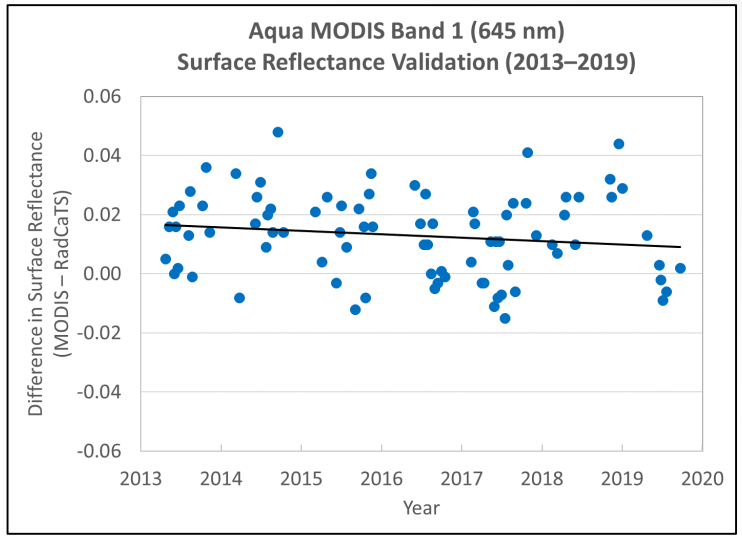


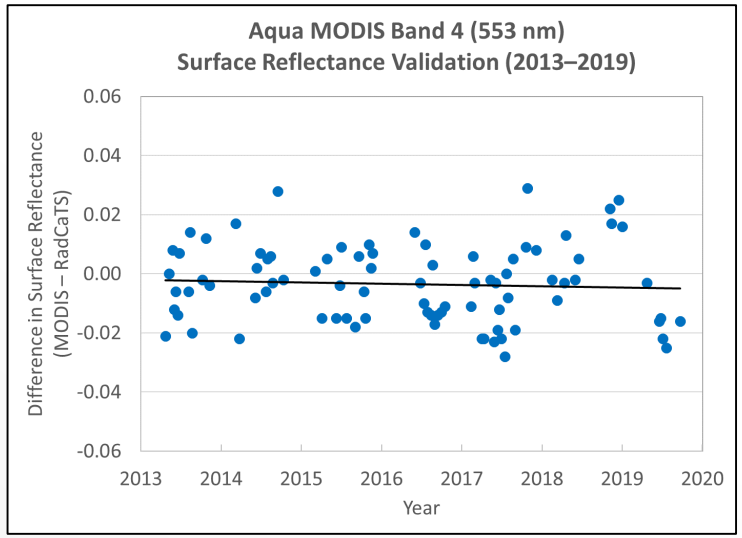
Band 1 (645 nm)



Band 4 (553 nm)

