Reflectance intercomparisons at a RadCalNet site for training and traceability

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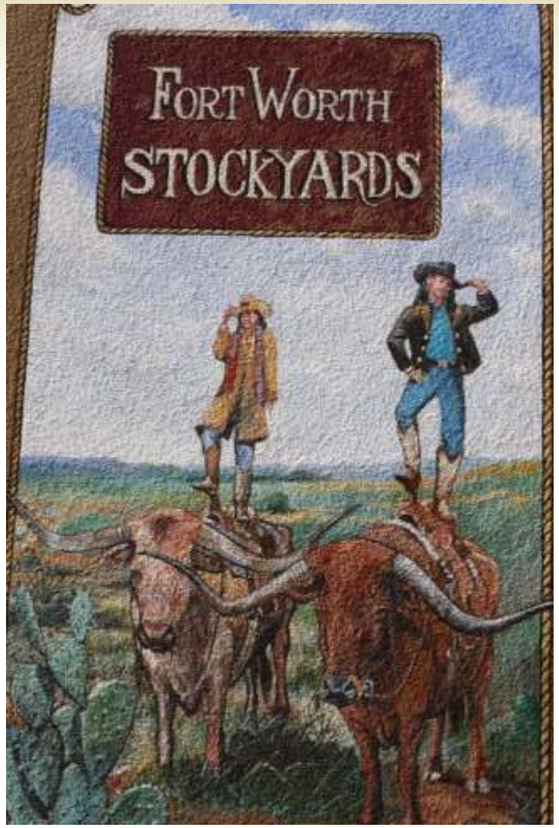
Training course background

Geoscience Spaceborne Imaging Spectroscopy Technical Committee (GSIS TC) within IEEE conducted a training activity in July 2017

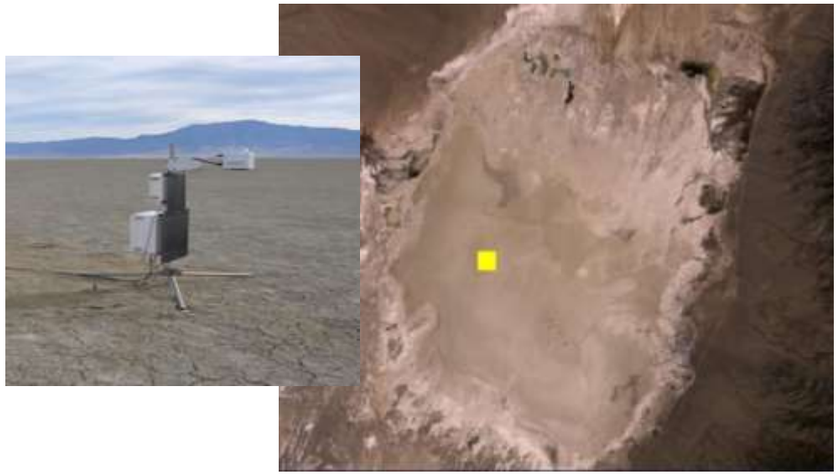


- Follow-on to a successful course at the 2016 IGARSS meeting in Beijing
- Outcome of the original course was that practical experience with field measurements would be beneficial
- Decision made to leverage the 2017 IGARSS locale of Ft. Worth, Texas to do the practicum at Railroad Valley Playa in Nevada

Goals

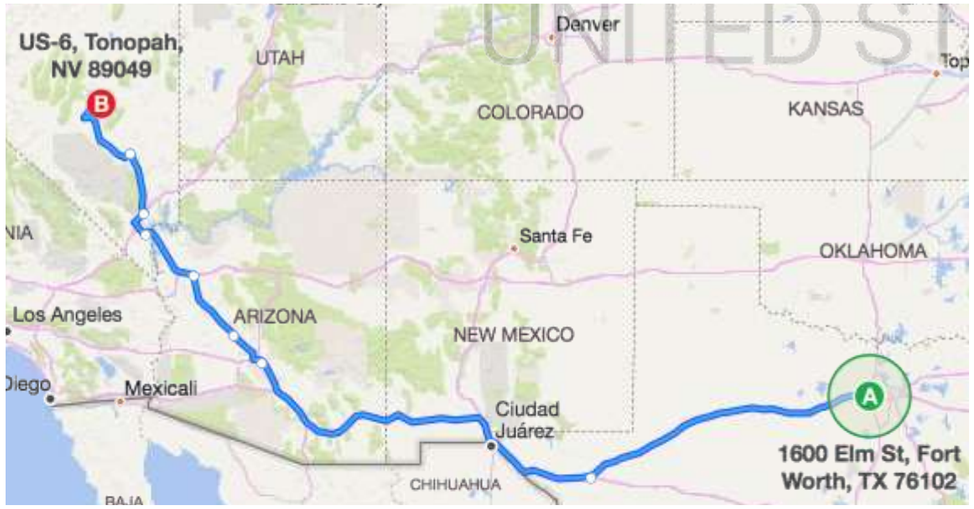
Training for personnel working across various earth observation areas including sensor engineers to calibration scientists

- Visit a CEOS WGCV RadCalNet test site and the associated calibration laboratory for that site
- Demonstrate measurement protocols for surface and atmospheric parameters
  - Concentrate on vicarious calibration of imaging spectrometers
  - Minimize uncertainties
- Perform a reflectance-based calibration of an on-orbit satellite sensor
- Expose the students to >30 hours of old guy road trip music



