



**MODIS/VIIRS Cal/Val Using RadCaTS**  
Jeffrey Czapla-Myers and Nikolaus Anderson

Wyant College of Optical Sciences  
University of Arizona

MODIS/VIIRS Calibration Workshop  
25–26 Feb 2021



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



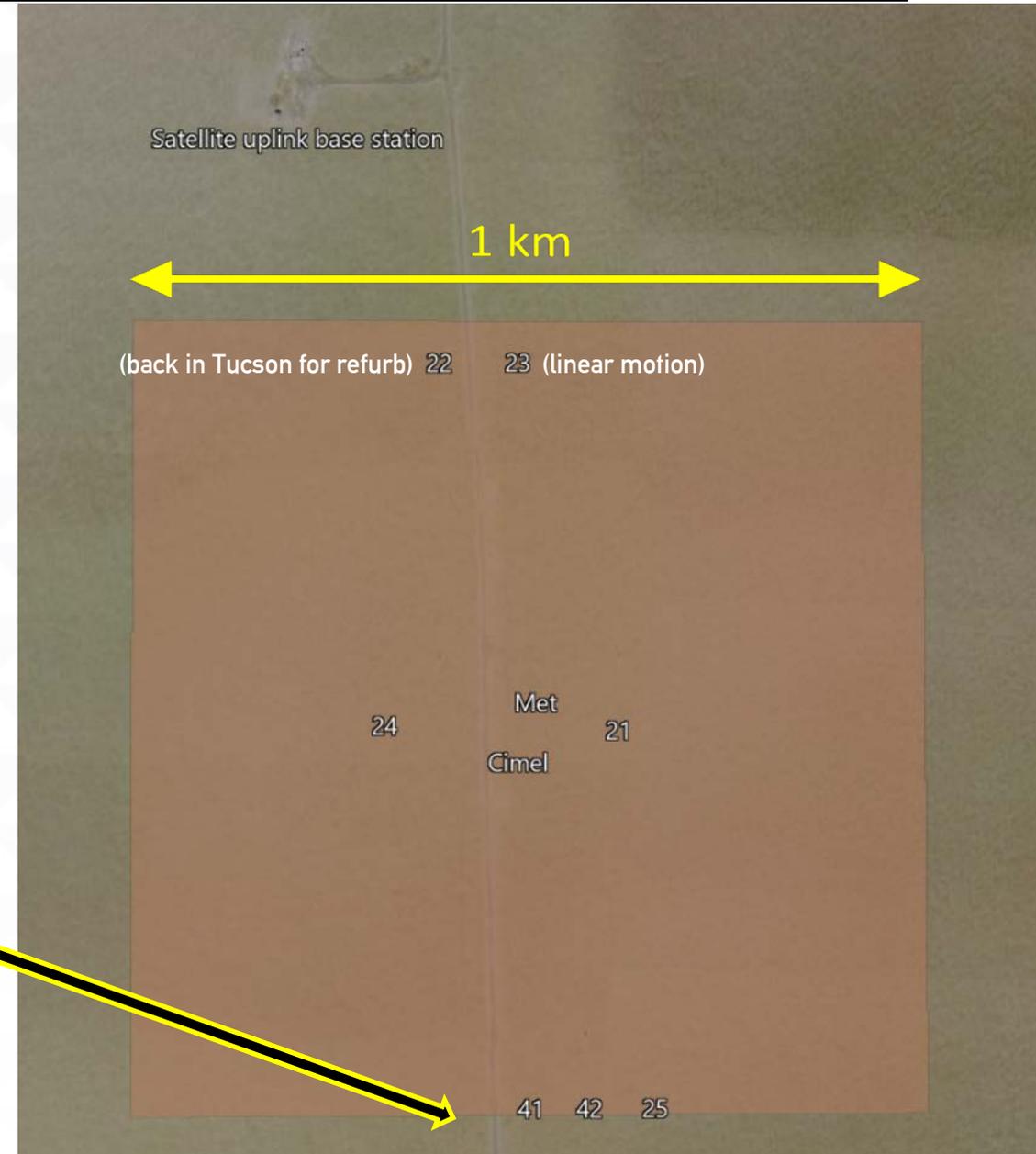
- UArizona is using the Radiometric Calibration Test Site (RadCaTS) at Railroad Valley, NV, as the primary data collection site
- RadCaTS has been in operation in its current form since 2012
- Previous studies were used to determine amount and placement of GVRs for spatial sampling similar to traditional reflectance-based approach
- Reflectance-based approach and RadCaTS are two independent methods
  - Reflectance-based:
    - Surface reflectance: ratio method of surface to reference panel
    - Automated solar radiometer used for atmospheric measurements
  - RadCaTS
    - Surface reflectance: absolutely-calibrated multispectral radiometers
    - AERONET Cimel solar/lunar photometer used for atmospheric measurements
- MODTRAN used to determine atmospheric propagation in both cases



# Equipment at RadCaTS



- 7 ground-viewing radiometers (GVRs)
  - All in nadir viewing configuration (as of 18 Oct 2020)
  - Monitoring ground under 41 and 42 to determine when to include in processing (recently moved from GOES-E and -W config)
  - One GVR (23) has 80 cm of linear motion
- 1 VNIR spectroradiometer (SpAM)
- 2 Cimel sun photometers (314 and 786)
- Met station
- Satellite uplink
- Web camera