Aqua MODIS



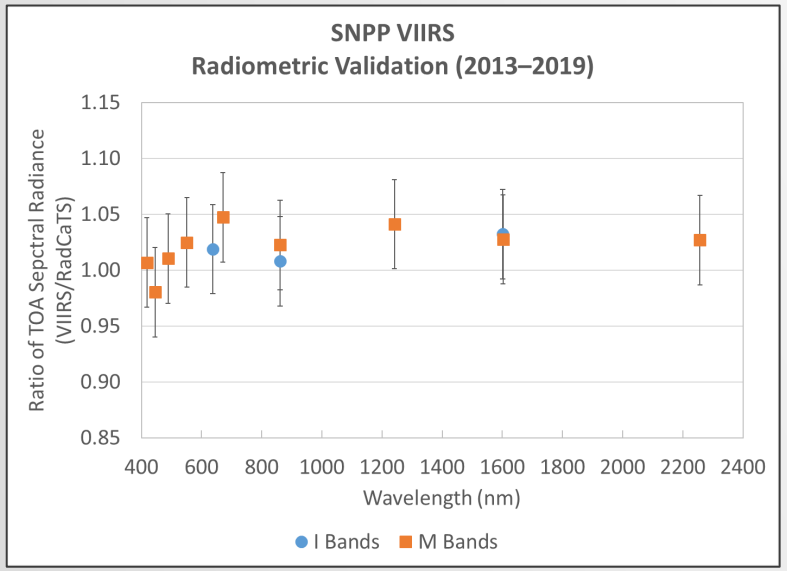


VIIRS Results

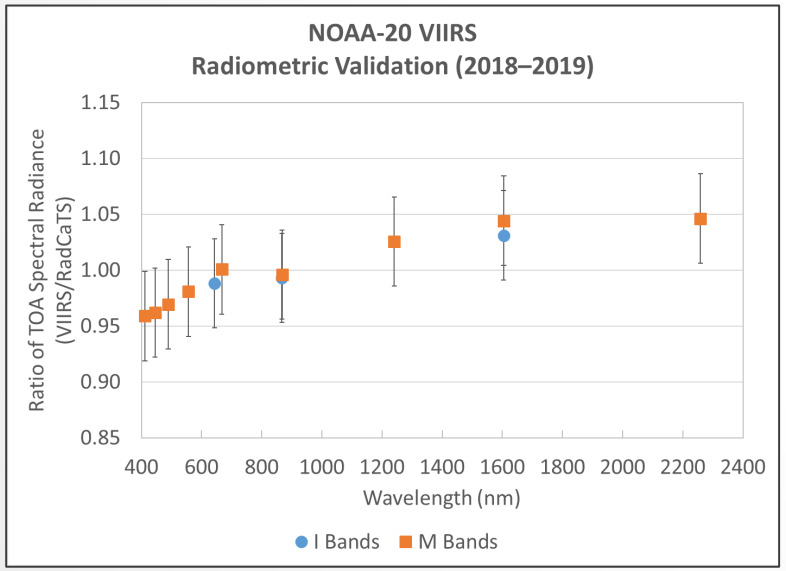
Current SNPP and NOAA-20 VIIRS Radiometric Calibration Results