Railroad Valley Playa, USA

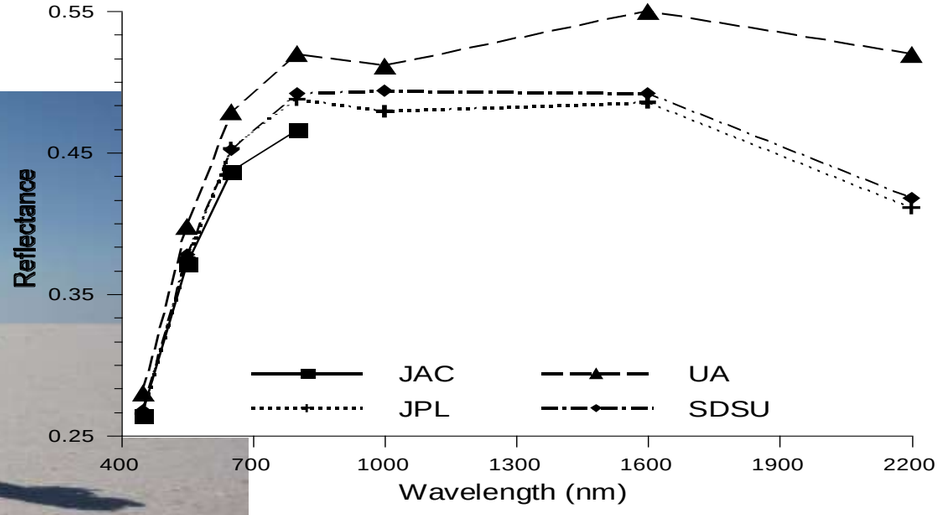
- >20 years working experience on site
- 4 radiometers, sun photometer, met station
- Dry lakebed



Course provided an opportunity

Number of people and availability of equipment allowed for studies of reflectance measurement uncertainties

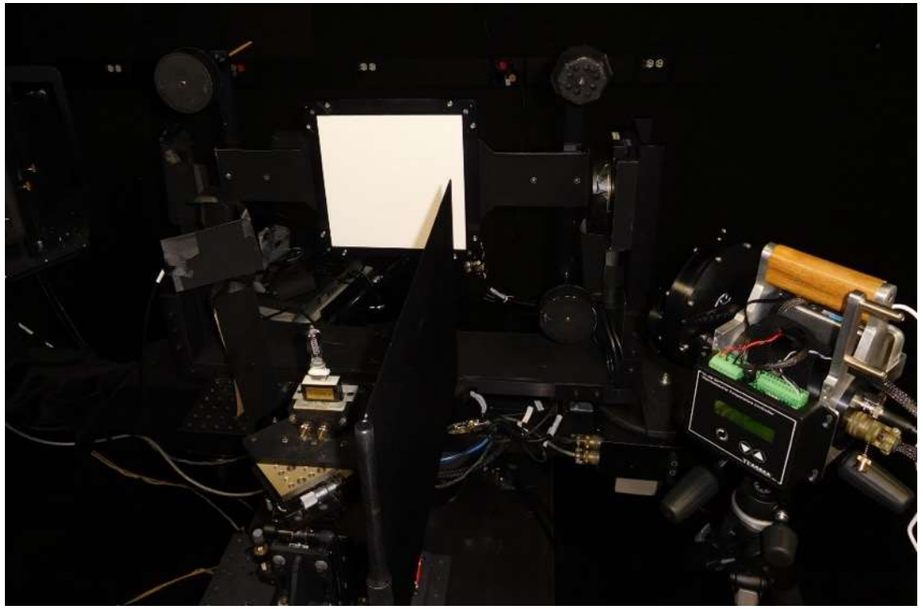
- Surface reflectance inter-comparison similar to past campaigns including those from Lunar Lake 2000 JACIE efforts
- Impacts of spatial and spectral homogeneity of the site being measured
- Approaches to separate instrumental variability from test site variability
- Methods to improve site sampling



Laboratory visit

Exercise included a tour of the optical calibration lab operated by University of Arizona Remote Sensing Group (RSG)

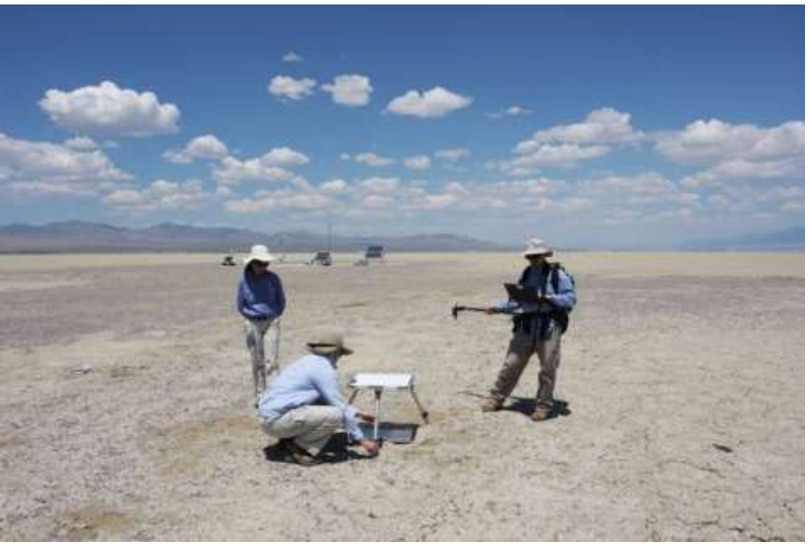
- S. Biggar of RSG described the facilities and led the tour of the group's radiometric calibration facility
- Tutorial put the laboratory measurements into context of the field data
- Also provided a chance to describe the measurement campaign plans



Measurement protocols

Underlying theme of the training course is related to SI-traceable uncertainties within reflectance-based calibration

- Lectures emphasize the development of error budgets and approaches to limit uncertainties
- 2017 Training Course examined uncertainties for reflectance-based vicarious calibration

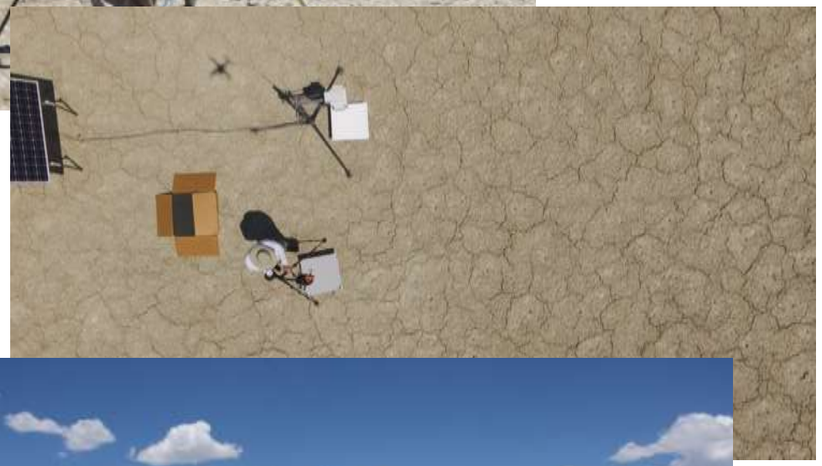


Leveling reference

Alignment to reference

Reference measurement and note taking

Intercomparison study



Two areas were used to evaluate the consistency between retrievals of surface reflectance