# Equipment at RadCaTS

VNIR Spectrometer



Met station



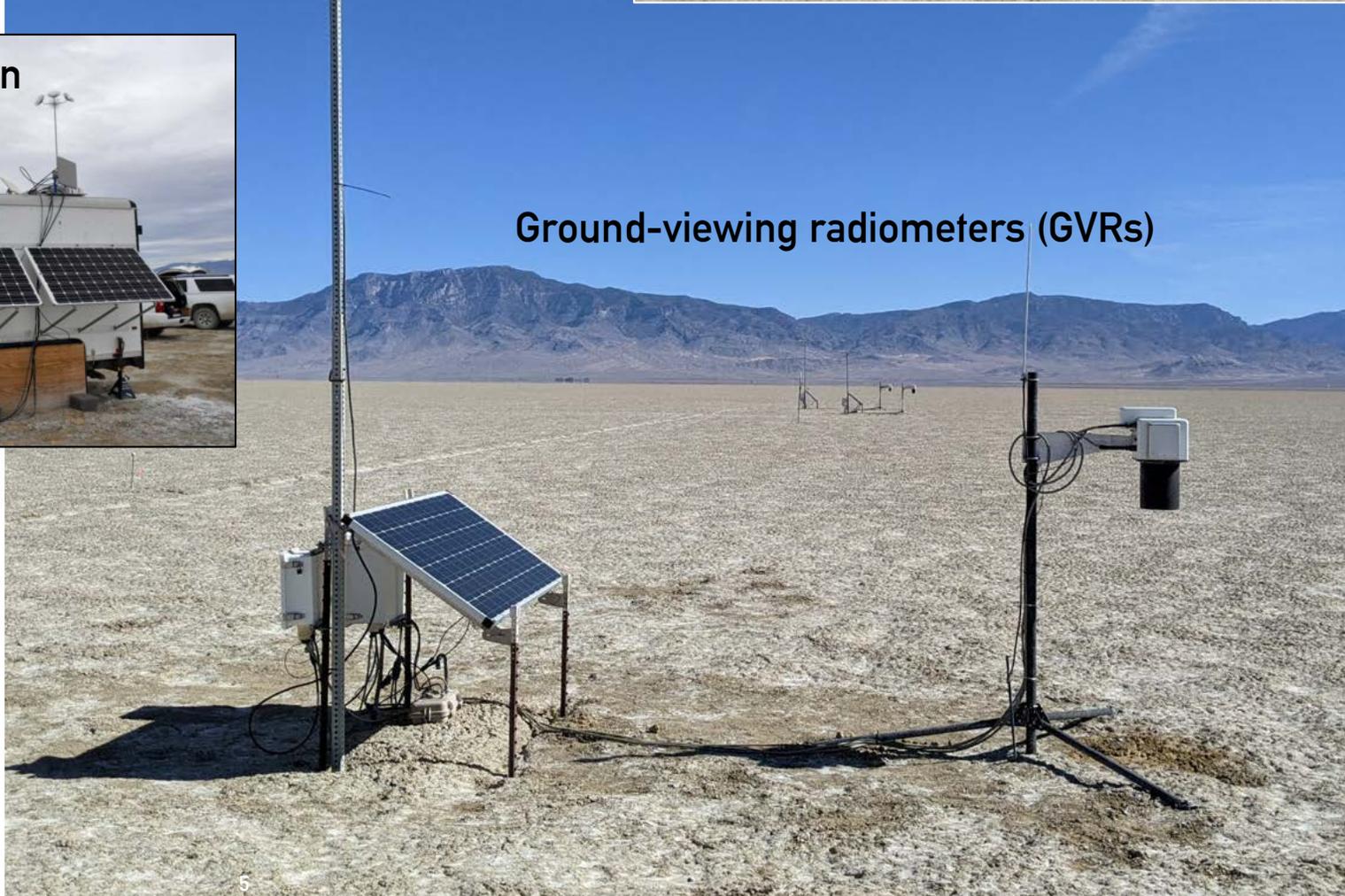
Web cam



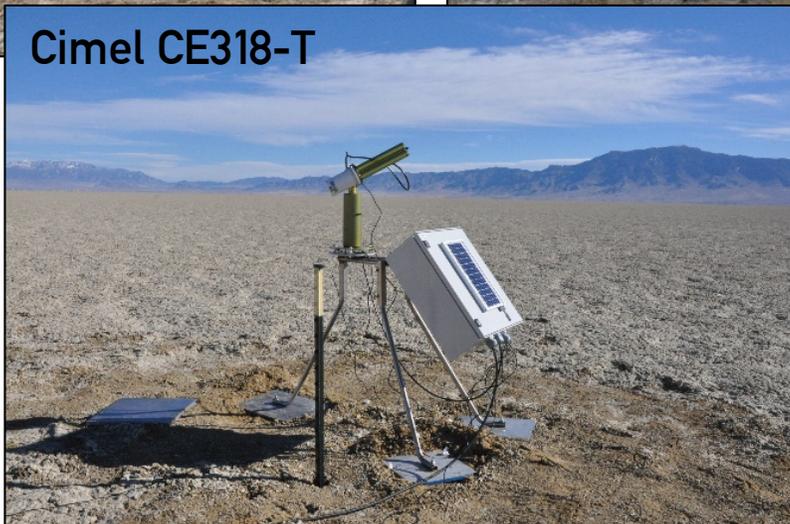
Satellite uplink station



Ground-viewing radiometers (GVRs)



Cimel CE318-T





## GVR 23: Linear Motion



- Operating since Mar 2020
- Same  $10^\circ$  field of view as current GVRs
- Mounted at same height as current GVRs
- Translation:  $\sim 80$  cm at a rate of  $0.5 \text{ cm s}^{-1}$
- Data collected every 10 s (equivalent to 5 cm)
- 6.8 minutes for full lap
- Operates from 16:00–23:00 UTC

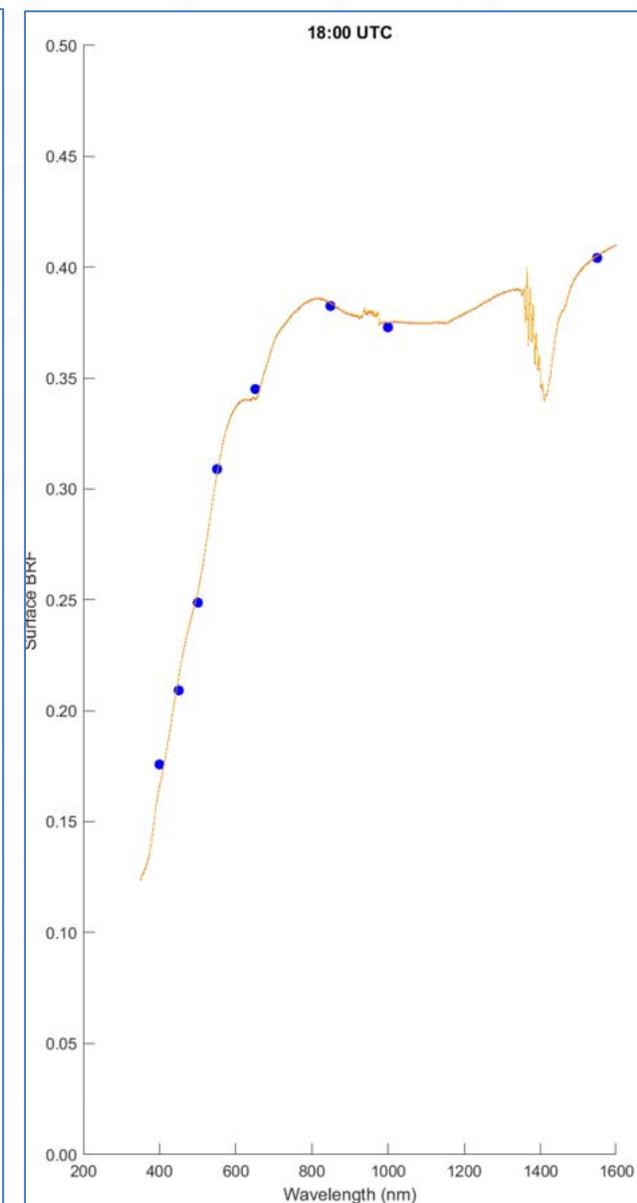
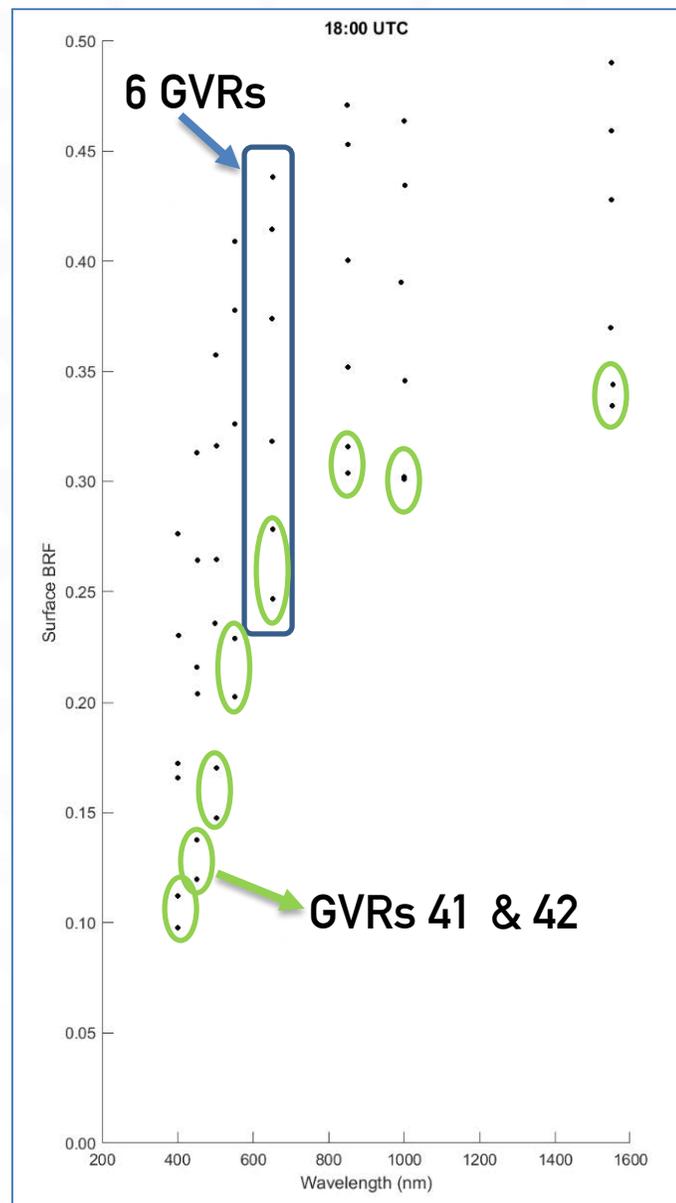




# Surface Reflectance Determination at RadCaTS



- 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)
  - GVR 41 and 42 are currently showing low BRF due to surface disturbance during installation. Will monitor and include them when surface dries.
  - **Note:** graphs are from 4 Nov 2020. Low sun angle. Two lowest BRFs in each band are due to 'watered' area under GVRs 41 and 42.





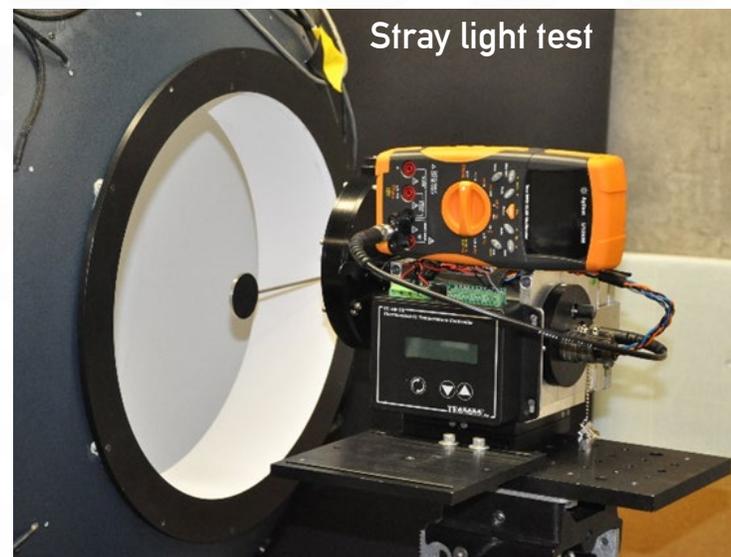
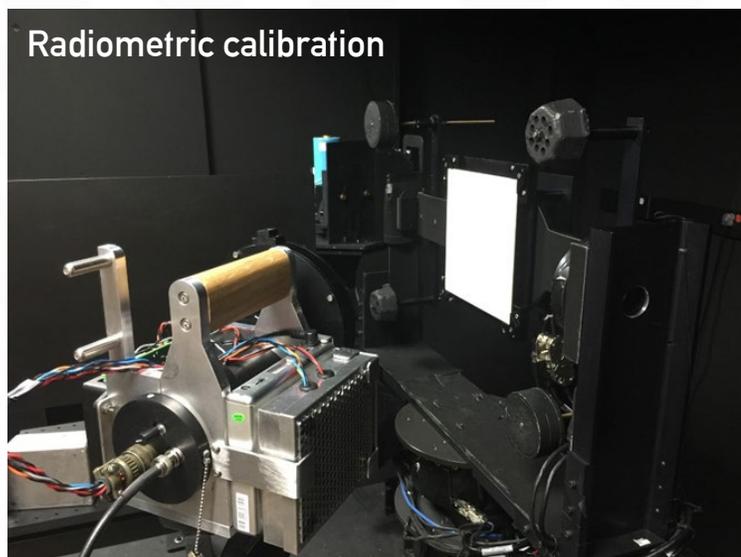
# Support Instrumentation and Measurements

