Use of RadCalNet in Calibration and Validation of Hyperspectral Instruments [WICSIS-2024; ID 124]

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Radiometric Calibration Network

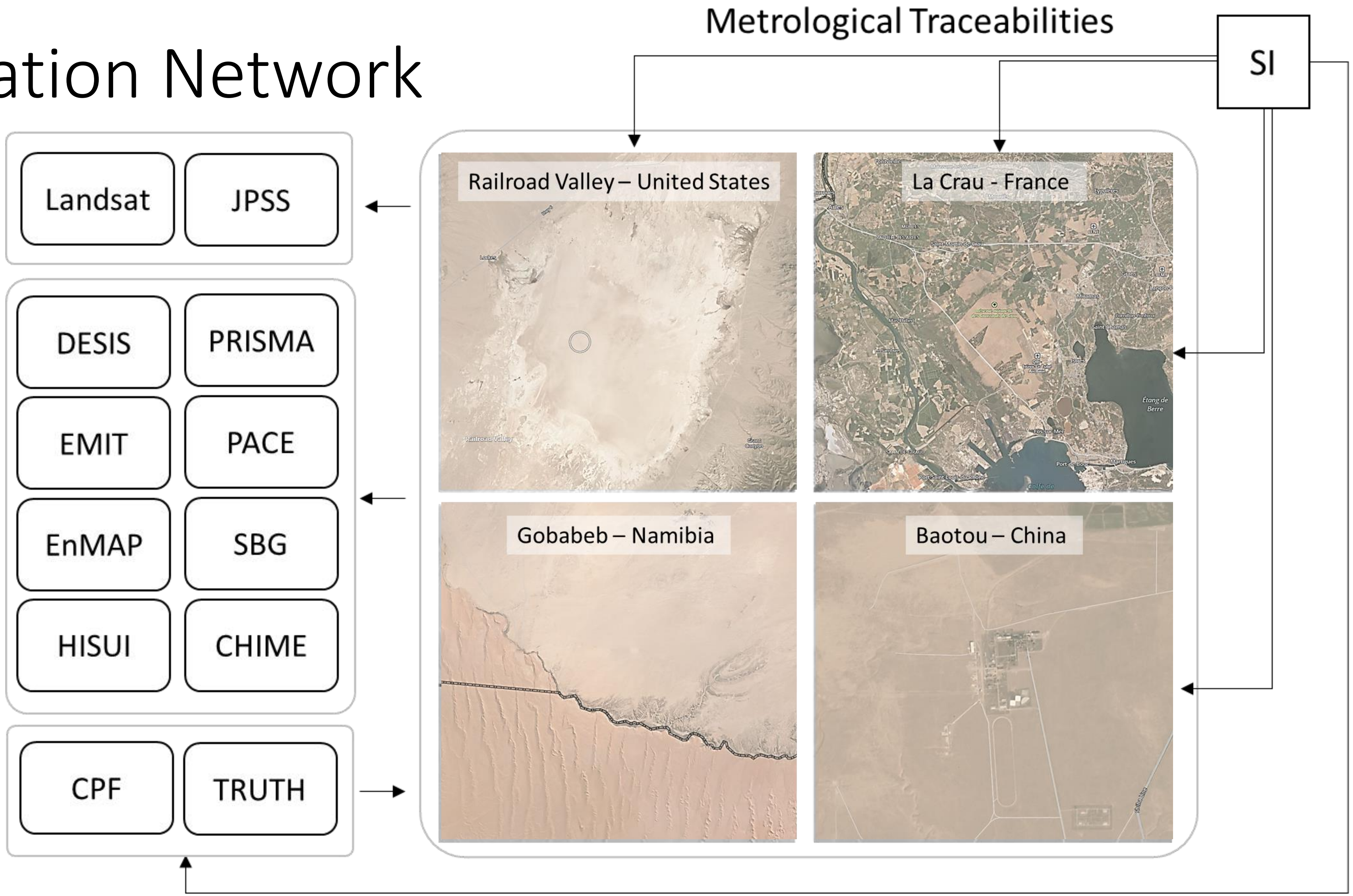
(RadCalNet)

In-situ network of high-quality data

- Independent site operators
- Choice of method to generate spectral surface reflectance

Rules for surface reflectance data

- Nadir surface reflectance at 10 nm intervals including 400- 1000nm
- 0900–1500 local standard time at 30 min intervals.
- Area larger than 45mX45m.
- Atmospheric data