- 2013–2019 (SNPP), 2018–2019 (NOAA-20)
- SNPP VIIRS: N=70, NOAA-20 VIIRS: N=18

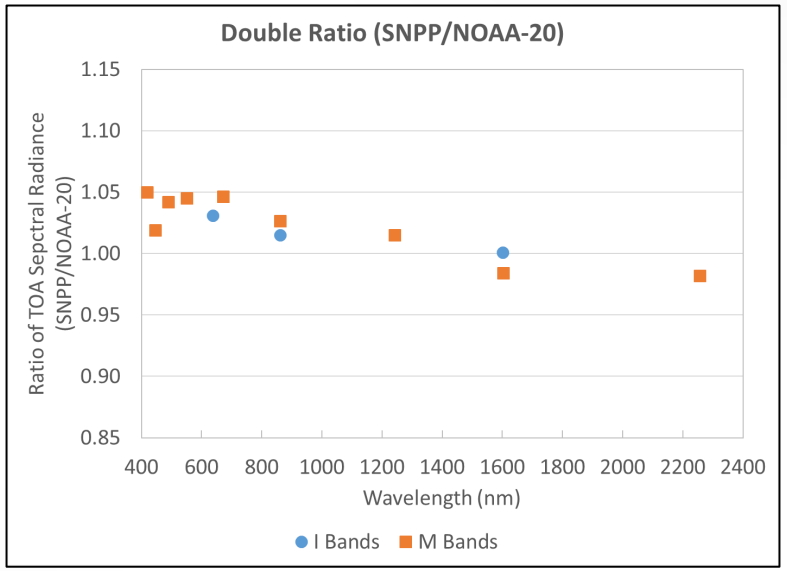
SNPP VIIRS



NOAA-20 VIIRS



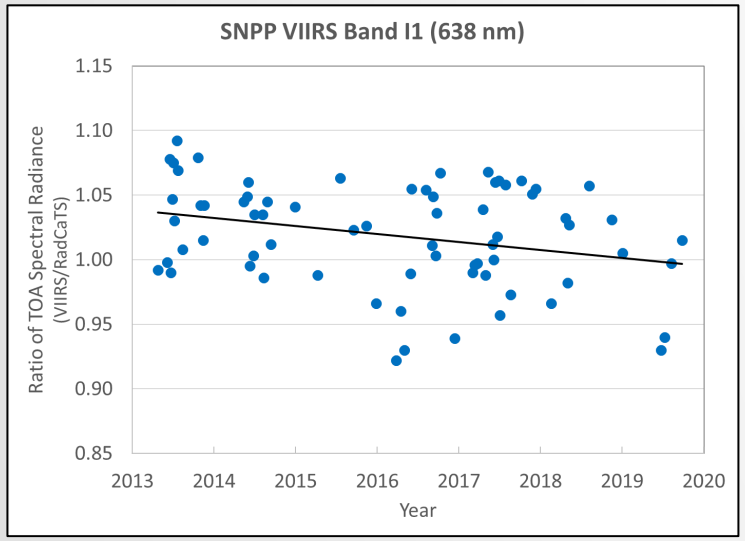
Double Ratio to Remove RadCaTS



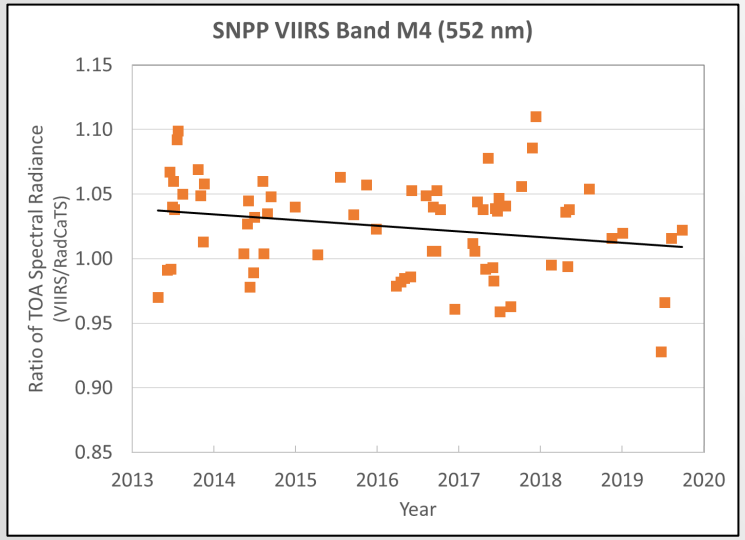
