SHIFT: Pseudo-invariant Targets, ASD Field Spectrometer Measurements, 2022

Get Data

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Dataset Version: 1

Summary

This dataset provides biweekly surface reflectance measurements of pseudo-invariant sites at Sedgwick Reserve, Santa Barbara, California, collected with an ASD FieldSpec Pro field spectrometer during the SBG High-Frequency Time-Series (SHIFT) campaign in Spring and Fall 2022. The dataset includes measurements of seven primary spatially-homogenous, temporally pseudo-invariant sites (three areas of gravel road, two dirt paddocks, two serpentinite outcrops); one spatially-homogenous, temporally variable site (vegetated meadow); component measurements of three pseudo-invariant sites with high spatial resolution features (a tennis court, a road and its surroundings, and a Y-intersection and its surroundings); and additional temporally transient targets (a car roof). These measurements were taken every two weeks and were made on the same day as the AVIRIS-NG overflights. Atmospheric measurements were also taken with a MicroTops sun photometer at the serpentinite outcrop site. The data are provided in comma separated values (CSV), JPEG image, and GeoJSON formats along with Python processing code.

The dataset holds 52 files: three files in comma separated values (CSV) format, 24 GeoJSONs, 24 JPEG images, and one zip archive holding raw data and Python processing code.

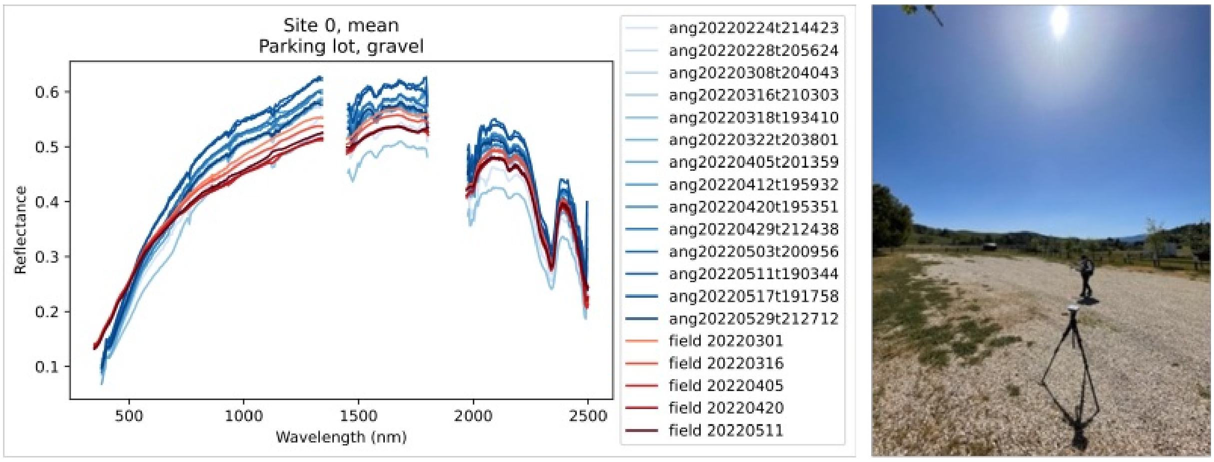

Figure 1. (Left) Spectra from gravel parking lot taken with ASD field spectrometer (red, this dataset) and from AVIRIS-NG L2A surface reflectance (blue, doi.org/10.3334/ORNLDAAC/2183) from February through May 2022. (Right) Picture of ASD field spectrometer in use at the gravel parking lot.

Citation

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Table of Contents

1. Dataset Overview

This dataset provides biweekly surface reflectance measurements of pseudo-invariant sites at Sedgwick Reserve, Santa Barbara, California, collected with an ASD FieldSpec Pro field spectrometer during the SBG High-Frequency Time-Series (SHIFT) campaign in Spring and Fall 2022. The dataset includes measurements of seven primary spatially-homogenous, temporally pseudo-invariant sites (three areas of gravel road, two dirt paddocks, two serpentinite outcrops); one spatially-homogenous, temporally variable site (vegetated meadow); component measurements of three pseudo-invariant sites with high spatial resolution features (a tennis court, a road and its surroundings, and a Y-intersection and its surroundings); and additional temporally transient targets (a car roof). These measurements were taken every two weeks and were made on the same day as the AVIRIS-NG overflights. Atmospheric measurements were also taken with a MicroTops sun photometer at the serpentinite outcrop site.