- Results would indicate how well the training went
- Also provide insight into uncertainties of the vaalidation of atmospherically-corrected, analysis ready surface reflectance products
- Help evaluate error budgets for Railroad Valley RadCalNet TOA reflectances
- Instrumentation and references were from RSG, thus evaluation of absolute uncertainty was more difficult
  - Did collect data to evaluate two different SI-traceability paths to surface reflectance
  - On-site characterization of RadCalNet radiometers

Repeatability

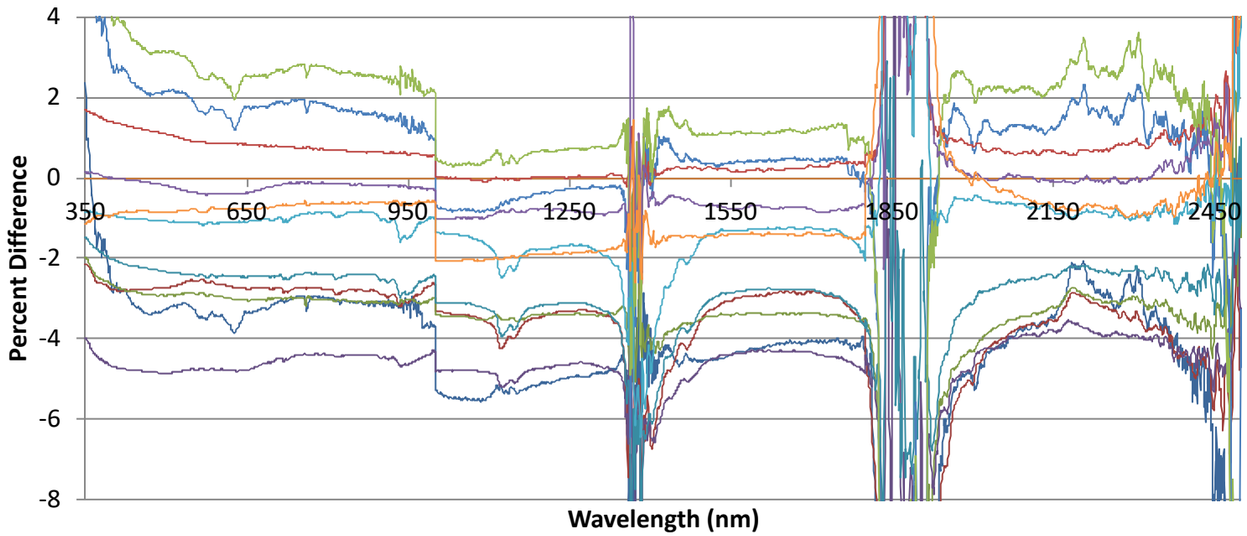
80 m linear transect collected multiple times by each group over multiple times

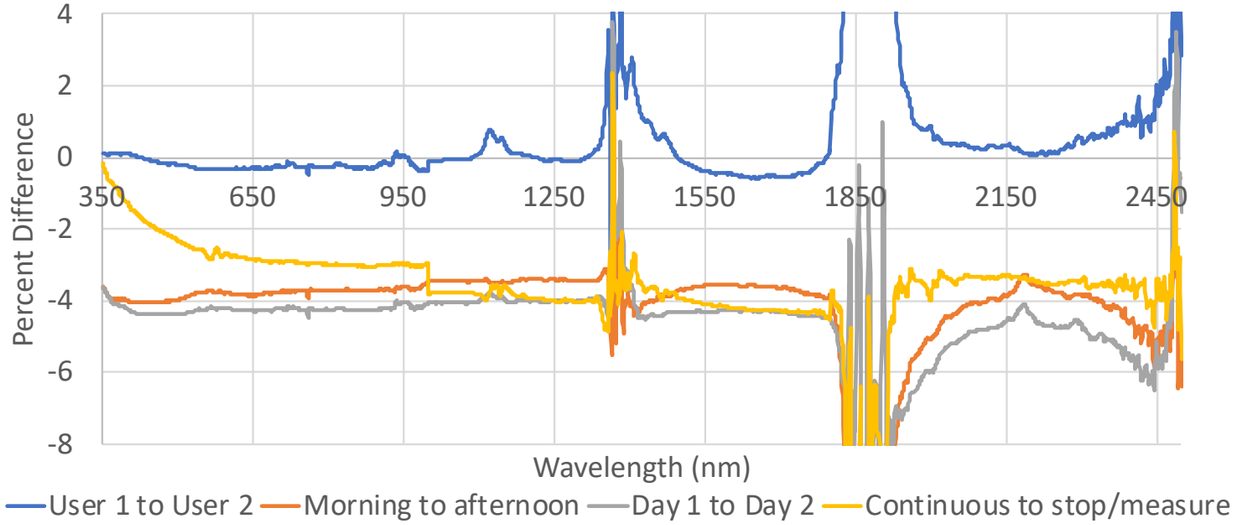
- Three teams of two people
  - Spectroradiometer operator
  - Note taker/spotter/reference panel operator
  - Teams consisted of a mixture of levels of field spectroradiometer experience
- Reference followed by 80-m transect and finish with reference
- Spectra of site collected while walking

Intercomparison Results

12 runs over 3 hours on the first day by 7 operators using 2 spectroradiometers and 2 panels

- Clear skies over sun with some patchy clouds as day progressed and temperatures >37 °C
- ~4% variability in the average reflectance of all runs from July 31
- Instrument dependant variations were seen between the spectroradiometers