- 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



- UAS
  - Laboratory calibration of Headwall hyperspectral instrument
    - Spectral
    - Radiometric
    - Temporal stability
  - Deployment at Railroad Valley and partner sites for BRDF and spatial uniformity analysis
  - RRV field measurements and comparison to previous PARABOLA-III and ULGS-II results
  - Spatial uniformity comparison with GVR linear motion system



- Online data portal went live in Jul 2018: [www.radcalnet.org](http://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](http://forum.radcalnet.org) (announcements, FAQs, documentation, etc.)

RadCalNet Committee on Earth Observation Satellites Jeff Czajka-Myers

## Welcome to the Radiometric Calibration Network portal

The portal provides access to all RadCalNet datasets, allowing users to visualize and download data acquired by the four instrumented reference test sites.

- University of Arizona's site at Railroad Playa, Nevada, USA,
- AoE's site at Baotou, China,
- the CNES site at La Crau, France,
- the new ESA/CNES site in Gobabeb, Namibia.

These test sites provide nadir-view top-of-atmosphere reflectance at 30 minute intervals from 9am to 3pm local standard time at 10 nm intervals from 400 nm to 2500 nm. This is calculated from ground nadir-view reflectance measurements, and atmospheric measurements such as surface pressure, columnar water vapour, columnar ozone, aerosol optical depth and the Angstrom coefficient. Correction to top-of-atmosphere will be performed for all sites in the same way using Modtran. The data are provided in a text format, defined in [R2-RadCalNetRequirements-DataFormatSpecification\\_V8.pdf](#). To download data from a site, please select a site. To download complete data sets, please press the hyperlink [download all data](#). Users are also asked to consider RadCalNet data policies especially providing appropriate citations when displaying data downloaded from this site. A quickstart guide for new users and for becoming a new RadCalNet site is available here : [RadCalNetQuickstartGuide\\_20180702.pdf](#). Please check the latest announcements, FAQ and discussions on the RadCalNet's [forum](#).

Please select a site :

- Railroad Valley Playa
- La Crau
- Gobabeb
- Baotou

RadCalNet Documents

RadCalNet Committee on Earth Observation Satellites Jeff Czajka-Myers

## Railroad Valley Playa

[return to site list](#)

Access data  
[Access data display and daily data download](#)

Geolocation

Site description

|                       |   |
|-----------------------|---|
| Railroad valley Playa | Google earth site location : <a href="#">RVUS.kmz</a>   |
| Latitude              | 38.497  |
| Longitude             | -115.69   |
| Altitude              | 1435m   |
| Characteristics       | The RadCalNet top-of-atmosphere reflectance spectra are representative of a square of 1km x 1km |

Available data by month

Last output data  
RVUS00\_2018\_206\_v02.03.output

Data file version  
[Download version list](#)

Documentation  
[Site Documentation](#)



- **Source:**

- LAADS DAAC

- **Radiometric Calibration**

- Terra & Aqua MODIS:      Collection 6.1      (2013–2021)

- SNPP VIIRS:      Collection 1 (Archive 5110)      (2013–2021)

- NOAA-20 VIIRS:      Collection 2 (Archive 5200)      (2018–2021)

- **Surface Reflectance Validation**

- Terra & Aqua MODIS:      Collection 6      (2013–2021)

- SNPP VIIRS:      Collection 1 (Archive 5000)      (2013–2021)

- NOAA-20 VIIRS:      No imagery (still working on extracting from NOAA-CLASS imagery)

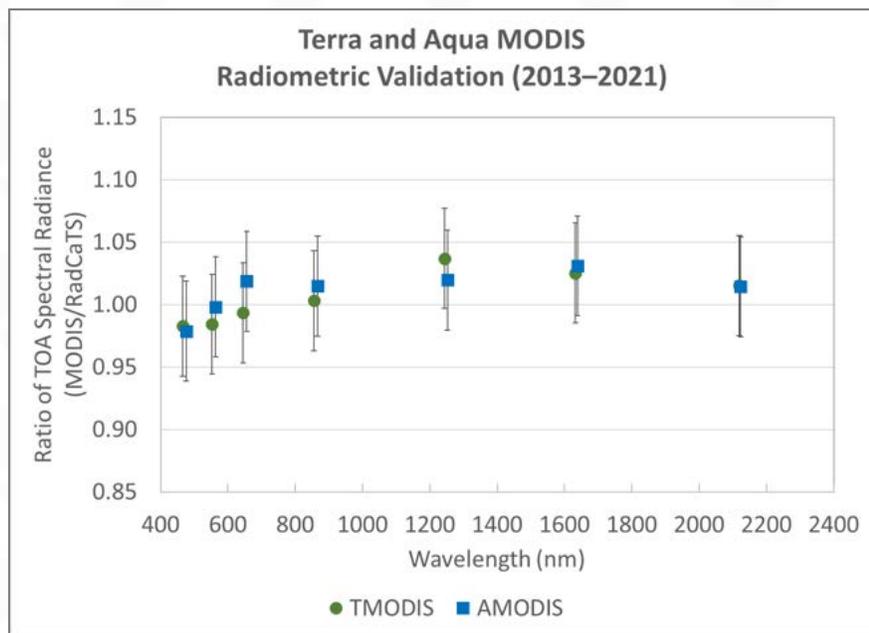


# Sensor Viewing Conditions (as of 1 Jan 2021)

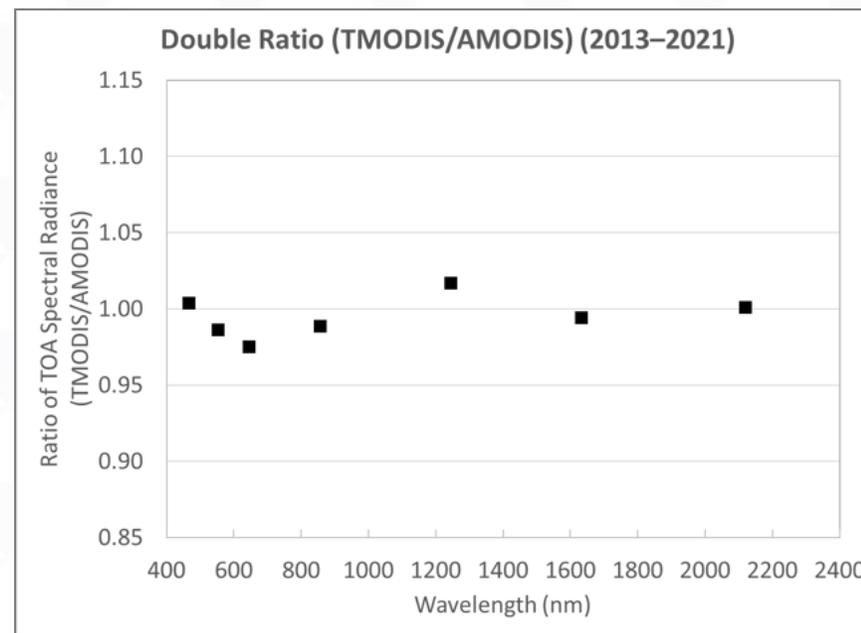


| Sensor        | Time (UTC) | View Zenith Angle | View Azimuth Angle (from ground) |
|---------------|------------|-------------------|----------------------------------|
| TMODIS        | 18:32      | 13.1°             | 102.4°                           |
|               | 18:38      | 1.5°              | 103.1°                           |
|               | 18:44      | 10.2°             | 284.3°                           |
| AMODIS        | 20:48      | 7.3°              | 75.9°                            |
|               | 20:55      | 4.5°              | 256.9°                           |
| SNPP VIIRS    | 20:33      | 11.0°             | 74.7°                            |
|               | 20:39      | 0.6°              | 75.1°                            |
|               | 20:45      | 9.8°              | 256.7°                           |
| NOAA-20 VIIRS | 20:33      | 10.9°             | 74.7°                            |
|               | 20:39      | 0.4°              | 74.7°                            |
|               | 20:46      | 9.9°              | 256.7°                           |