Project: SBG High Frequency Time Series (SHIFT)

The Surface Biology and Geology (SBG) High Frequency Time Series (SHIFT) was an airborne and field campaign during February to May, 2022, with a follow up activity for one week in September, in support of NASA's SBG mission. Its study area included a 640-square-mile (1,656-square-kilometer) area in Santa Barbara County and the coastal Pacific waters. The primary goal of the SHIFT campaign was to collect a repeated dense time series of airborne Visible to ShortWave Infrared (VSWIR) airborne imaging spectroscopy data with coincident field measurements in both inland terrestrial and coastal aquatic areas, supported in part by a broad team of research collaborators at academic institutions. The SHIFT campaign leveraged NASA's Airborne Visible-Infrared Imaging Spectrometer-Next Generation (AVIRIS-NG) facility instrument to collect approximately weekly VSWIR imagery across the study area. The SHIFT campaign 1) enables the NASA SBG team to conduct traceability analyses related to the science value of VSWIR revisit without relying on multispectral proxies, 2) enables testing algorithms for consistent performance over seasonal time scales and end-to-end workflows including community distribution, and 3) provides early adoption test cases to SHIFT application users and incubate relationships with basic and applied science partners at the University of California Santa Barbara Sedgwick Reserve and The Nature Conservancy's Jack and Laura Dangermond Preserve.

Acknowledgement

The SHIFT project is jointly led by NASA's Jet Propulsion Laboratory, The Nature Conservancy, and the University of California, Santa Barbara (UCSB). This research was funded by the NASA Earth Science Division. The research was carried out at the Jet Propulsion Laboratory, California Institute of Technology, under a contract with the National Aeronautics and Space Administration (80NM0018D0004).

2. Data Characteristics

Spatial Coverage: Sedgwick Reserve, Santa Barbara County, California, USA

Spatial Resolution: Point measurements

Temporal Coverage: 2022-03-01 to 2022-09-15

Temporal Resolution: Bi-weekly

Site Boundaries: Latitude and longitude are given in decimal degrees.

Site	Westernmost Longitude	Easternmost Longitude	Northernmost Latitude	Southernmost Latitude
Sedgwick Reserve, Santa Barbara County, California	-120.044	-120.0398	34.7430	34.6879

Data File Information

The dataset holds 52 files: three files in comma separated values (CSV) format, 24 GeoJSONs, 24 JPEG images, and one zip archive holding raw data and Python processing code.

SHIFT_2022_invarianttargets_asd_data.csv holds processed surface reflectance data from the ASD field spectrometer (Table 1).
SHIFT_2022_invarianttargets_microtops_data.csv holds measurements of aerosol optical depth from the MicroTops sun photometer (Table 2).
SHIFT_2022_invarianttargets_site_descriptions.csv holds site characteristics and locations (Table 3).

The GeoJSON files hold polygons outlining the location of the invariant target sites. The file naming convention is **SHIFT_invariatetargets_polygon_site***<XX>***.json**, where *<XX>* is the site identifier that corresponds to the "site_id" field in the CSV files. These GeoJSONs hold geographic coordinates based on WGS 84 datum (EPSG: 4326).

The JPEG images hold photographs to illustrate site characteristics. The file naming convention is **SHIFT_invariatetargets_site***<XX>_<YYYYMMDD>***.jpg**, where *<XX>* is the site identifier (multiple sites may be listed) and *<YYYYMMDD>* (*YYYY* = year, *MM* = month, *DD* = day) is the date of the photograph.

SHIFT_2022_invarianttargets_rawdata.zip holds raw data from the ASD spectrometer and processing code in Python language. The folder structure within the zip archive is important to the operation of the processing code.
The raw ASD data are stored in separate folders inside the zip file, named by day with the convention *YYYYMMDD*. The raw ASD data files follow the naming convention ***<A>_site<XX>_<B>_<ZZZZZ>.asd***, where

- <A> identifies the campaign ("SHIFT") or date
- <XX> is the site ID for the site
- <B> is a description of the site
- <ZZZZZ> is the measurement number, starting from 00000 for each site.