Measurement method comparison

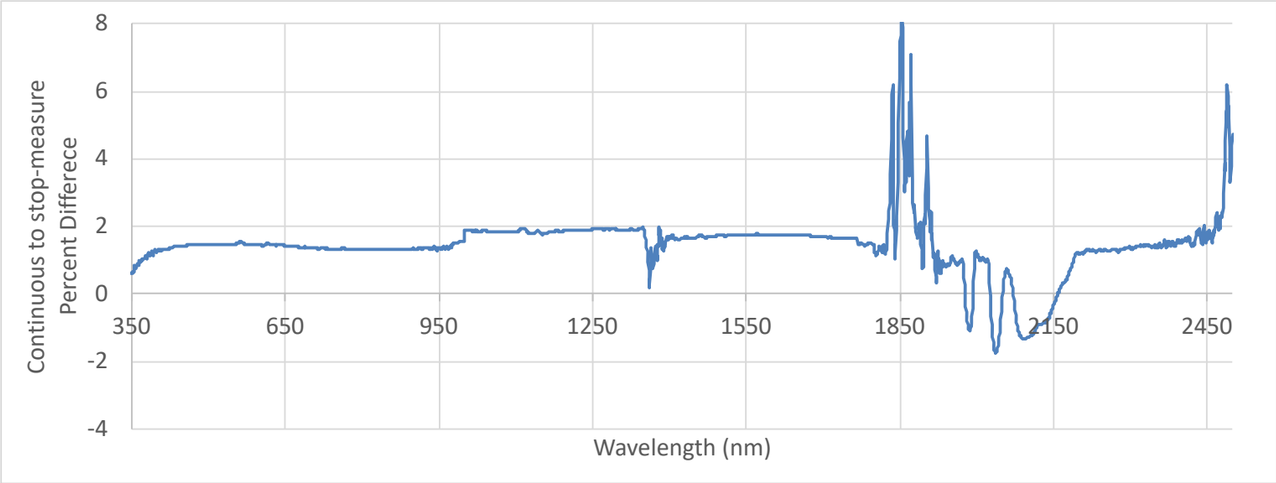
Comparison of the moving collection (continuous) method versus a stop and measure method

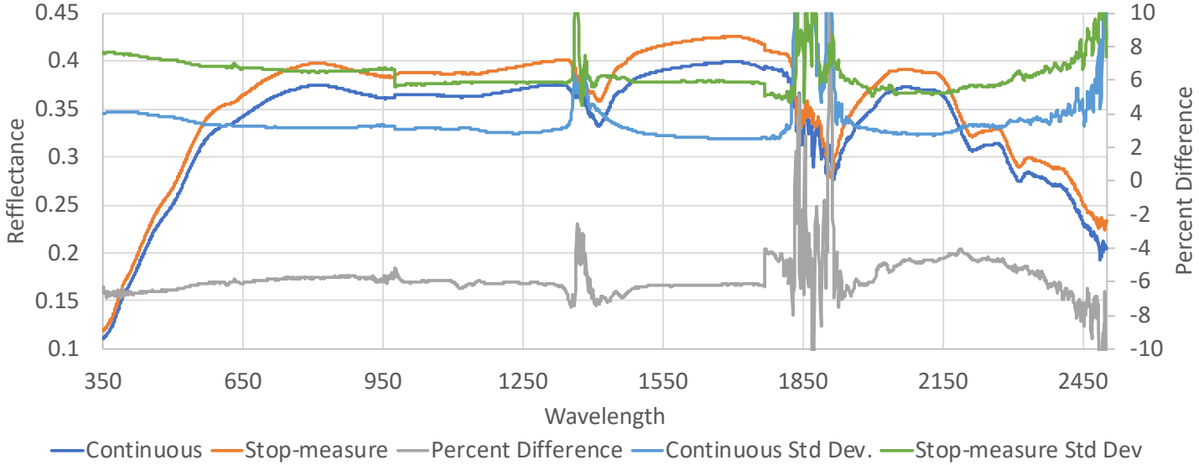
- Collect data at 8 spots on 80-m transect
- Operator collects at while standing stationary
- Panel reference measurement at start and end of each surface measurement
- Minimize impacts of atmosphere, instrument variations
- Drawback is collection samples less area and can take longer to cover site

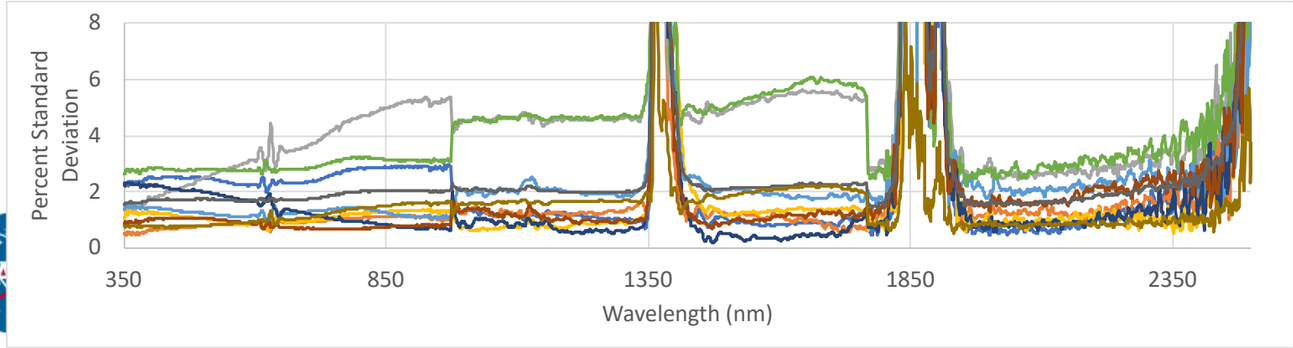
Stop-Measure Results

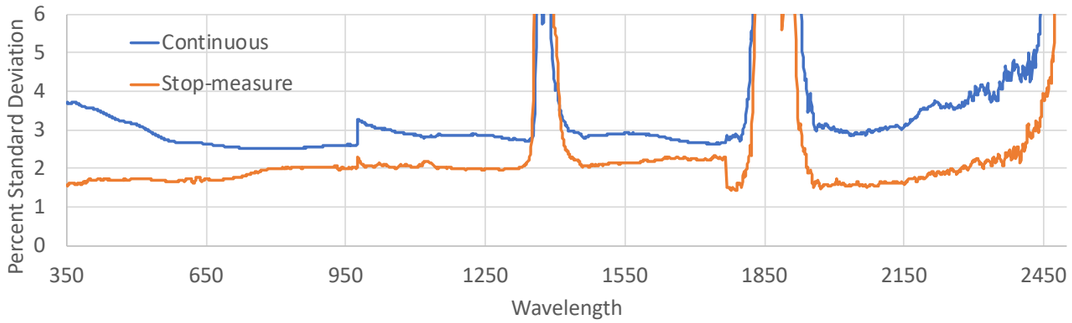
Retrieved reflectance from two different collection approaches within variability of a single collection approach