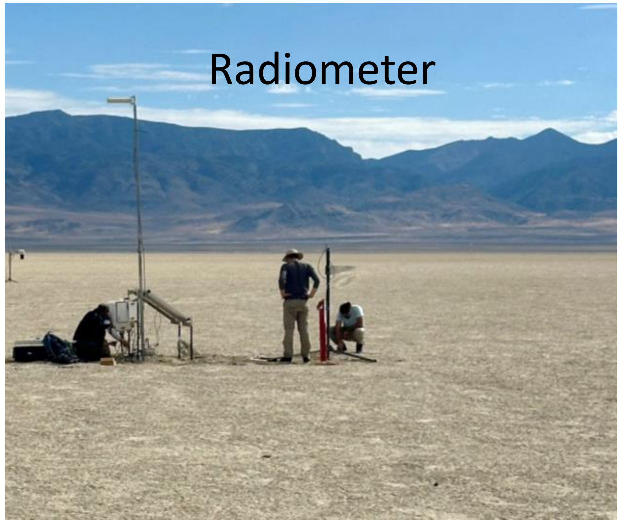
- Bouvet et al. “RadCalNet: A Radiometric Calibration Network for Earth Observing Imagers Operating in the Visible to Shortwave Infrared Spectral Range” [10.3390/rs11202401]
- Wenny et al. “Look-up table approach for uncertainty determination for operational vicarious calibration of Earth imaging sensors” [10.1364/AO.442170]
- Tahersima et al. “Intercomparison of Landsat OLI and JPSS VIIRS Using a Combination of RadCalNet Sites as a Common Reference” Remote Sens. 2023. [10.3390/rs15235562]
- Voskanian et al. “Combining RadCalNet Sites for Radiometric Cross Calibration of Landsat 9 and Landsat 8 Operational Land Imagers” [10.3390/rs15245752]
- Yarahmadi et al. “Intercomparison of Landsat Operational Land Imager and Terra Advanced Spaceborne Thermal Emission and Reflection Radiometer Using RadCalNet” [10.3390/rs16020400]

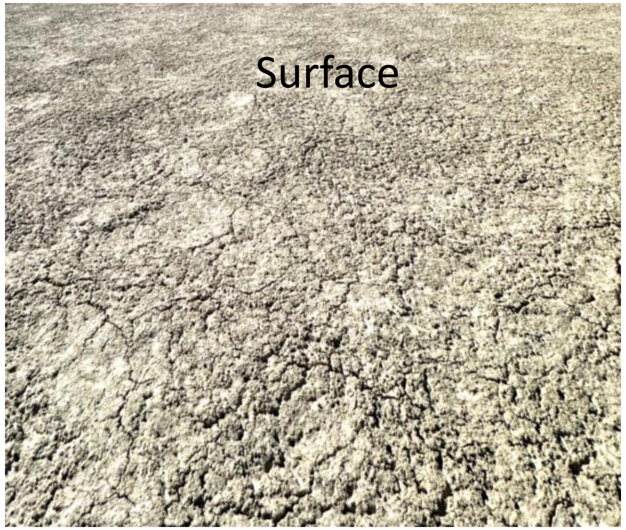
Uncertainty Budget

- RadCalNet relies on process outlined in NPL's Quality Assurance Framework for Earth Observation (QA4EO)
- Uncertainties of surface effects dominate
- Focus is on surface effects: temporal, spatial, and directionality dependence to illumination-observation