- 2013–2021
- **TMODIS: N=135**, **AMODIS: N=112**



## Double ratio to remove RadCaTS



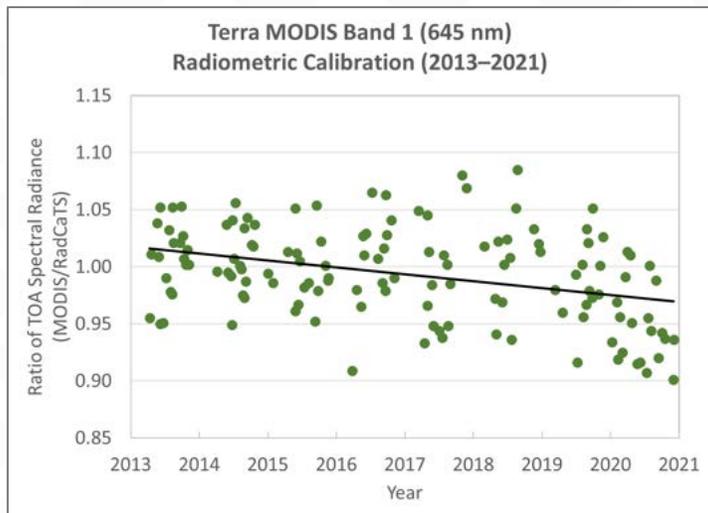
- MODIS Bands: 1–7
- Double ratio:  $(\text{TMODIS}/\text{RadCaTS})/(\text{AMODIS}/\text{RadCaTS}) = \text{TMODIS}/\text{AMODIS}$



# Temporal Radiometric Calibration Results

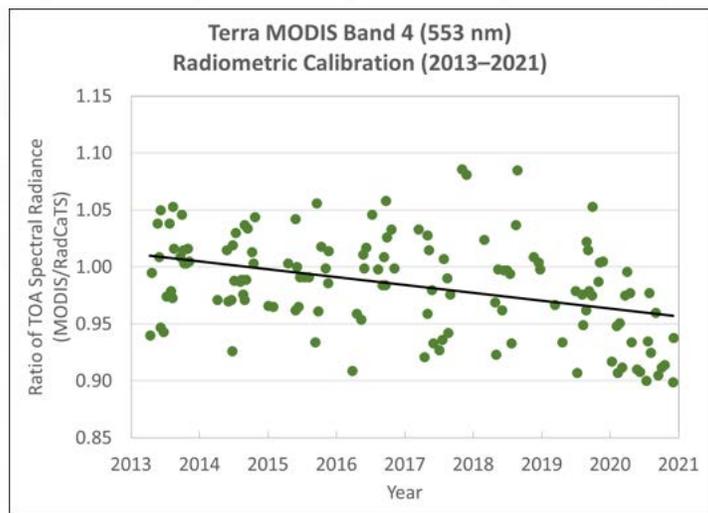
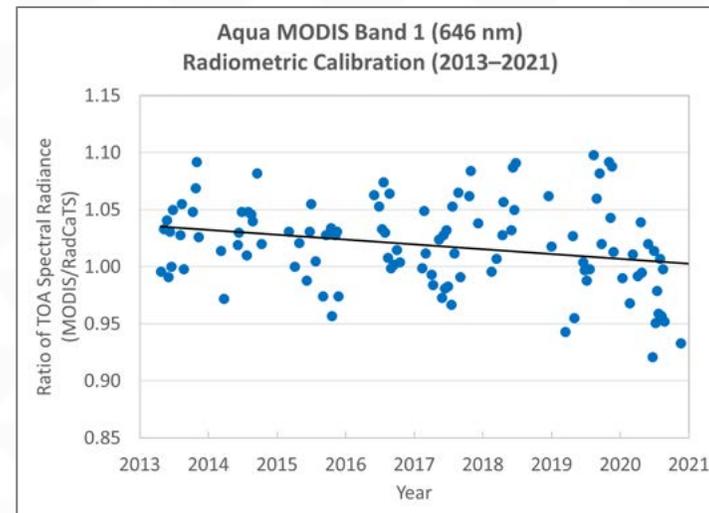


## Terra MODIS

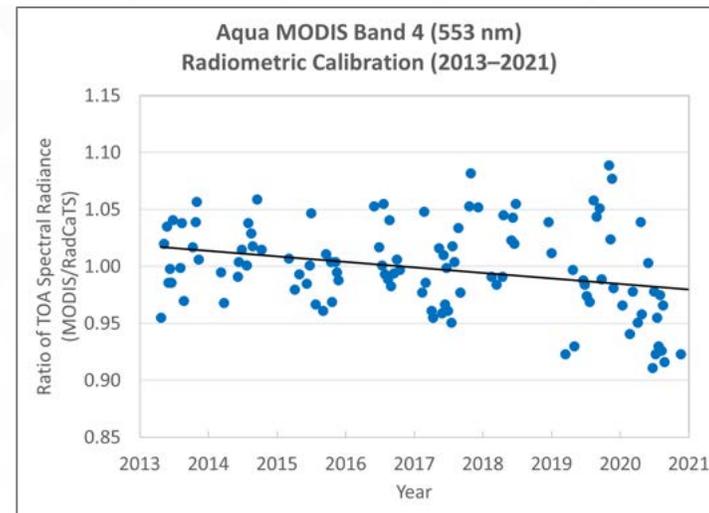


Band 1 (645 nm)

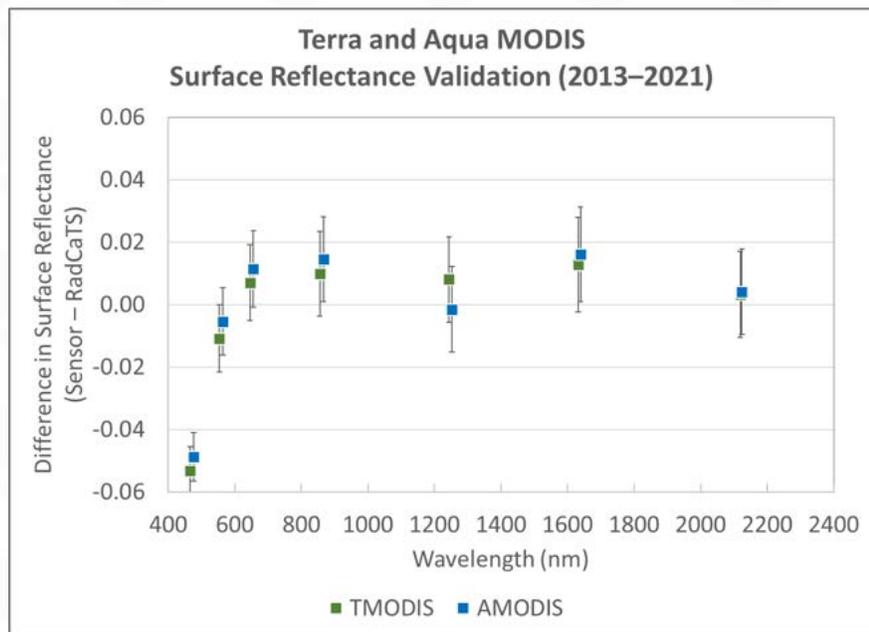
## Aqua MODIS



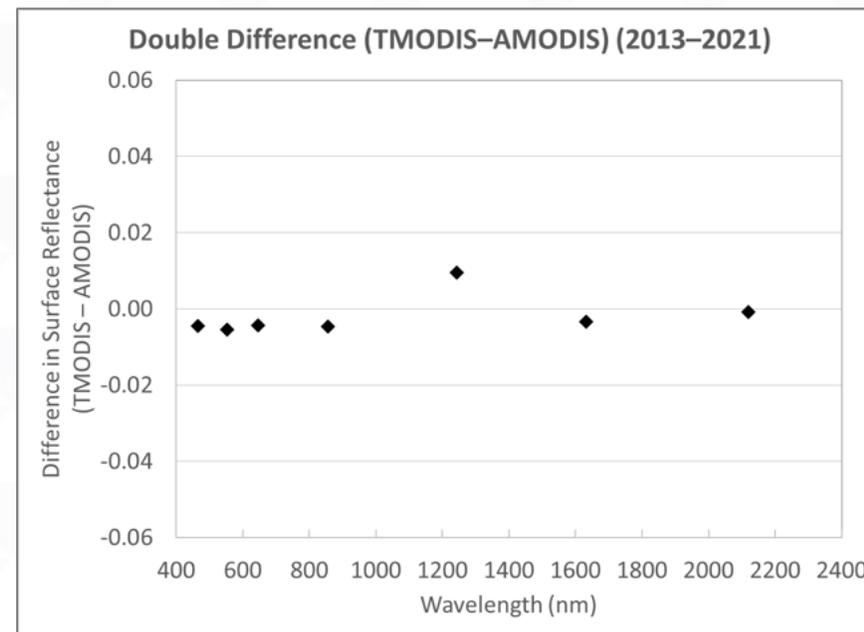
Band 4 (553 nm)