- VIIRS Bands: I1–I3, M1–M5, M7, M8, M10, M11
- Double ratio: (SNPP/RadCaTS)/(N20/RadCaTS) = SNPP/N20

Radiometric Calibration Results (Temporal Example)

SNPP VIIRS

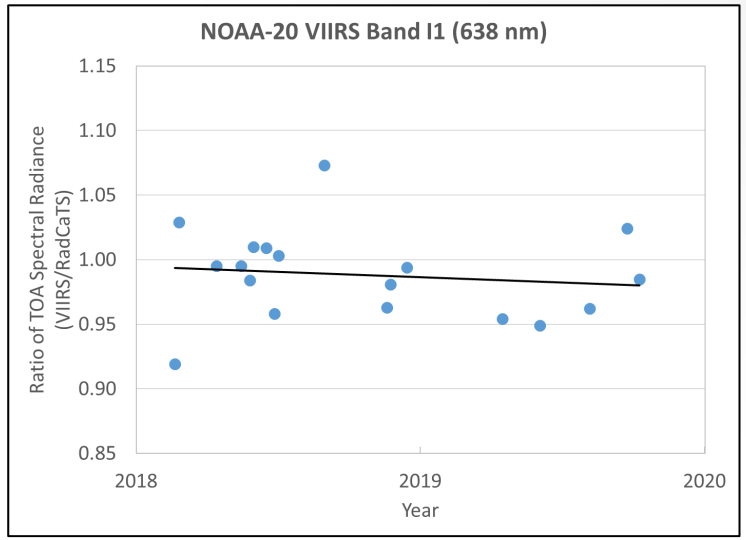


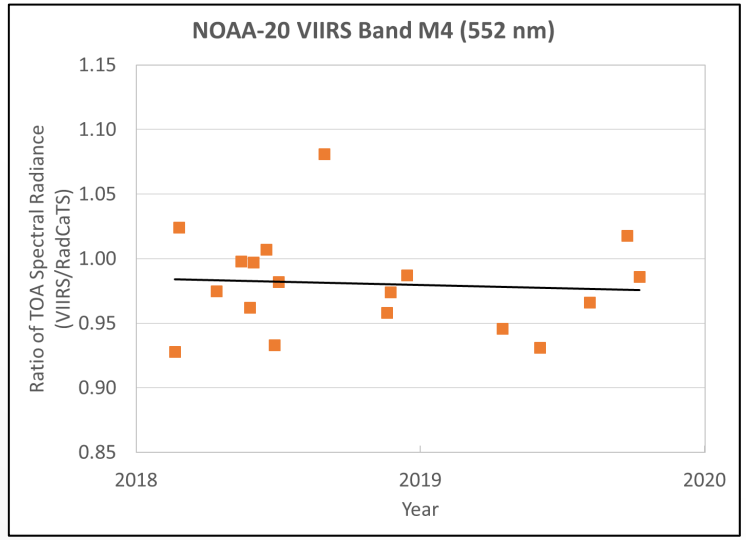
Band I1 (638 nm)