Uncertainty in TOA Reflectance

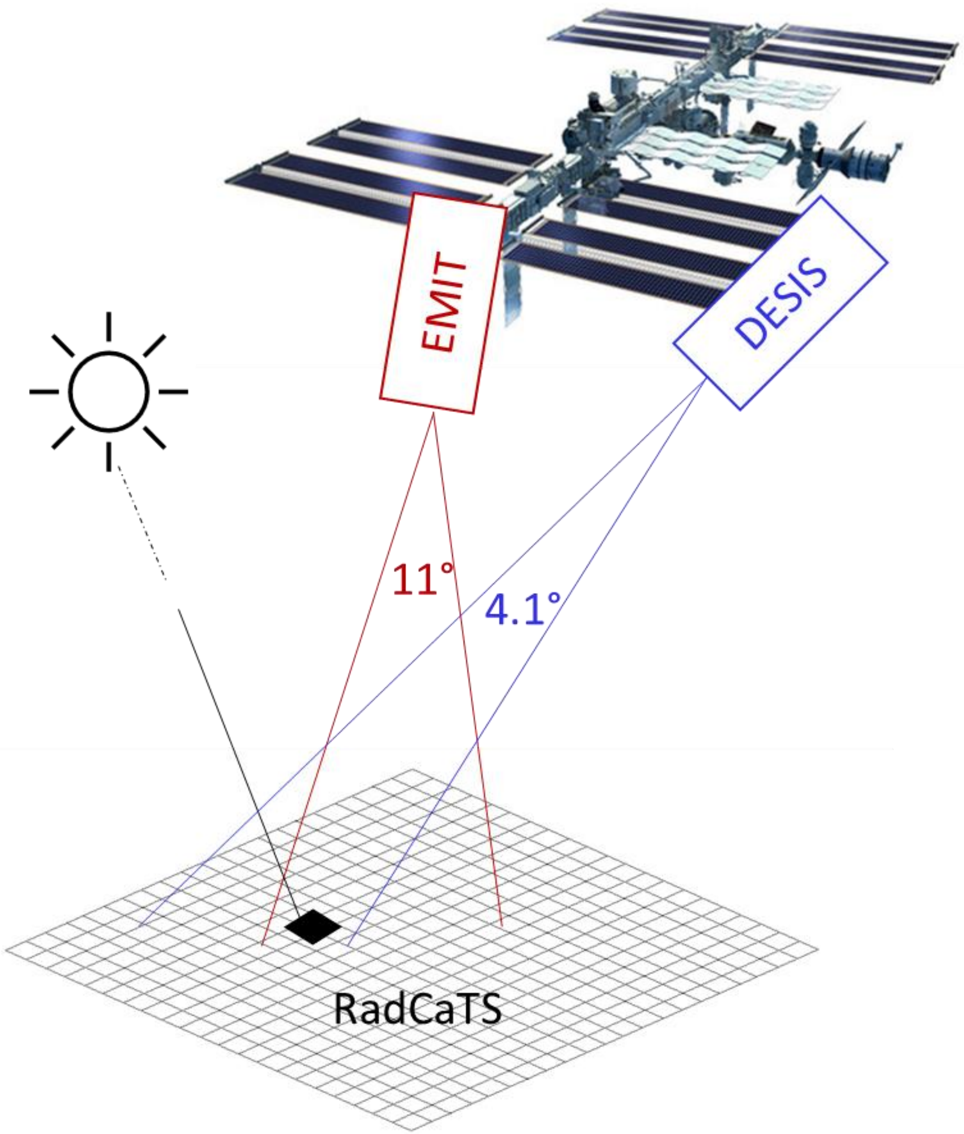
- Radiance in Field
- Radiative Transfer Code
- Atmospheric Input
- Solar Irradiance
- Surface Representativeness
- Surface BRDF





DESIS, EMIT, and RadCaTS (‘RVUS’)

	DESIS	EMIT	RadCaTS
Organization	Teledyne, DLR	JPL, NASA	University of Arizona
Operation Period	2018 – present	2022 – present	2013 – present
Platform	ISS (375 to 435 km)	ISS	In-Situ
Ground Sampling	30 m	60 m	Seven GVRs
Ground Swath	30 km	80 km	Representative of 1 km^2
Revisit Time	not fixed	not fixed	30 minutes from 09:00 to 15:00
Spectral Range	400 – 1000 nm	410 – 2450 nm	400 - 2500 nm
Spectral Sampling	2.55 nm	7.4 nm	10 nm
On-board Cal	Shutter, LED array	None	CaTSSITTR and SRBC