The processing code is inside the "processing_code" folder and includes these files:

- *process_shift_asd_files.py*: Top-level processing script. Executing this script on the command line will process the raw data to reproduce the ASD data file (*SHIFT_2022_invarianttargets_asd_data.csv*).
- *process_asd_files.py*: Called to process each *YYYYMMDD* date folder containing the raw data files (*.asd).
- *asdprocessor.py*: Contains field spectrometer processing functions.
- *asdreader.py*: Reads raw *.asd files into python.
- *asd_jump_correction.py*: Performs either "hueni" (Hueni and Bialek, 2017) or "asdparabolic" (ASD, 2016) jump correction at the ASD boundary between spectrometers at 1000 nm and 1800 nm.
- *correction_data/asd_temp_corr_coeffs.mat*: Correction coefficients used for "hueni" jump correction algorithm.
- *correction_data/spectralon_rfl.txt*: Known smooth spectralon reflectance used for surface reflectance processing.

The processing code is run by executing: "python process_shift_asd_files.py"

Table 1. Variables in *SHIFT_2022_invarianttargets_asd_data.csv*.

Variable	Units	Description

unique_id	-	Unique id of the measurement with format <YYYYMMDD>t<hhmmss>_site<XX>_<ZZZZ>, where <YYYYMMDD> and <hhmmss> identify the UTC date and time, respectively, <XX> is the site ID, and <ZZZZ> is the measurement number at the site, starting at 0000
latitude	degrees north	Average latitude of site in decimal degrees
longitude	degrees east	Average longitude of site in decimal degrees
site_id	-	Site ID number
site_description	-	Short site description
location_name	-	Overall location name
date_utc	YYYY-MM-DD	UTC date of measurement
time_utc	hh:mm:ss	UTC time of measurement
instrument	-	Instrument name
instrument_num	-	Instrument serial number
foreoptic_degrees	degrees	Field of view of the foreoptic
measurement_type	-	Measurement type
light_source	-	Light source
weather_conditions	-	Weather conditions
target_type	-	Target type (gravel, rock, vegetation, etc)
target_distance_m	m	Distance from instrument to target in meters
target_picture	-	Whether a photograph of the target exists (yes/no)
microtops_data	-	Whether contemporaneous MicroTops sun photometer data is available (yes/no)
processing_jump_correction	-	ASD jump correction algorithm that was used (“hueni” or “asdparabolic”)
processing_averaged	-	Whether the measurements at site were averaged during processing (yes/no)
processing_white_ref_interpolation	-	Type of interpolation was used on the white references during processing (linear, none, etc)
350, ..., 2500 (2151 columns)	1	2151 fields holding surface reflectance values. Columns are named by the wavelength in nanometers (nm).

Table 2. Variables in *SHIFT_2022_invarianttargets_microtops_data.csv*.

Variable	Units	Description
unique_id	-	Unique id of the measurement with format <YYYYMMDD>t<hhmmss>_site<XX>_<ZZZZ>, where <YYYYMMDD> and <hhmmss> identify the UTC date and time, respectively, <XX> is the site ID, and <ZZZZ> is the measurement number at the site, starting at 0000
site_id	-	Site ID number
instrument	-	Instrument name
SN	-	Instrument serial number
date_utc	YYYY-MM-DD	UTC date of measurement
time_utc	hh:mm:ss	UTC time of measurement
site_desc	-	Short site description
location	-	Overall location name
latitude	degrees north	Latitude of measurement in decimal degrees
longitude	degrees east	Longitude of measurement in decimal degrees
altitude	m	Altitude of measurement in meters above mean sea level
pressure	mB	Measured atmospheric pressure in milliBars
SZA	degrees	Solar zenith angle (0 degrees for overhead)
AM	1	Air mass (unitless ratio)
SDCORR	1	Factor accounting for earth-to-sun distance
temp_optblk	C	Temperature of optical block inside the instrument
ID	-	User adjustable number of each scan