Band M4 (552 nm)

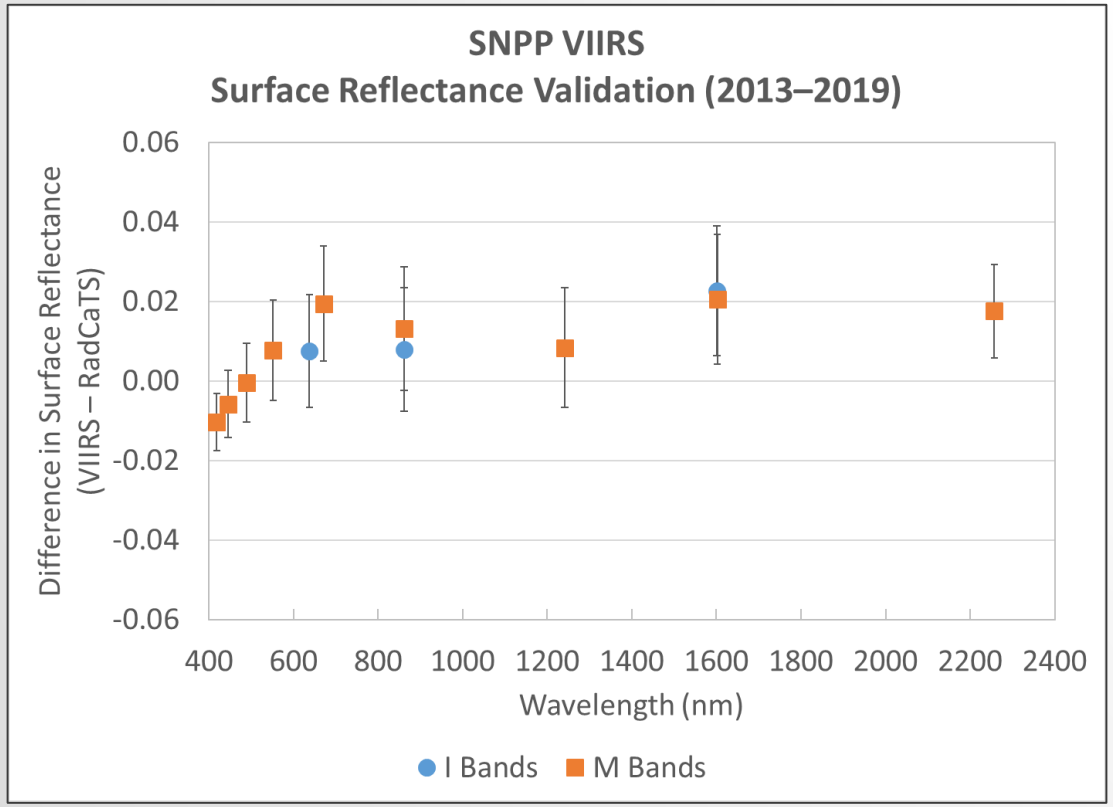
NOAA-20 VIIRS





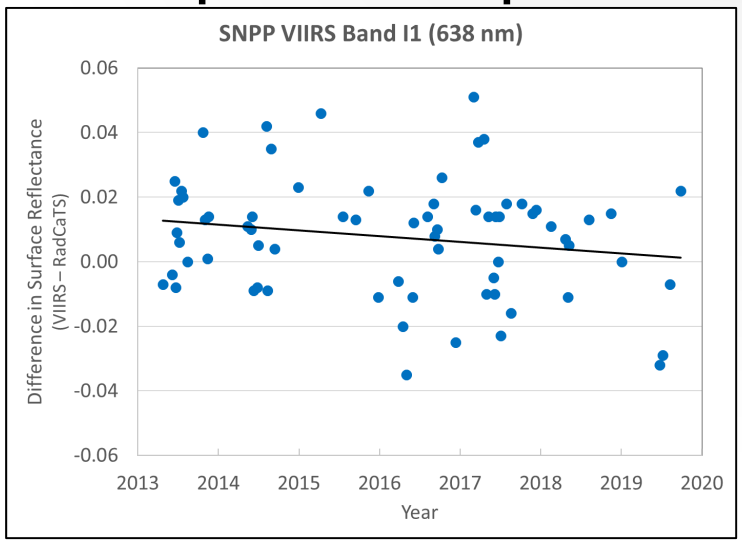
Current SNPP VIIRS Surface Reflectance Validation Results