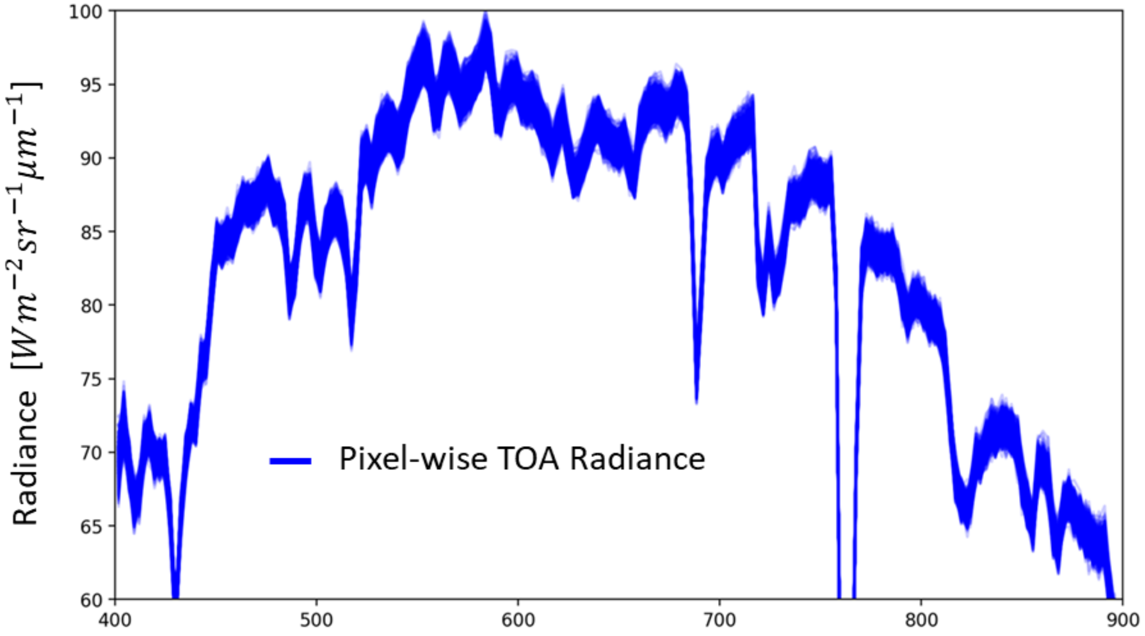


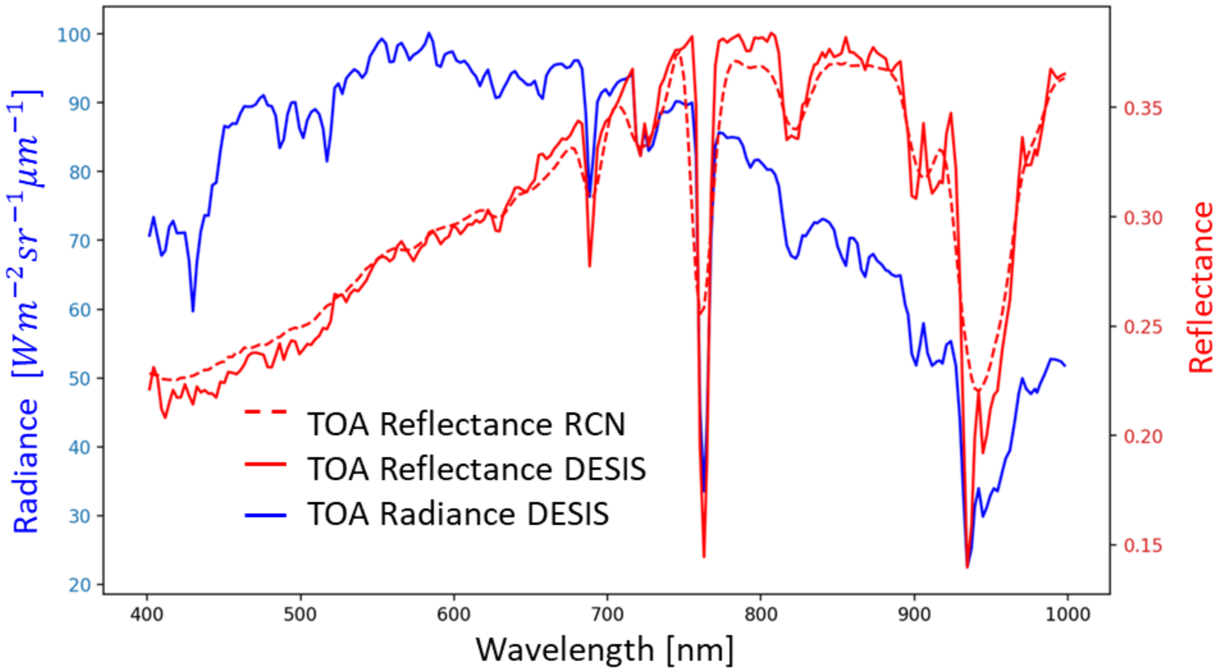
ISS visits a range of overpass times along with the corresponding changes in sun illumination geometry

Preprocessing Steps of Each Image

to compare with RadCalNet predicted TOA reflectance

- Pixels from the 1 km^2 area are averaged
- Radiance-based images of EMIT and DESIS are converted to reflectance
- TSIS-1 HSRS spectral solar irradiance is used