- Noticeable difference between results of the two sampling strategies
- Standard deviations were typically larger for the stop-measure approach (overall, per sample, averaged per sample)





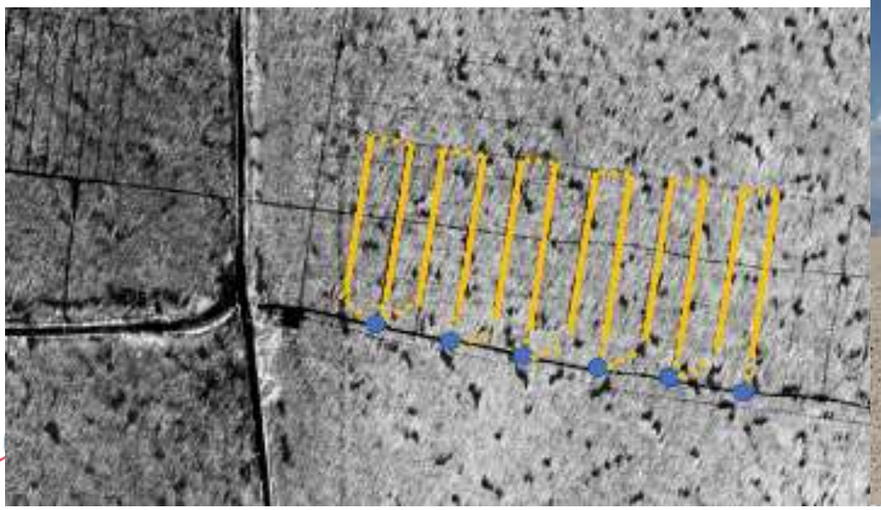


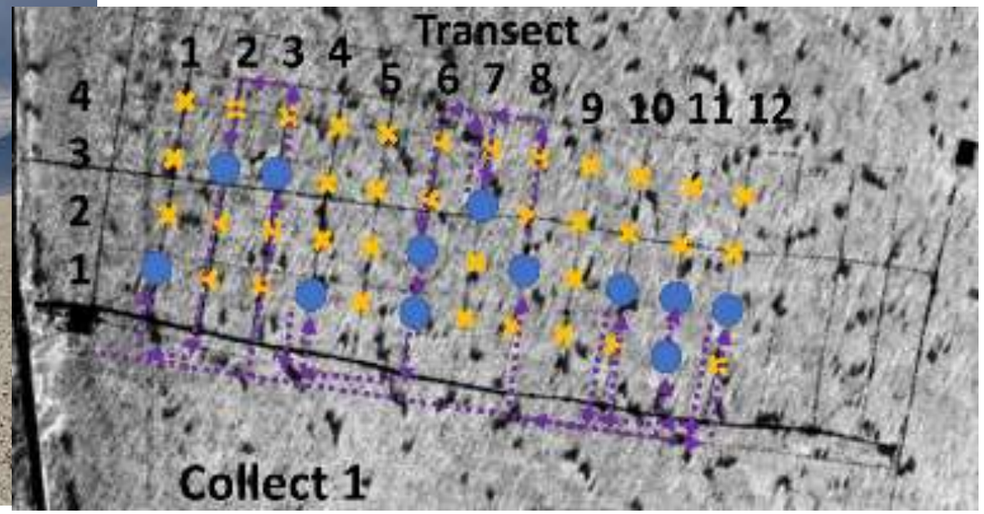


Reflectance-based test site

Sentinel-2a overpass offered an opportunity to evaluate large-site retrievals

- Used continuous sampling and stop-measure sampling approaches
- Transects are 20 m apart over a 240-m x 80-m area
- Reference panel measurement, relocated at the southern end, at the start and every second transect
- Stop-measure relied on 12 random transect locations from the 48 possible