- 2013–2019
- N=70

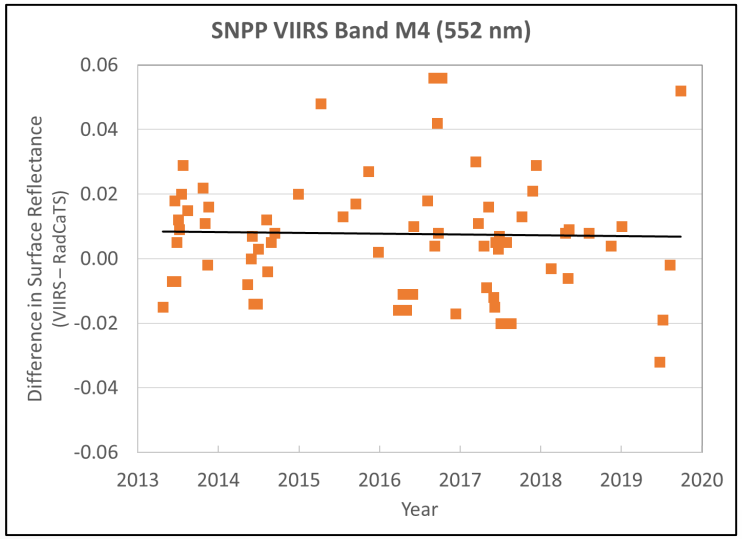


Temporal Examples

Band I1 (638 nm)



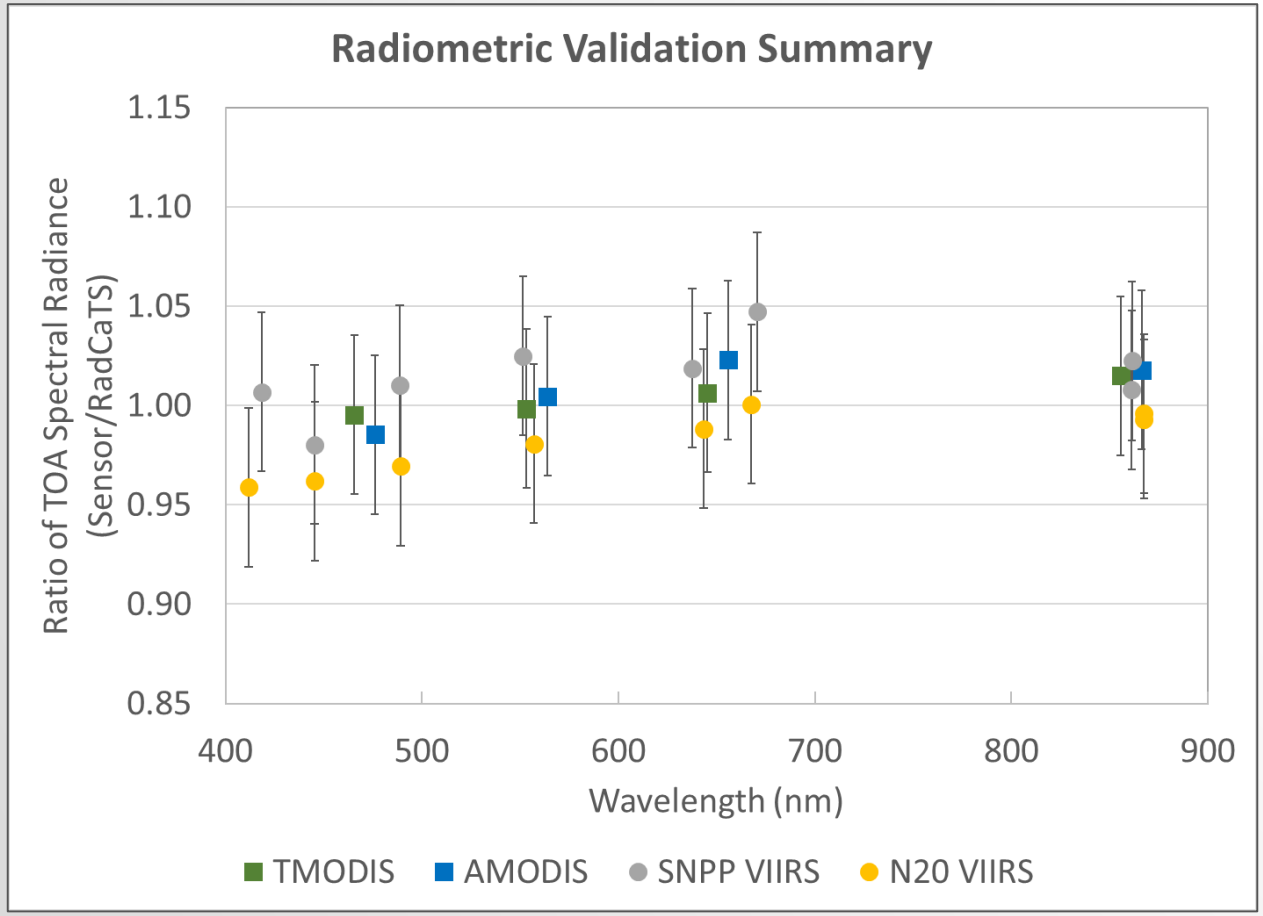
Band M4 (552 nm)