SIG380, SIG440, SIG500, SIG675, SIG870	mV	Signals from optical channels for five wavelengths: 380, 440, 500, 675, and 870 nm (five columns)
STD380, STD440, STD500, STD675, STD870	1	Standard deviation of ratios between channels (see next line in this table) for five wavelengths
R380_440, R440_500, R500_675, R675_870	1	Ratio of signals wavelengths. For example, R380_440 is the ratio of the signals from wavelength 380 nm and wavelength 440 nm.
AOT380, AOT440, AOT500, AOT675, AOT870	1	Aerosol optical depth for five wavelengths
WATER	cm	Precipitable water column in cm
LNV01, LNV02, LNV03, LNV04, LNV05, C1, C2, C3, C4, C5, K, B, C, POFFS, PSCALE	1	Instrument calibration coefficients (15 columns). See Solar Light (2001) for more information.

Table 3. Variables in *SHIFT_2022_invarianttargets_site_descriptions.csv*.

Variable	Units	Description
site_id	-	Site ID number
description	-	Short site description
latitude	degrees north	Average latitude of site in decimal degrees
longitude	degrees east	Average longitude of site in decimal degrees
target_type	-	Target type (gravel, rock, vegetation, etc)
polygon_file_name	-	Name of GeoJSON polygon file

3. Application and Derivation

Current and future orbital imaging spectrometers will acquire data across the globe, spanning a diverse range atmospheric and surface conditions. Validating the accuracy of surface reflectance retrievals for these spectrometers is critical for quantifying the measurement uncertainty in downstream scientific applications. Currently, validation efforts rely on field teams who face the daunting task of measuring in situ spectra with a field spectrometer over the large sampling footprints of current and planned instruments. Consequently, this validation method is biased towards easily accessible and measurable regions, leading to systematic biases. Recent work has proposed using scene invariants, or sites with stable spectra over time, as an extendible, data-driven approach to bound the uncertainty of surface reflectance retrievals (Thompson et al., 2021). However, further investigation into the stability of such "invariant targets" is required to understand what surfaces can be expected to be invariant, the scale of any variation in these targets, and the timescale for any spectral changes.

The SBG High-Frequency Time-Series (SHIFT) campaign provided an opportunity to investigate the use of scene invariants. The AVIRIS-NG flew over an area near Santa Barbara, CA, USA on a weekly basis from February through May 2022 for this campaign. Seven pseudo-invariant sites were identified (Table 4), which were at least three AVIRIS-NG pixels on a side and included three large sections of gravel road, two dirt paddocks, and two large serpentinite outcrops. The pseudo-invariant sites were measured with an ASD field spectrometer five times over the 13-week spring 2022 SHIFT campaign and once in the fall 2022 SHIFT reprise. These field measurements were all captured within two hours of the AVIRIS-NG overflight of the SHIFT area, except for the March 1, 2022 data, which was a day after the AVIRIS-NG flights.

Three additional sets of sites were measured to explore invariant targets where the surface features were smaller than the spatial sampling of the AVIRIS-NG instrument, resulting in mixed pixels. These sets of sites included a blue tennis court area; a gravel road and its adjacent vegetated roadsides; and a gravel road fork with its adjacent vegetated roadsides. The tennis court area was measured five times in the spring 2022 campaign, and once in the fall 2022 campaign. The gravel road and gravel road Y-intersection were measured on a subset of days.

In order to compare with the surface and atmospheric retrieval from AVIRIS-NG, MicroTops II sun photometer data were captured at the large serpentinite outcrop site (site 9) for each day where the field data was within 2 hours of the AVIRIS-NG overflight (i.e, all days except March 1, 2022). MicroTops II sun photometer data was also captured at the gravel road site (site 0) on September 15, 2022. The sun photometer data provides a measurement of aerosol optical depth at 500 nm which is comparable to the aerosol optical depth at 550 nm retrieved in the AVIRIS-NG surface and atmospheric retrieval algorithm with the ISOFIT code base. These data can be used to validate the AVIRIS-NG retrievals of both surface reflectance and atmospheric parameters.