- 2013–2021
- **TMODIS: N=135**, **AMODIS: N=112**



Double difference to remove RadCaTS



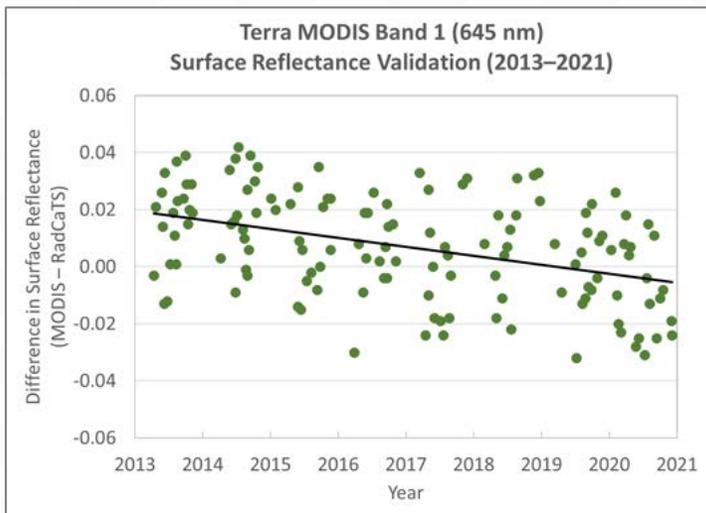
- MODIS Bands 1–7
- Double difference:  $(\text{TMODIS} - \text{RadCaTS}) - (\text{AMODIS} - \text{RadCaTS}) = \text{TMODIS} - \text{AMODIS}$



# Temporal Surface Reflectance Validation Results

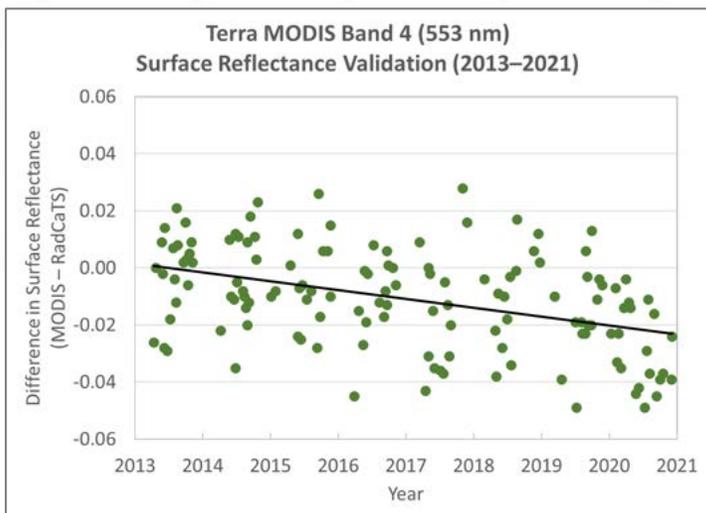
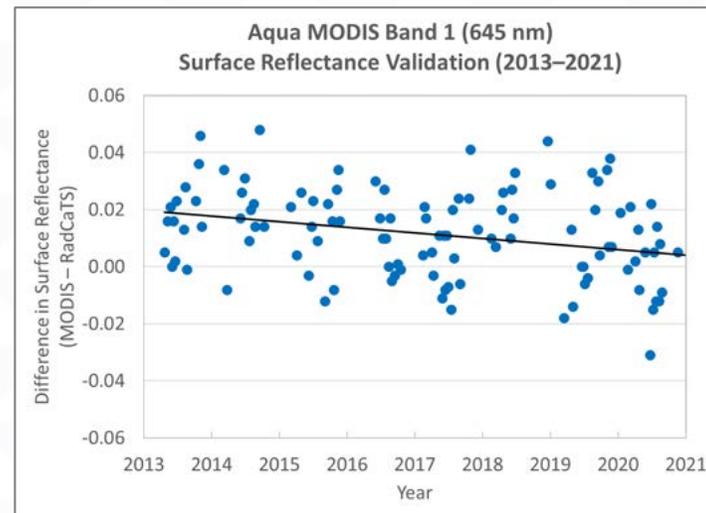


## Terra MODIS

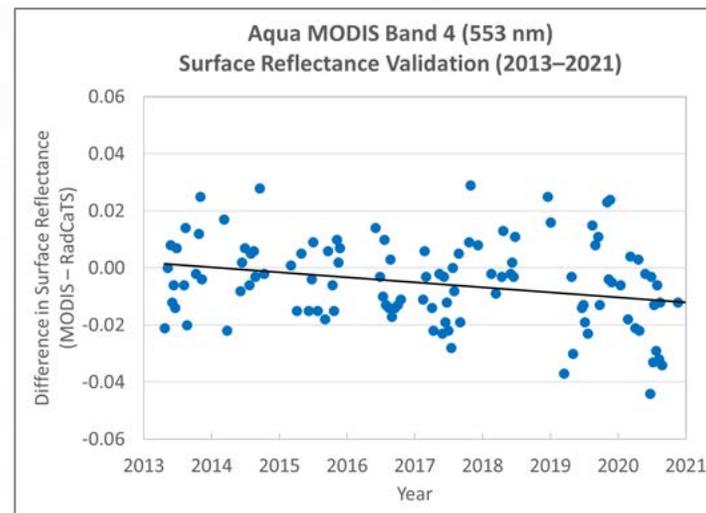


Band 1 (645 nm)

## Aqua MODIS



Band 4 (553 nm)





THE UNIVERSITY OF ARIZONA

Wyant College  
of Optical Sciences

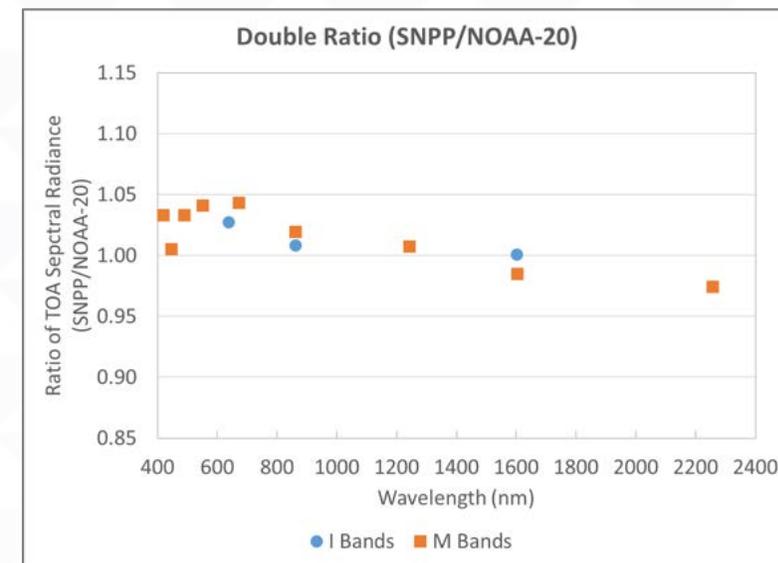
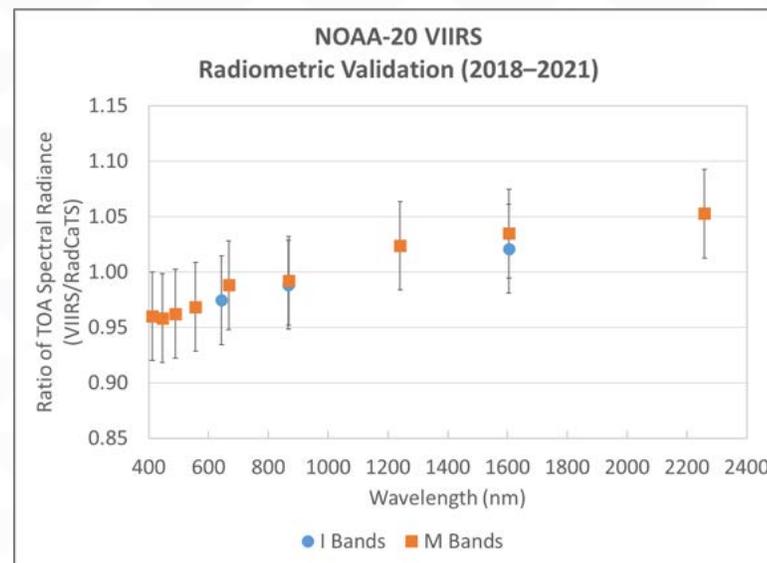
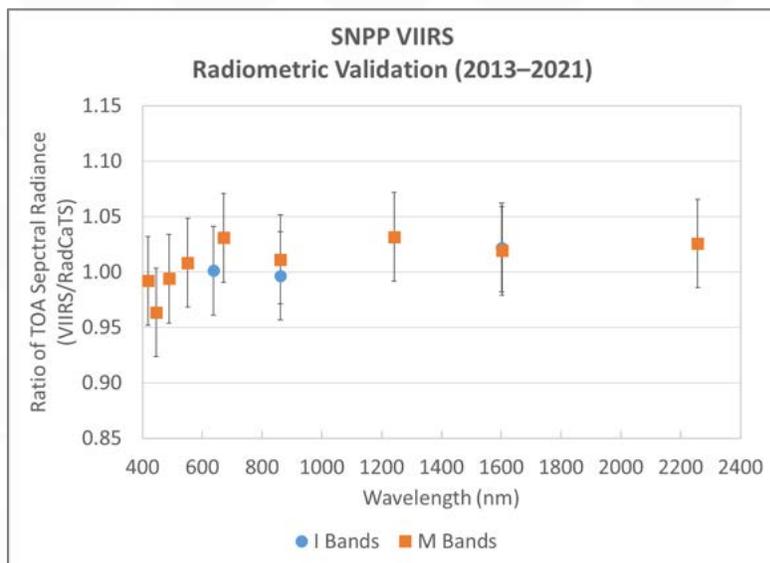
# VIIRS Results