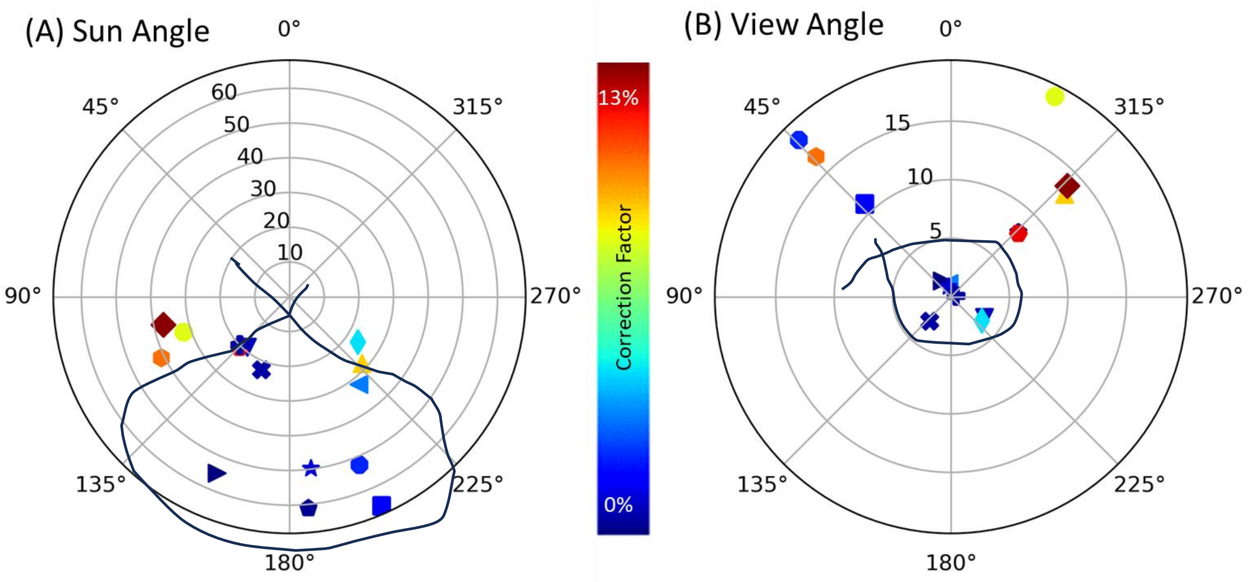


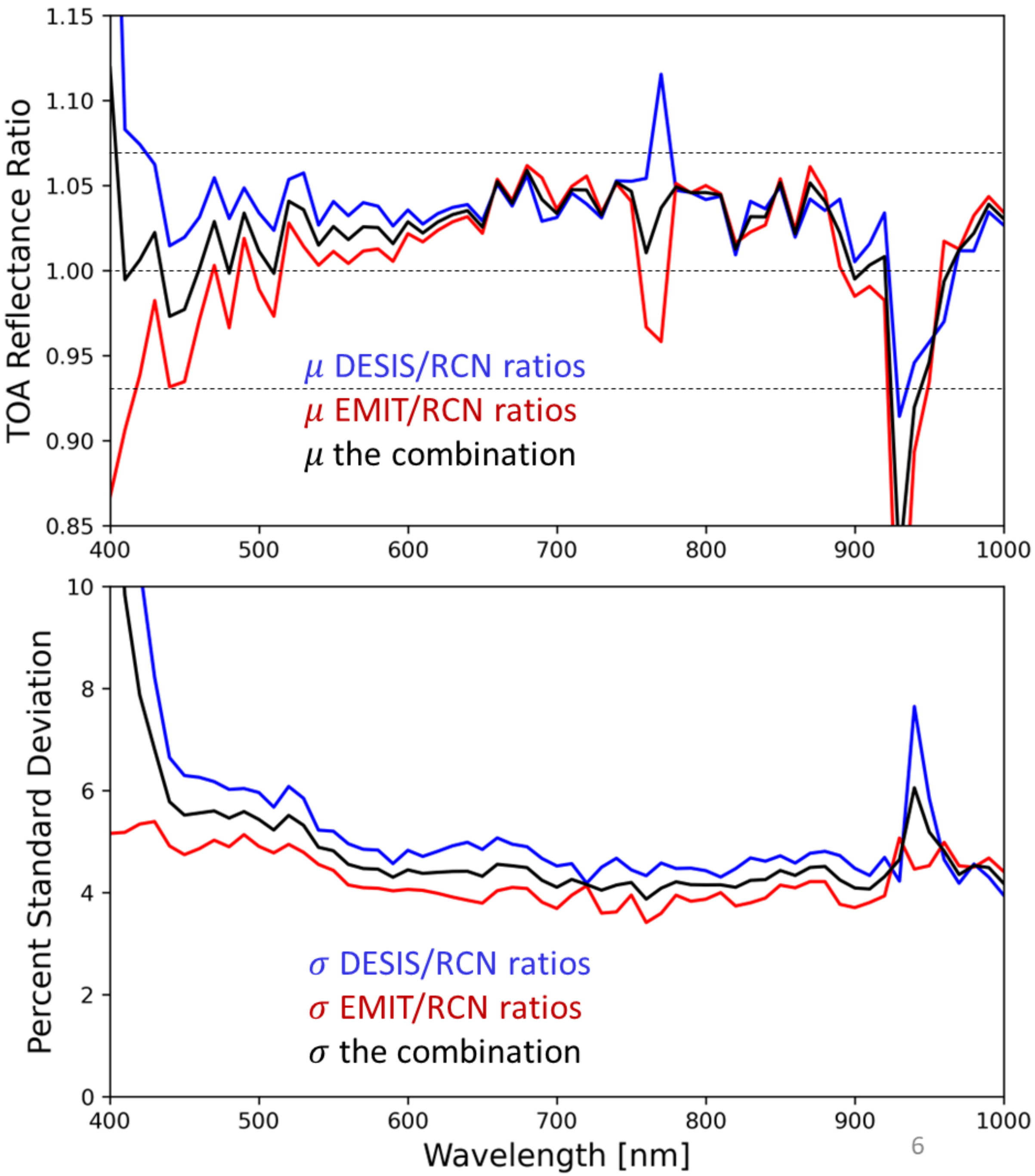


Absolute Intercomparisons

Statistics of Ratios

- 19 coincident views of RVUS ($\Delta t < 15$ min)
  - 15 DESIS scenes and 4 EMIT scenes
- Instruments agree within their combined uncertainty
  - Assumption: flat 5% uncertainty for each of DESIS and EMIT
  - Except $\lambda < 450$ nm and at 760 nm and 940 nm absorption lines.
- Larger spread of the DESIS/RCN ratio is expected
- Better agreement with ground truth when observation is near-nadir and closer to solar-noon