4. Quality Assessment

Field spectrometer data consists of capturing two quantities: the signal reflected by a known spectralon white reference panel, s_{ref}, and the signal reflected by the target surface, s_{target}, all to determine the surface reflectance of the target by a known spectralon white reference panel, s_{ref}, and the signal reflected by the target surface, s_{target}, all to determine the surface reflectance of the target (ρ_{target})

$$s_{ref} = \rho_{ref} L_{down}$$
$$s_{target} = \rho_{target} L_{down}$$
$$\rho_{target} = \frac{s_{target}}{L_{down}} = \frac{s_{target}}{s_{ref}} \rho_{ref}$$

where ρ_{ref} is the known surface reflectance of the spectralon white reference panel and L_{down} is the downwelling radiance from the sun. Thus, quality assessment must deal with the quality of the target and reference spectrometer measurements and the assumption that the downwelling solar radiance did not change between the measurements of the target and the reference (i.e., how variable the atmosphere was on the relevant capture timescales).

To assess this, multiple sets of spectra of the white reference panel were captured at approximately two-minute intervals, interleaved with measurements of the target. Using these multiple captures, the variability of the atmosphere in the field was assessed. If the atmosphere showed more variability in the field, white reference spectra was captured more often to reduce the effects on the final surface reflectance. In addition, many measurements of each target site were captured to allow outlier rejection, in the case where the operator's shadow or the white reference panel were accidentally included as part of an averaged measurement. This statistical population allowed calculating the standard deviation of the surface reflectance at each site. While the sites were not completely homogenous due to point-to-point variation and vegetation growth, standard deviations below 10% of the average surface reflectance for each site provided confidence in the quality of the data.

Similarly, multiple MicroTops sun photometer measurements per set were captured. Data with null values were removed. For the remaining data, the repeatability of measurements within a short time frame provided confidence in the data quality. As this data was captured within 2 hours and not synchronously with the AVIRIS-NG overflight, however, the measured aerosol optical depth values are not expected to provide an exact match for the retrieved values from AVIRIS-NG.

5. Data Acquisition, Materials, and Methods

ASD visible to short-wave infrared (VSWIR) field spectrometer data were measured for various homogenous target sites six times during the SHIFT campaign. All measurements except for those taken March 1, 2022 were captured within two hours of corresponding AVIRIS-NG overflights, which provide retrieved surface reflectance and atmospheric parameters from top-of-atmosphere VSWIR radiance. In addition, atmospheric parameters including aerosol optical depth (AOD) were measured with a MicroTops II sun photometer on all days except March 1, 2022. The timeline of these measurements during the overall SHIFT campaign context are shown in Figure 2. These measurements were intended to validate the surface reflectance and atmospheric parameters retrieved from the AVIRIS-NG measurements. In addition, these measurements were of pseudo-invariant sites that were expected to not vary over the course of the campaign (i.e., gravel, rock, and dirt surfaces). These in situ measurements were used to determine how invariant these surfaces were over time.

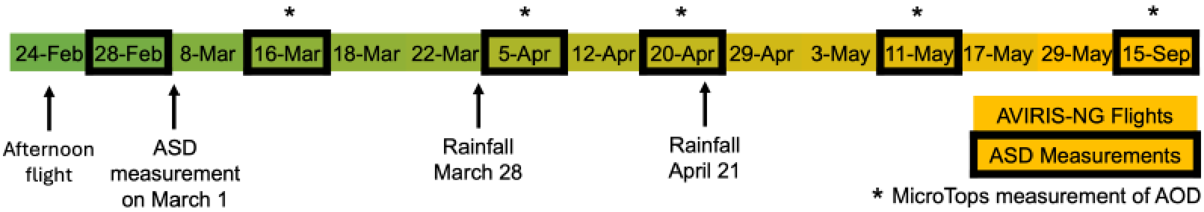

Figure 2. Timeline of SHIFT campaign AVIRIS-NG flights and corresponding ASD and MicroTops data provided in this dataset.

Site selection and Field methods

Given these goals, sites were selected that were homogenous over a 15-m x 15-m area, so that at least one 5-m x 5-m AVIRIS-NG pixel would be captured of the site (Table 4) . For each site, the ASD spectrometer was optimized to avoid saturation. Sets of five white references from a spectralon panel were captured at approximately two minute intervals, interleaved with measurements of the target surface. The goal was to capture target spectra that corresponded well with the averaged view from AVIRIS-NG, so measurements were captured continuously while walking slowly, with the ASD fiber optic mounted on the palm grip on a pole held out to the operator's side. The 8-degree foreoptic was used to limit the angular field of view (FOV) of the measured light to be more similar range to an AVIRIS-NG pixel. Each measurement is an average of the surface reflectance over a certain area on the ground, approximately 10 cm in size.