- 2013–2021 (SNPP), 2018–2021 (NOAA-20)
- SNPP: N=106

NOAA-20: N=64

Double ratio to remove RadCaTS



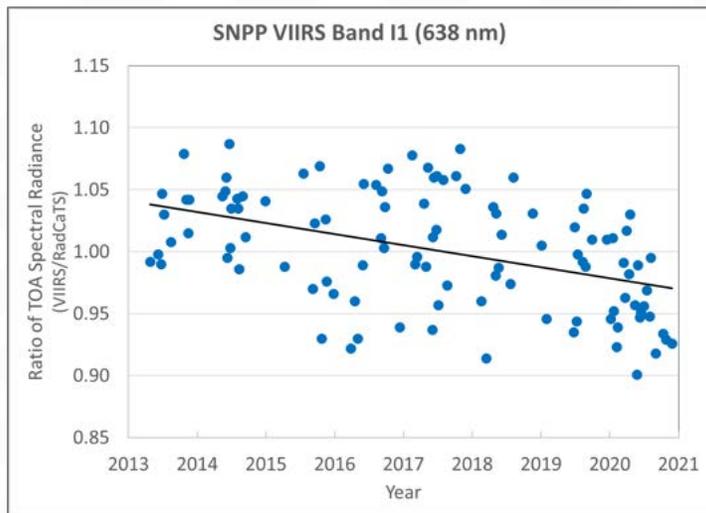
- VIIRS bands: **I1–I3**, **M1–M5**, **M7**, **M8**, **M10**, **M11**
- Double ratio:  $(\text{SNPP}/\text{RadCaTS})/(\text{N20}/\text{RadCaTS}) = \text{SNPP}/\text{N20}$



# Temporal Radiometric Calibration Results

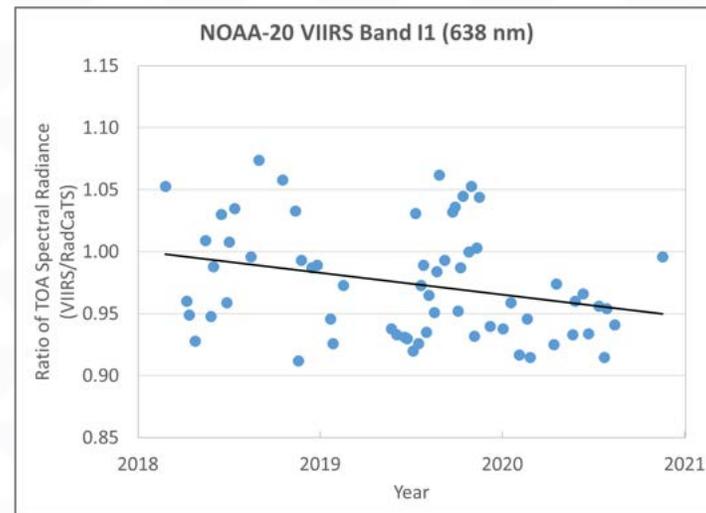


## SNPP VIIRS

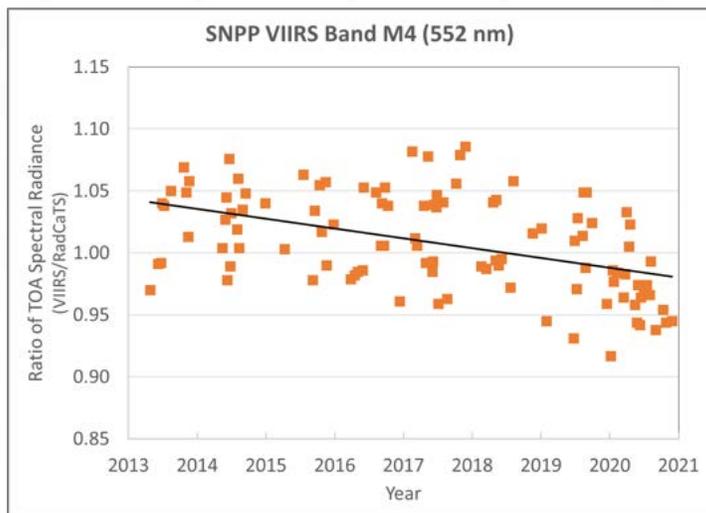


Band I1 (638 nm)

## NOAA-20 VIIRS

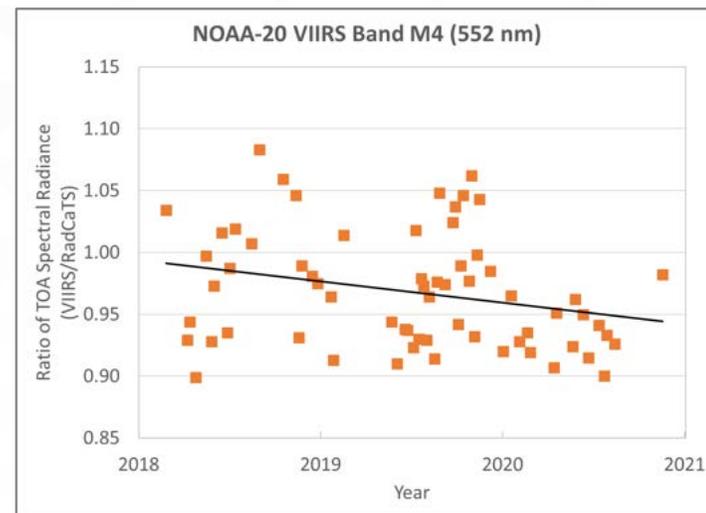


## SNPP VIIRS Band M4 (552 nm)



Band M4 (552 nm)