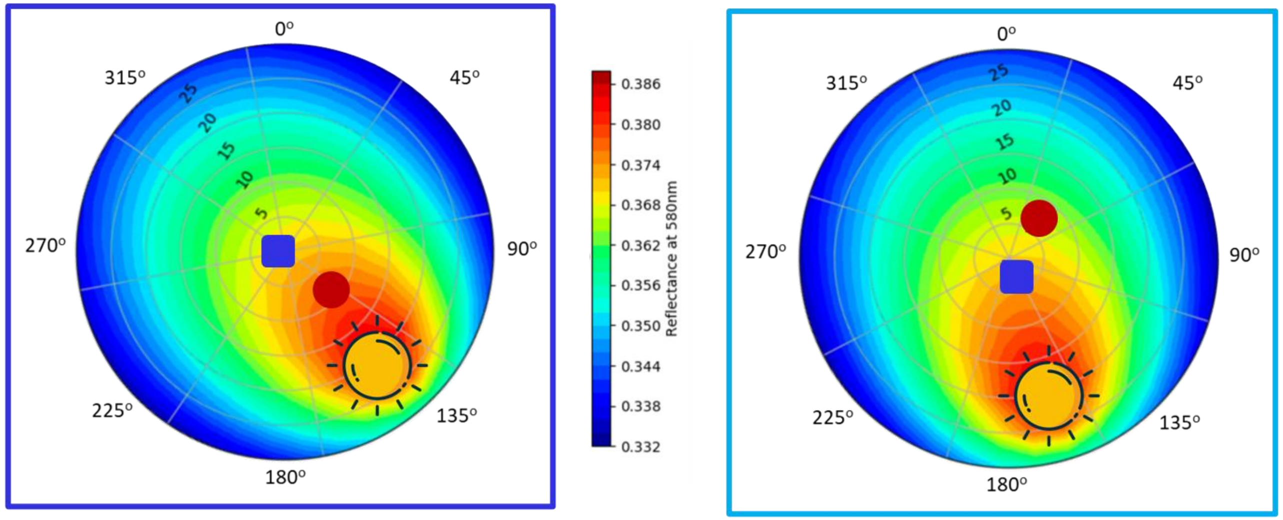
Relative EMIT/DESIS Study

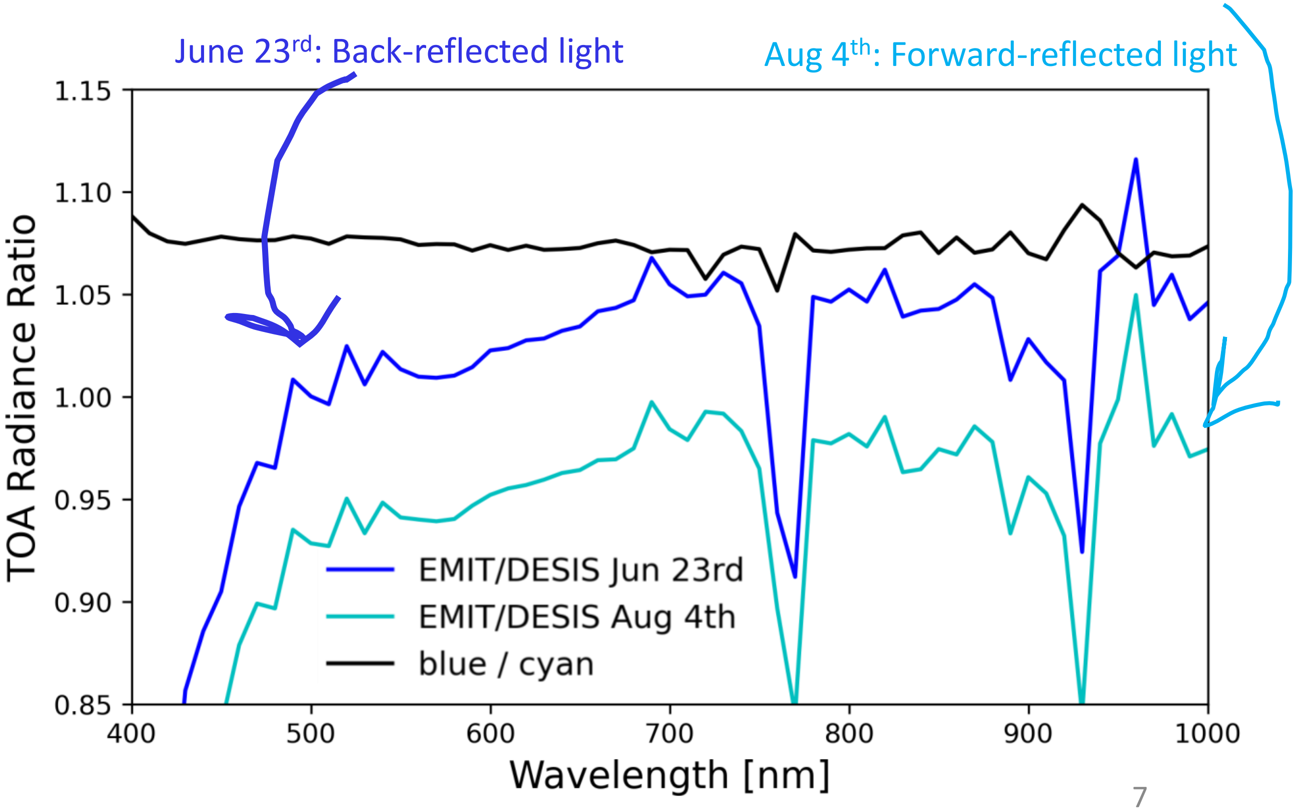
Viewing the Same Source
At Different Angles