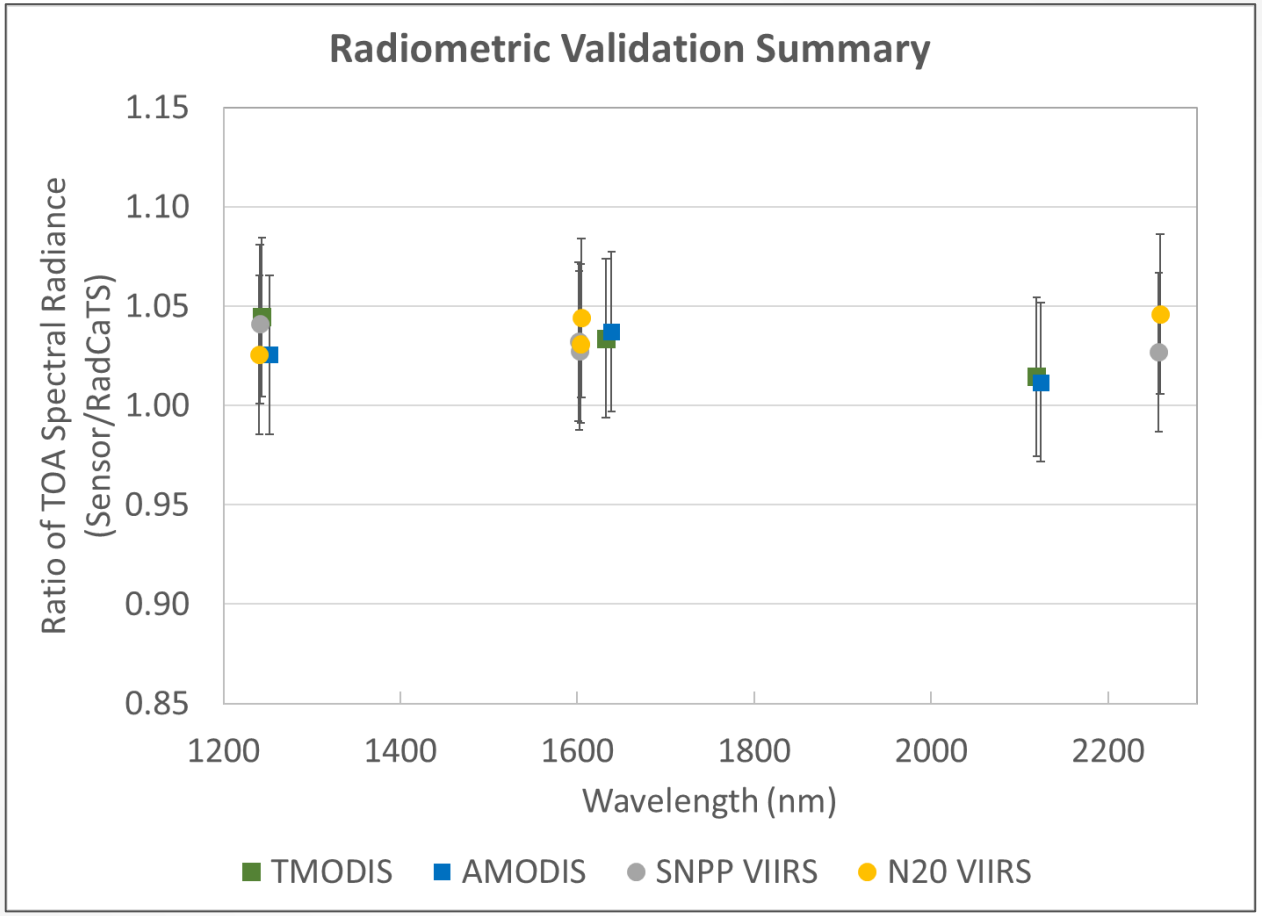
Recap

Summary of All Radiometric Calibration Results

VNIR

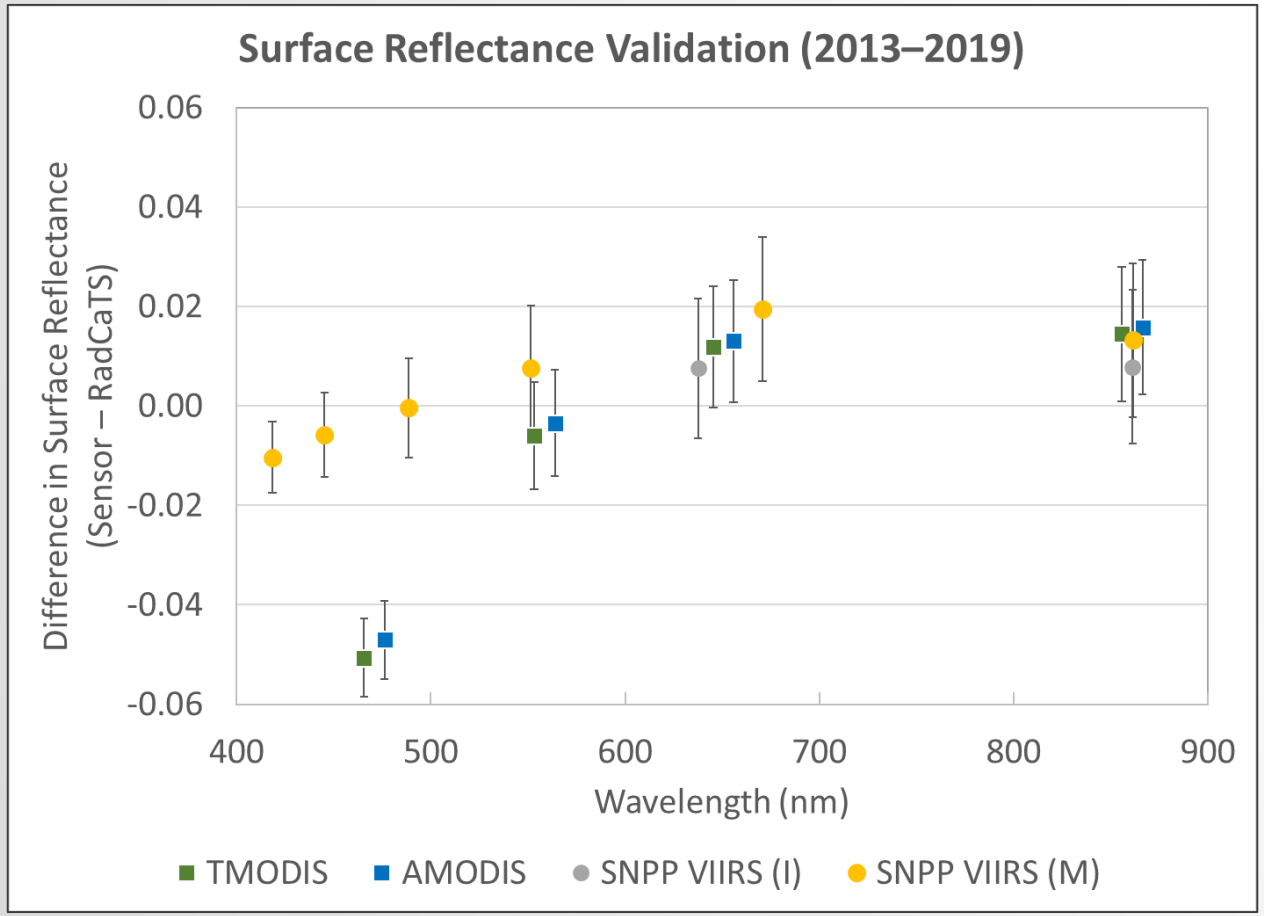


SWIR