Each site was chosen to be approximately 15 m by 15 m. Each site location and dimensions are described by a convex hull formed by the points included in the GeoJSON files. These polygons were defined by picking pixels from the AVIRIS-NG L2A reflectance that corresponded to the site location, and saving the longitude, latitude of each of these points based off of the AVIRIS-NG georectification. The mean longitude and latitude of the polygon is stored in the measurement metadata for each site. Field photographs (JPEG images) document the appearance of each site.

The MicroTops II sun photometer was used to measure atmospheric parameters such as aerosol optical depth (AOD) at one of the sites on all days where ASD measurements were within two hours of the AVIRIS-NG overflights. A GPS unit was used to initialize the sun photometer, and then multiple measurements were taken within a minute. The sun photometer was handheld by the operator.

Eight main sites were measured that were relatively homogenous over at least a 15-m x 15-m area: three gravel sites, two dirt, two rock, and one vegetated meadow (Table 4; Figures 3-4). In addition, three other sites were measured that had finer spatial features than could be resolved in the 5-m spatial resolution AVIRIS-NG data, resulting in mixed pixels: a tennis court, a road and roadsides, and a road fork "Y" intersection and its roadsides (Figure 5). Additional sporadic measurements were taken, such as of the operator's car (red Honda Fit, seen in the Site 10 image below) and weeds in the dirt paddock. The car is visible in the AVIRIS-NG imagery on multiple days adjacent to sites 9, 10, and 11. These are identified by independent site numbers as well. The sites were numbered in order of measurement occurrence but were reused on subsequent days. That is, "Site 0" refers to the same physical area for all measurement days.

Table 4. Descriptions of target sites.

Sequence Description	Site ID	Description	Latitude	Longitude	Target type
Large, homogenous sites	0	Parking lot, gravel	34.69196	-120.04060	gravel
	1	Road, gravel	34.69283	-120.04060	gravel
	2	Road, gravel	34.69310	-120.04051	gravel
	5	Paddock, dirt	34.69276	-120.04234	dirt
	6	Paddock, dirt	34.69300	-120.04248	dirt
	9	Roadside serpentinite outcrop (top)	34.74290	-120.04354	rock
	10	Flat roadside (serpentinite + clay/dirt)	34.74279	-120.04408	rock

	11	Meadow near roadside	34.74258	-120.04439	vegetation
Tennis court endmembers	3	Tennis court (blue). Contains sites 12, 24, 27.	34.69301	-120.03988	paint
	4	Concrete around tennis court	34.69305	-120.03992	concrete
	12	Tennis court middle (light blue)	34.69301	-120.03988	paint
	24	Tennis court lines (white)	34.69301	-120.03988	paint
	27	Tennis court (dark blue only)	34.69301	-120.03988	paint
Road area endmembers	13	Grass along road, east	34.69116	-120.04075	vegetation
	14	Road, dirt + rock	34.69116	-120.04075	gravel
	15	Roadside vegetation, west	34.69118	-120.04080	vegetation
Road fork "Y" intersection endmembers	17	Road fork - vegetation northwest	34.68810	-120.04086	vegetation
	18	Road fork - road west (light gravel)	34.68809	-120.04090	gravel
	19	Road fork - vegetation southwest	34.68802	-120.04087	vegetation
	20	Road fork - road middle (dark gravel)	34.68810	-120.04079	gravel
	21	Road fork - road east (dirt)	34.68812	-120.04079	dirt
	22	Road fork - vegetation northeast edge	34.68808	-120.04079	vegetation
Miscellaneous transient targets	7	Large weed in paddock	34.69304	-120.04247	vegetation
	16	Red Honda Fit	34.74273	-120.04421	paint

Figure 3. Photographs and locations of homogenous pseudo-invariant dirt and gravel sites near Sedgwick Reserve Headquarters near Santa Barbara, California, U.S.

Figure 4. Photographs and locations of homogenous pseudo-invariant rock and varying vegetation sites at the northern boundary of Sedgwick Reserve.