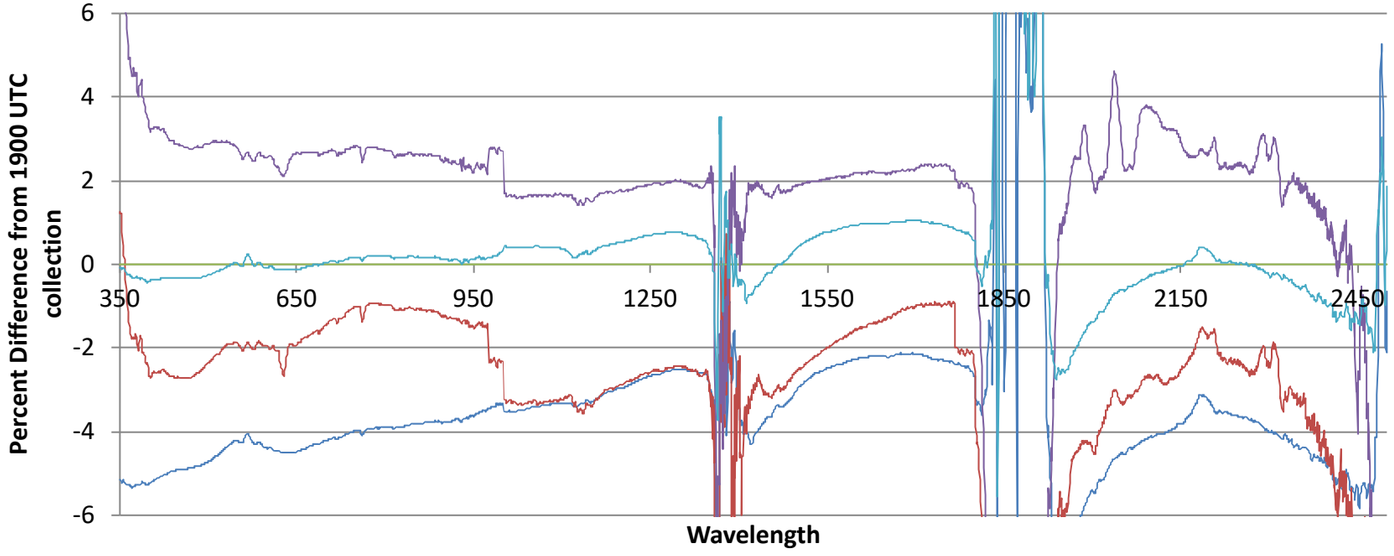


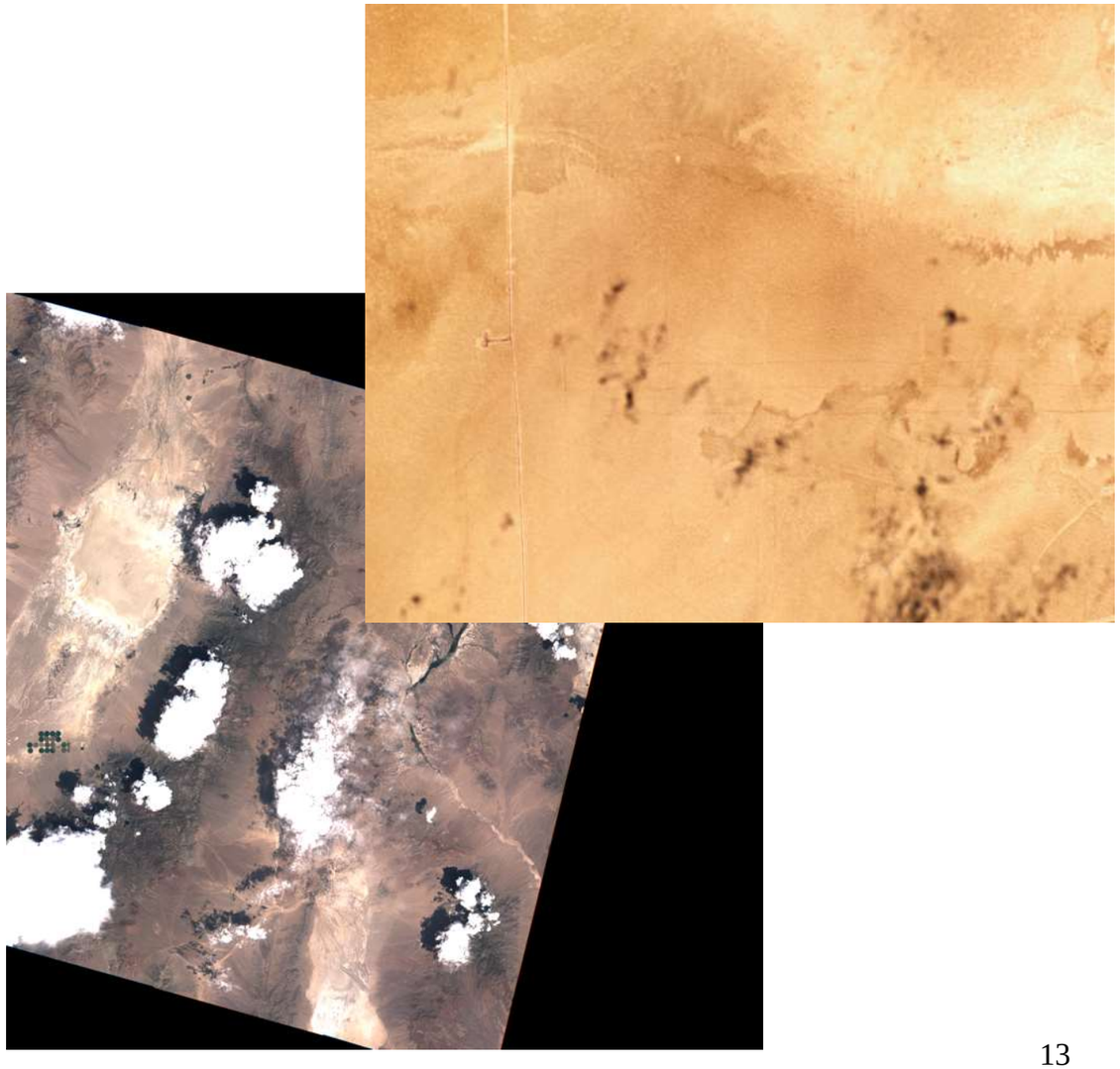


Reflectance-based site results

Cloudiness prevented all operators from collecting and from determining the Sentinel-2A comparison

- Results match with 80-m transect collections
- Results are within typical results of reflectance-based collections