- Scenes are captured in 2023, 6 weeks apart
- Spectrally flat 7% BRDF factor for the ratio of the ratios of coincident views
- Validates 2018 Goniometric measurements of the site [Bruegge et al. 2019]

Same	Surface
Similar	Atmospheres
Similar	Time
Same ratio of	Instruments
Different	**Angles**

[BRDF model taken from Bruegge et al. 2019; 10.3390/rs11222601]



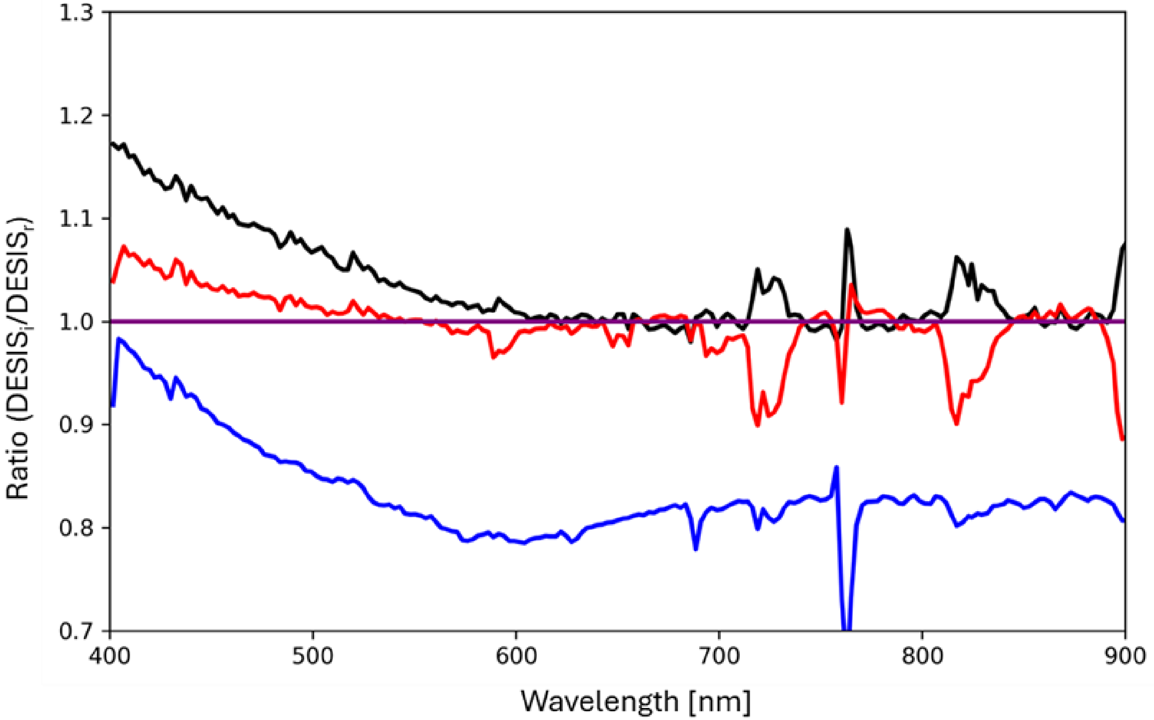


Tahersima et al. “Characterizing Vicarious Calibration Test Sites using Imaging Spectroscopy ”, SPIE 2024 [10.1117/12.3028315]