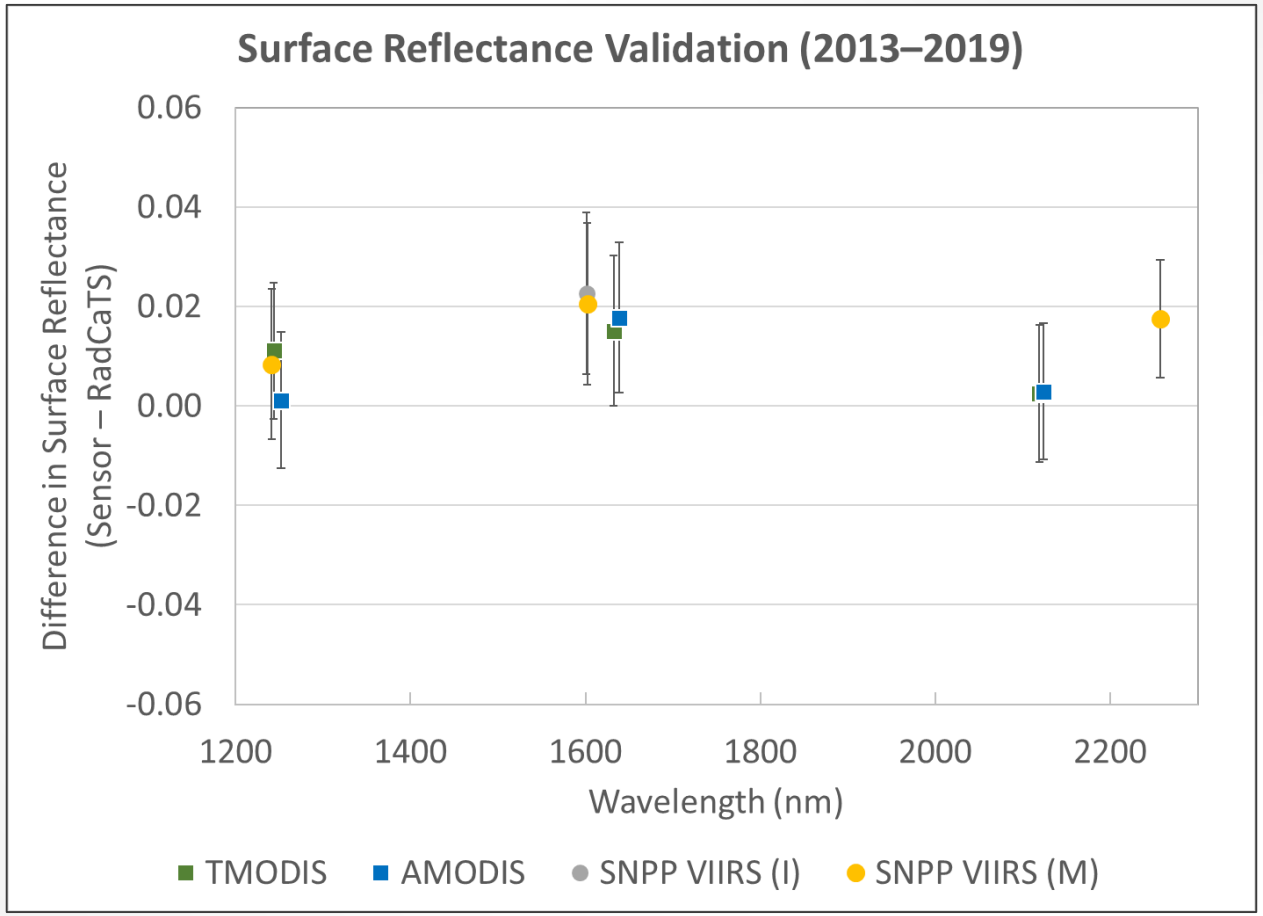


Summary of All Surface Reflectance Validation Results

VNIR



SWIR



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