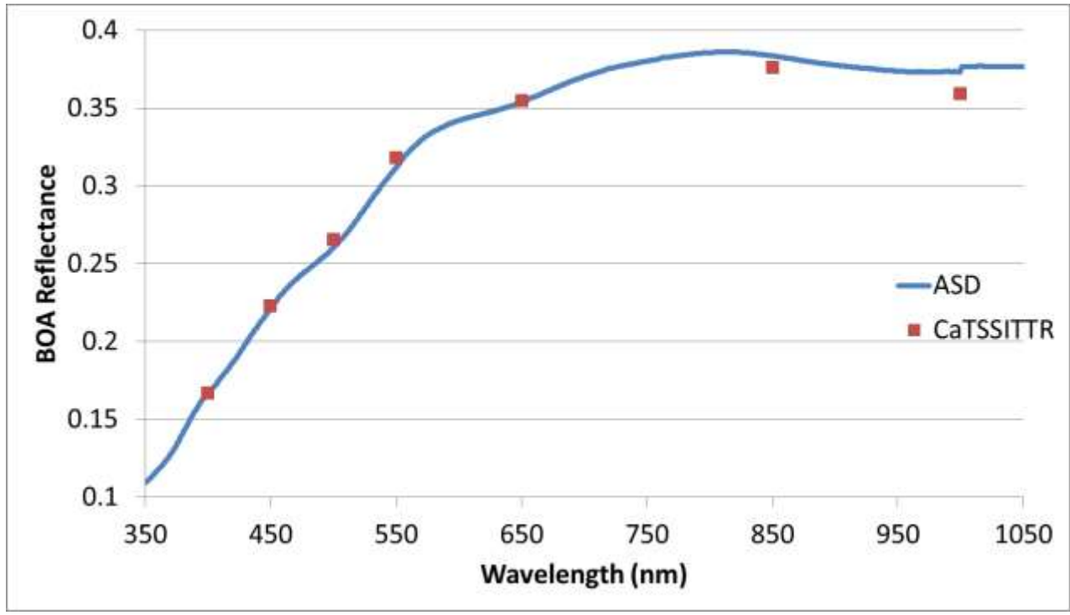


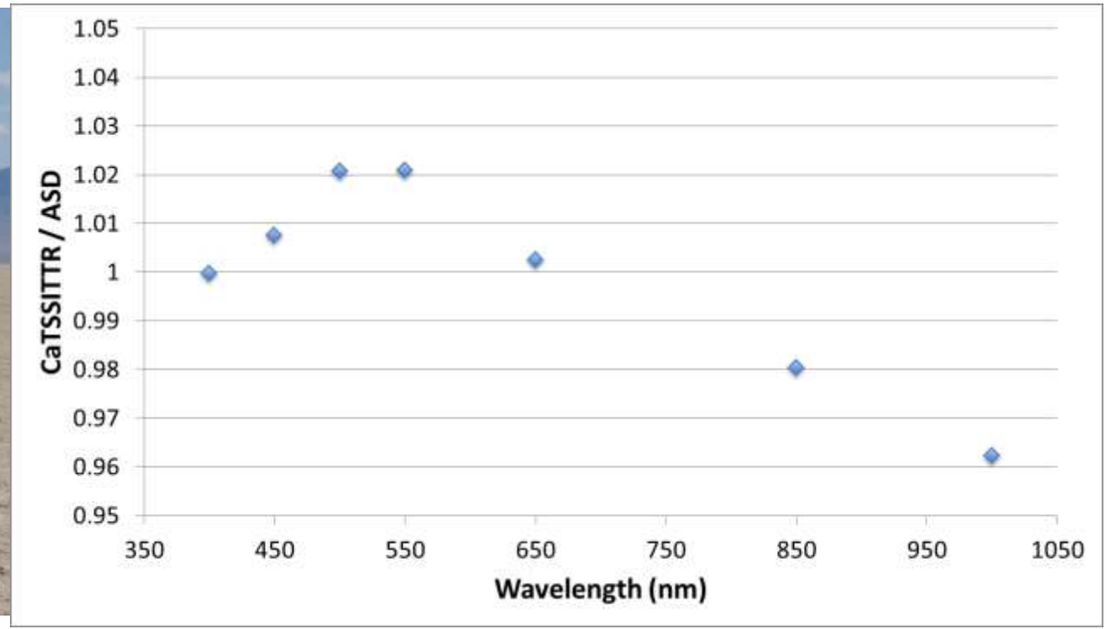


Reflectance- versus radiance-based retrieval

Compared surface reflectance reflectance ratio to absolute radiance measurements

- Near simultaneous collection
- Field spectrometer data converted to reflectance using diffuser
- Radiance data converted to reflectance via radiative transfer code calculations based on measured atmospheric conditions





Was the training successful?

Groups demonstrated that they could retrieve surface reflectance within the uncertainties of the approach

- Results raised further questions
- Variability of the stop and measure approach was larger than continuous sampling
  - Cause is unclear whether it was surface, instrumental, or atmospheric
  - Points to the need for a better sample for Type A uncertainty assessment
- Difference between the continuous results and stop and measure results indicate the need for better site sampling techniques

2018 Joint campaign sought to answer questions from 2017 training

Refine collection approaches and develop a set of guidelines for future intercomparisons and surface reflectance validation

- Four basic collections
  - Reflectance-based calibration of Terra platform sensors
  - 80-m playa transect
  - 60 cm x 60 cm gray tarp sample
  - 60 cm x 60 cm barium sulfate painted panel
- Sky conditions were not the most cooperative
- Intercomparison results still being evaluated