Relative Short-term Studies

Not using ground truth

- Short-term observations limits the changes in the sensor and the site conditions
  - Isolates BRDF effects
    - But also includes atmospheric effects
  - Large solar zenith angle results in the largest difference in this set
  - Consistent scatter angles with values close to 160 degrees show good agreement

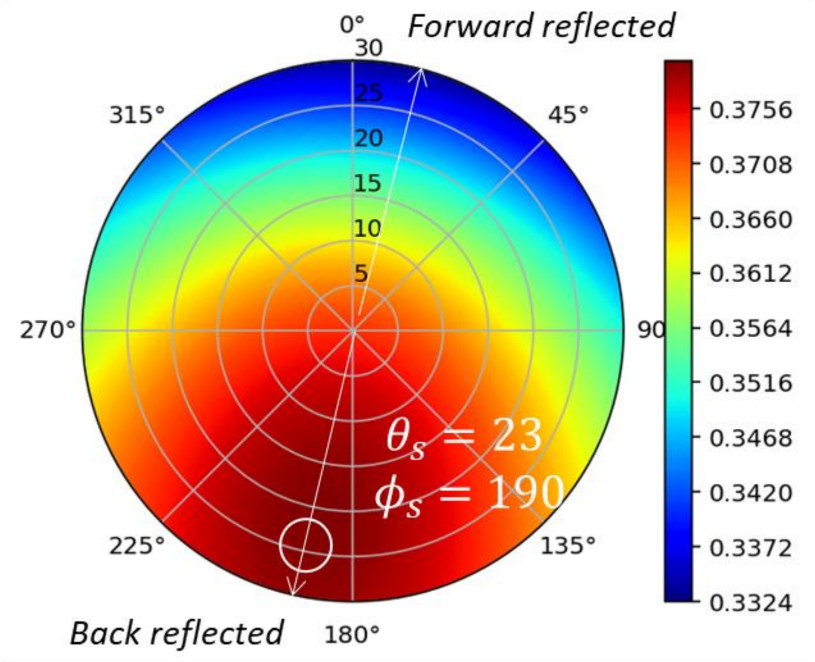


Date	θ_v	θ_s	ϕ_v	ϕ_s	Θ
6/10/2019	7	17	258	154	163
6/14/2019	19	32	333	108	158
6/21/2019	3	62	150	81	117
6/28/2019	3	19	239	140	161

Tahersima et al. “Characterization of the Railroad Valley Playa Test Site using DESIS Imaging Spectrometer from the Space Station Orbit” (In review)

Conclusions

- RadCalNet as a common reference for intercomparison of the radiometric scale of two hyperspectral sensors
- DESIS and EMIT data was used to characterize BRDF effects of the site
  - BRDF model based on the on-orbit sensor data
  - 2018 goniometric measurements of the site remain valid
  - Radiometric data is more sensitive in the forward reflection



θ_v	$\mu_\rho(\theta_v,\phi_v)/\rho(0,0)$ [%]	Max deviation from nadir in forward reflection [%]	Max deviation from nadir in back reflection [%]
5	0.07	1.18	0.77
10	0.30	2.96	1.32
20	1.03	7.25	1.71
30	1.89	10.90	1.53

Outlook

✓ Directional UAV collection of RadCaTS site

✓ In-situ validation using transect ASD collections

➢ Add data from other imaging spectrometers (e.g., PACE, PRISMA, and EnMAP)

➢ Similar approach for the radiometric scales of SBG and CHIME

Thanks to CSDA, JPL, Teledyne, and RadCalNet

1. How many vicarious calibration sites might be needed worldwide to ensure accurate characterization of the radiances and reflectances (L1B and L2 products) returned by spectral imaging missions? And what are the core measurements that should be made at these sites (and uncertainty/performance requirements)?

- The trade-off is between number of sites and how quickly we can reach a desired accuracy. One month of data from four RadCalNet-like sites suffices to reach a 5% accuracy.
- Spectral surface reflectance, AOD, Angstrom, WV column, Ozone column, Temperature, Pressure, and quality flag for surface/atmosphere conditions. Surface reflectance uncertainties close to 3% is desired.

2. What are the main challenges in harmonizing CAL/VAL approaches across different EO missions, sites, and campaigns, and how can these be addressed?

- Challenge: differing levels of adherence to the critical principles like metrology, transparency, and openness.
- Solution: Adherence to the FRM or an FRM-like framework.

3. What is currently missing to carry out holistic and all-encompassing CAL/VAL activities, and how, for example with which innovations, can this be supported?

- Having one or more on-orbit metrological references (SITSats) would enable that vision.

4. How can emerging technologies, such as artificial intelligence and machine learning, be leveraged to improve the accuracy and efficiency of calibration and validation processes?

- Machine learning modelling could be beneficial for anomaly flagging of high temporal resolution calibration data. They could also be used to speed up atmospheric and/or terrestrial correction algorithms.