## NOAA-20 VIIRS Band M4 (552 nm)

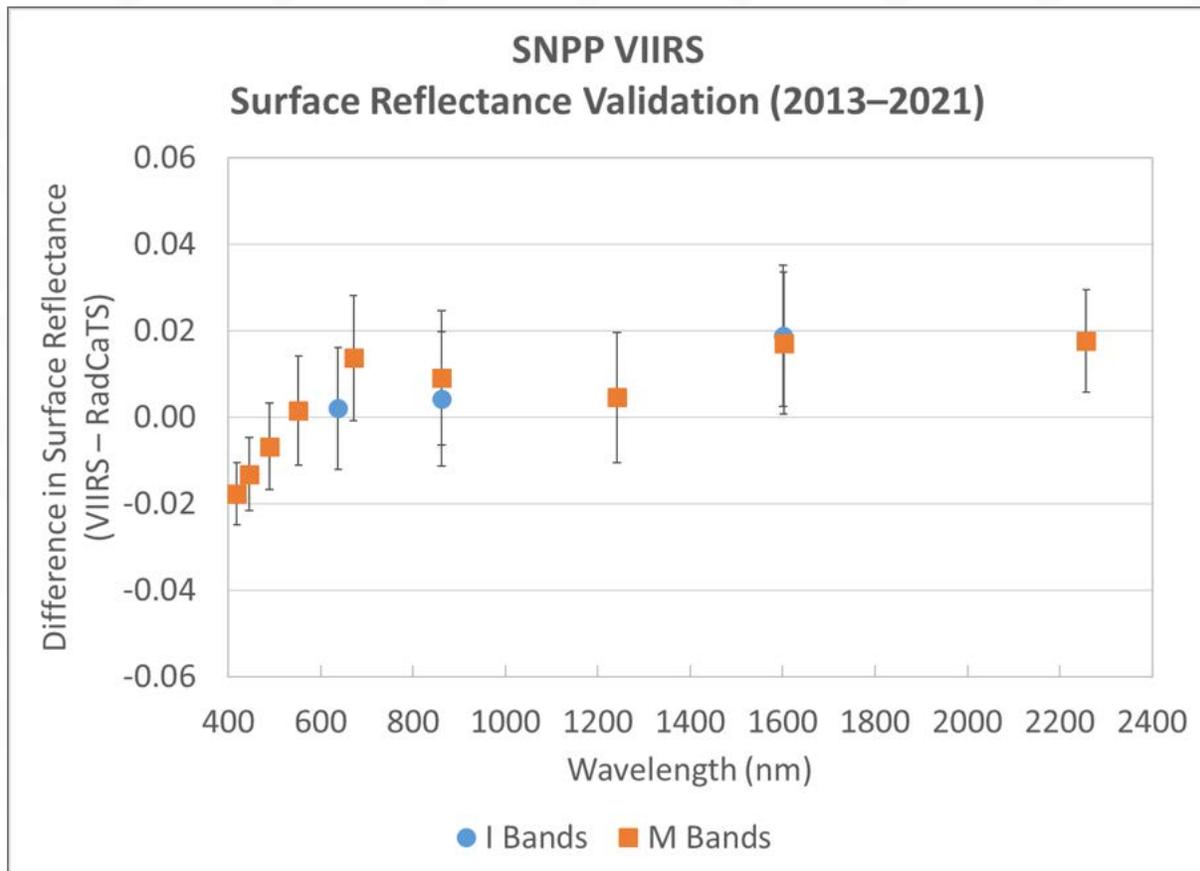




# SNPP VIIRS Surface Reflectance Validation Results



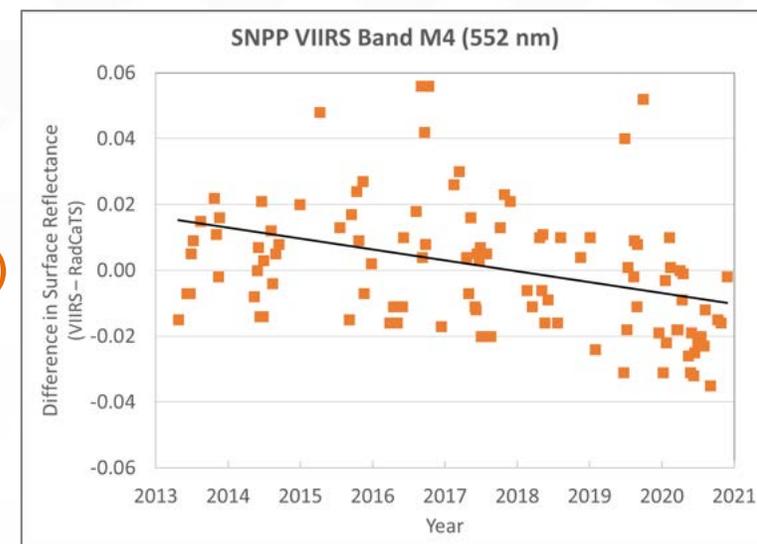
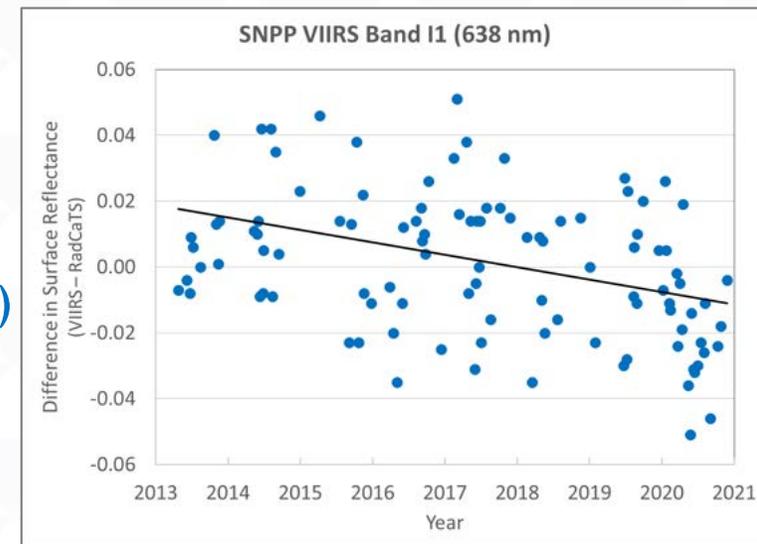
- 2013–2021
- N=106



Band I1 (638 nm)

Band M4 (552 nm)