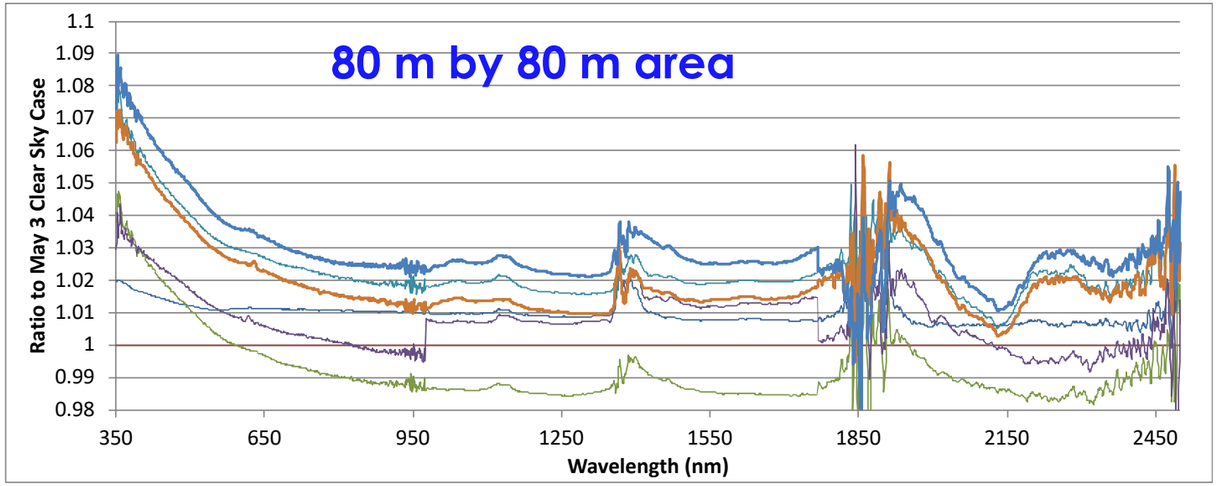


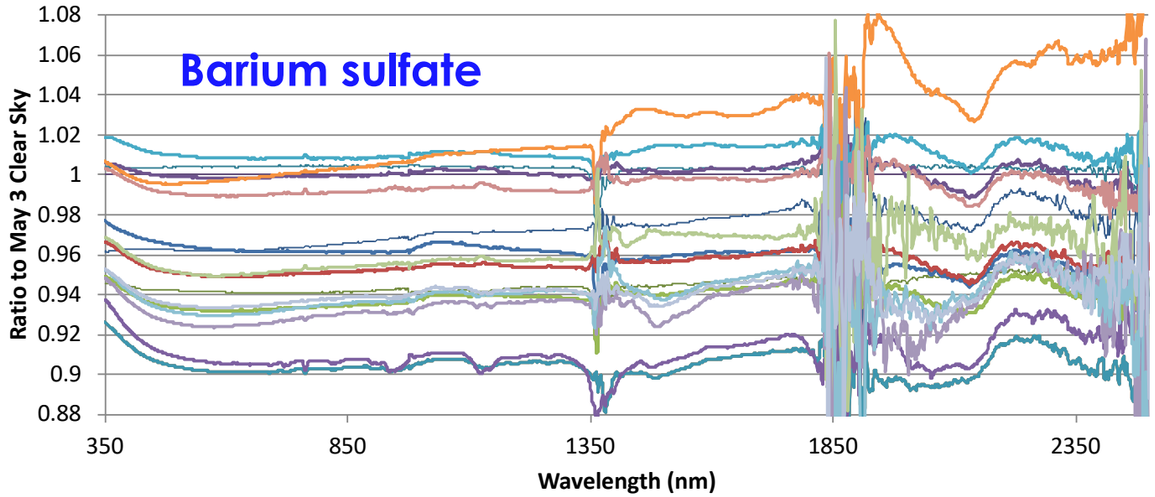


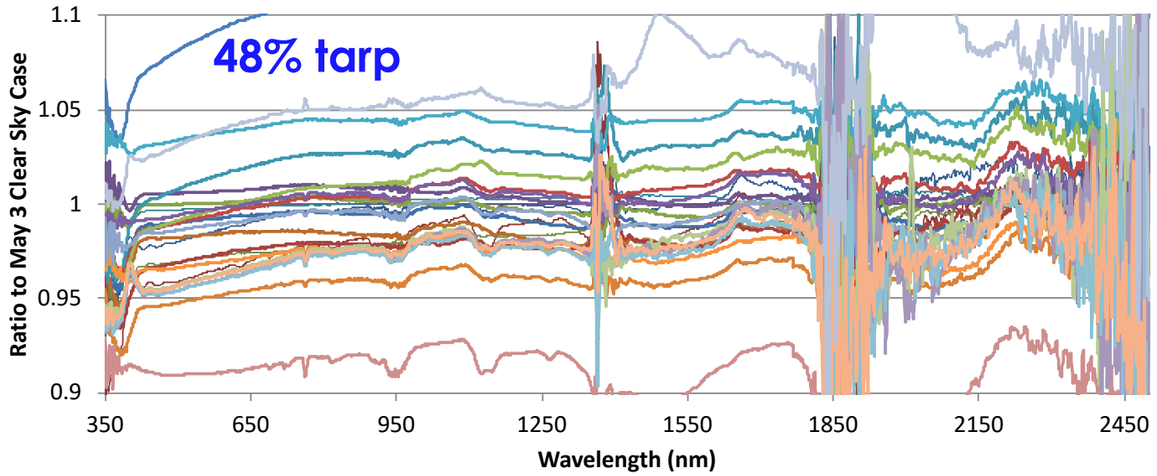
2018 NASA GSFC results

Ratio of retrieved reflectance from NASA GSFC data sets relative to clear-sky, optimal collection for that target

- GSFC results indicate reflectance can be retrieved with better than 5% repeatability regardless of sky conditions
  - Key is representative reference sample
  - Result of near-lambertian samples
  - Will impact experiment designs for surface reflectance validation campaigns







Added measurement from 2017 - Gray tarp

Limiting reflectance collection to a small sample area leads to teams measuring the same area

- Tarp sample measurements will isolate differences caused by the instruments or the reference
  - Effects from from changing solar irradiance are limited because of short time between references and the gray sample
  - Short time between groups limits the BRDF effects of the sample
- Tarp is being evaluated as a traveling standard that would allow intercomparisons without the need for groups to gather in a single location
- One round of collections had all groups using the same reference standard

Added measurement from 2017 - Barium sulfate panel

Barium sulfate has a reflectance similar to those of the reference standard

- Using $BaSO_4$ panel reduces instrument effects such as those caused by non-linearity, lower SNR at lower reflectance, etc.
- Both $BaSO_4$ and gray tarp retrievals can be compared to laboratory-based predictions of reflectance allowing a check on the absolute uncertainty

What we hope to learn from 2017 and 2018

The ensemble of results should help indicate what the limits could be to absolute and relative uncertainties

- Best agreement should be for retrieval of reflectance of $BaSO_4$ panel
  - Highest SNR
  - Uniform sample
  - Rapid data collection
  - Minimal BRDF effects
- Gray sample should give next best results since it is still of a very limited spatial area
  - Lower reflectance could point out SNR or linearity effects
  - Can still be some BRDF and spatial heterogeneity effects
- 80-m transect gives a realistic measurement while limiting area
- Full site measurements evaluated against calibration of an imaging sensor viewing all of the characterized areas

Summary

Training of students during the practicum shows that following protocols leads to repeatability similar to experienced groups

- Previous work shows absolute uncertainties are dominated by reflectance standard uncertainty as show
- Still unclear what dominates the lack of repeatability
- Methods to isolate Type A uncertainties need development
  - Small, stable samples
  - Stable mounting of spectrometer relative to small sample
- Stop and measure approach should limit uncertainties from variability in spectrometer and atmosphere
- Need to implement more rigorous evaluations of temporal and spatial sampling approaches

Acknowledgements

- Thank you to IEEE Geoscience & Remote Sensing Society and the Geoscience Spaceborne Imaging Spectroscopy (GSIS) Technical Committee
- Thank you to the University of Arizona for access to their laboratory and test site
  - http://www.grss-ieee.org/hyperspectral-calval-workshop-2/
  - http://www.grss-ieee.org/hyperspectral-calval-field-practicum/