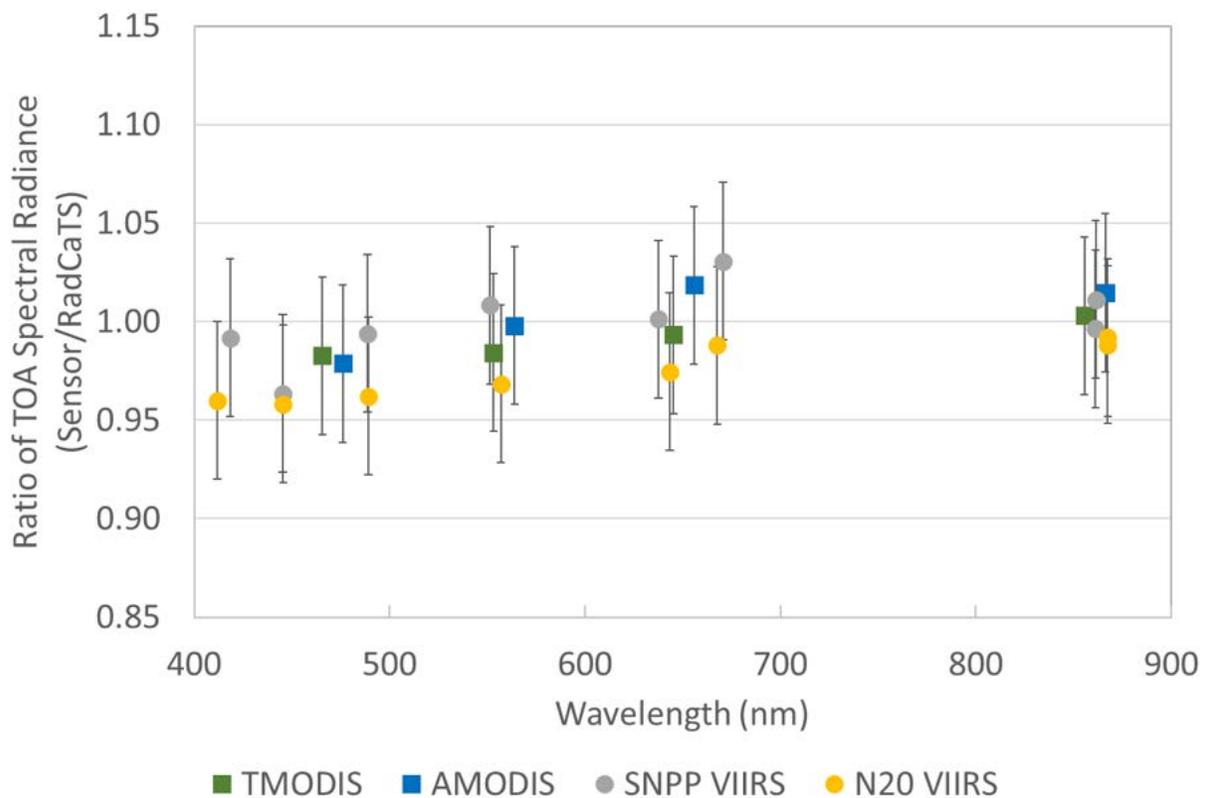
## Temporal Examples



- Summary of all radiometric calibration results

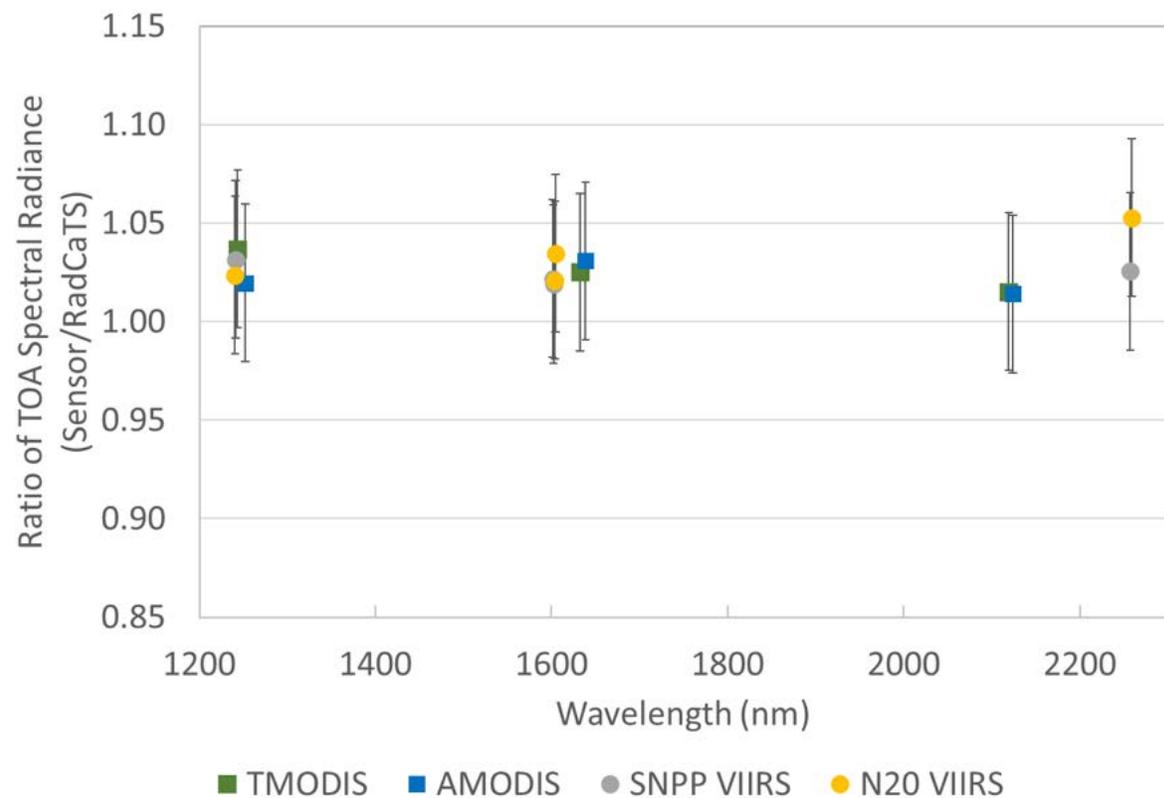
## VNIR

Radiometric Validation Summary



## SWIR

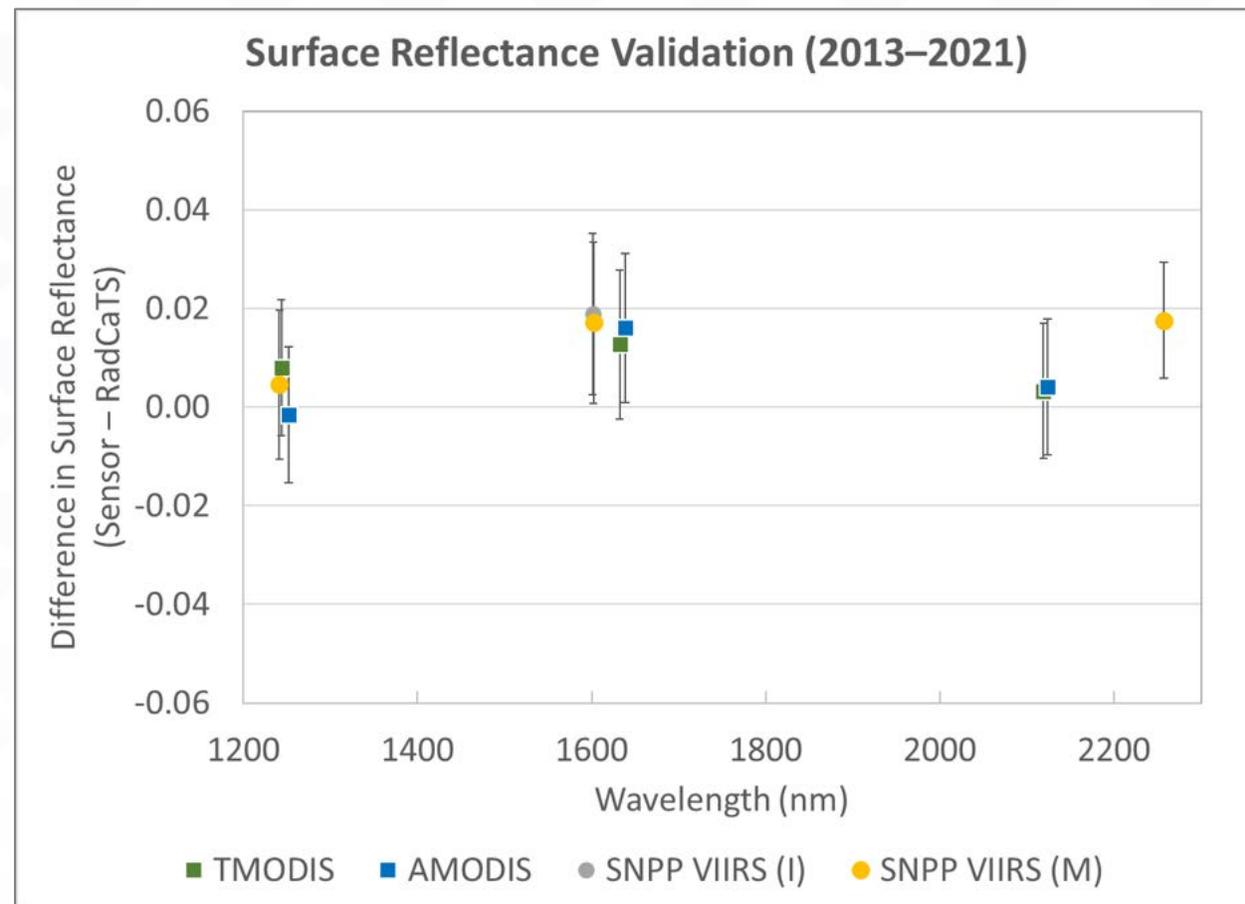
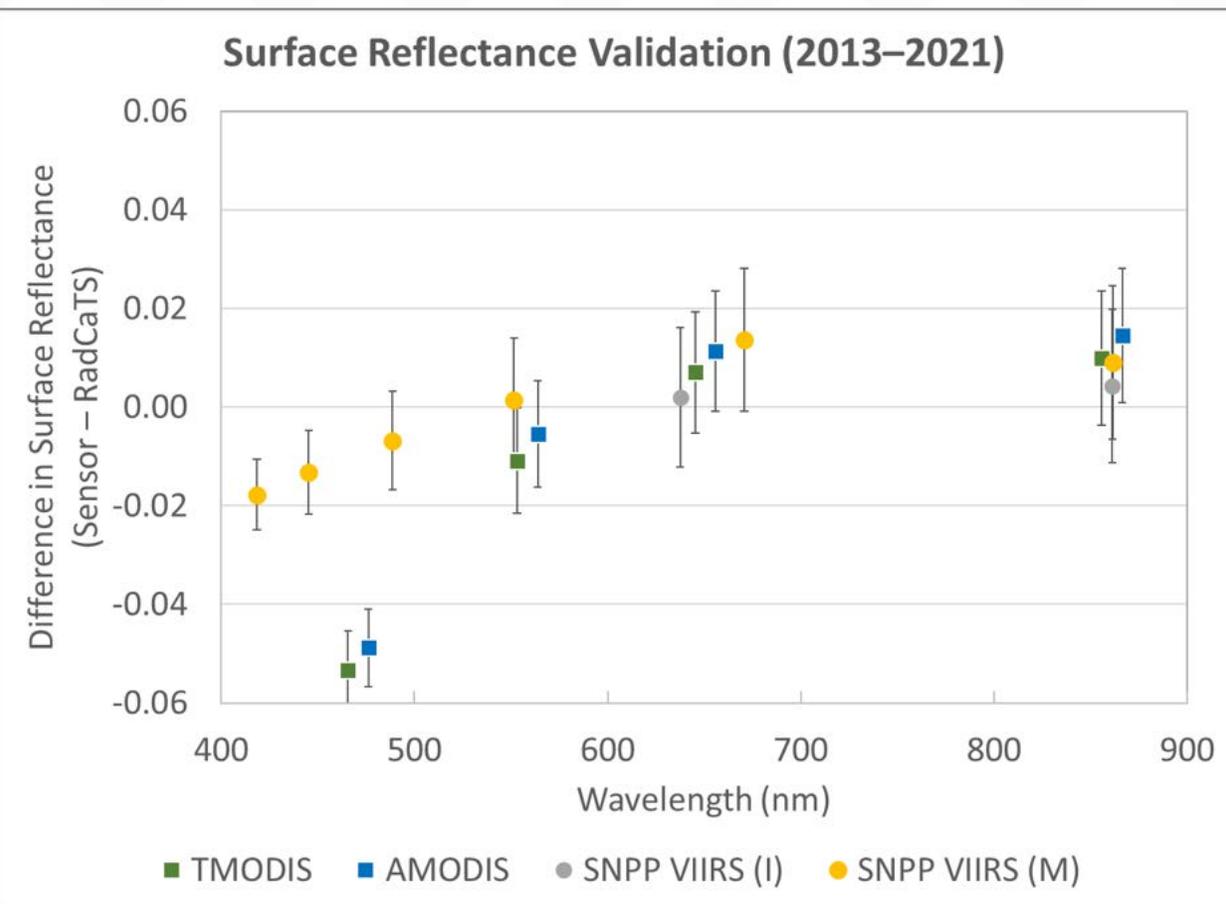
Radiometric Validation Summary



- Summary of all surface reflectance validation results

## VNIR

## SWIR





- **Conclusions**

- Terra and Aqua MODIS radiometric calibration agrees with RadCaTS to within uncertainties
- Terra and Aqua MODIS surface reflectance has bias with RadCaTS in blue band
- SNPP and NOAA-20 VIIRS radiometric calibration also agrees with RadCaTS to within uncertainties, except for NOAA-20 Band M11 (2.3  $\mu\text{m}$ )
- Both pairs of sensors are in agreement to within RadCaTS uncertainty when using double ratio (or difference)

- **Upcoming work in 2021**

- Deployment of Headwall UAS for BRDF measurements at Railroad Valley
- On-site calibration of GVRs using CaTSSITTR
- Continued spatial analysis comparison with traditional reflectance-based approach and RadCaTS
- Integrate on-site VNIR spectrometer data into RadCaTS processing

**Note:** these results will be presented at SPIE Optics and Photonics (Aug 2021)