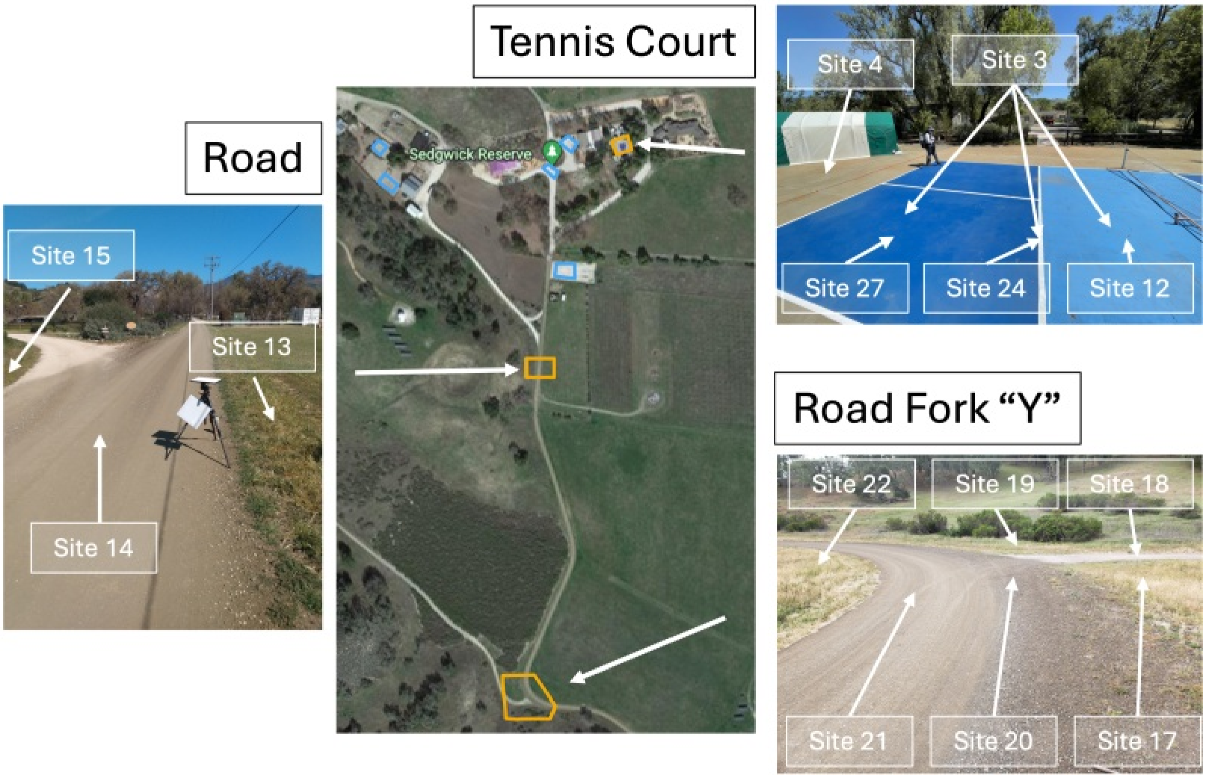

Figure 5. Photographs and locations of sites with higher spatial variation, resulting in mixed pixels for the AVIRIS-NG imagery. End-members from these areas were recorded as different sites.

Data processing

The surface reflectance spectra are returned for each site for each date. The processing code follows these basic steps:

1. Identifies groups of white reference measurements using a cosine similarity score to a known white reference spectrum
2. Rejects white reference outliers that are below a cosine similarity threshold or outside three standard deviations from the mean
3. Takes a mean of each group of white reference measurements
4. Interpolates between white reference groups to produce a white reference for each target spectrum
5. Divides the target spectra by the white reference spectrum (s_target/s_ref)
6. Multiplies by the known spectralon reflectance spectrum to get the target reflectance spectrum:
   $\rho_{target} = (s_{target} / s_{ref}) \times \rho_{ref}$
7. Applies a 1.015x correction factor to account for the sun and measurement angles being roughly at 45 degree angles, to account for the non-perfectly Lambertian nature of the spectralon panel
8. Applies a jump correction algorithm to account for the differences in the three ASD detectors across the VSWIR range, which occur at 1000 nm and 1800 nm
9. Rejects target spectrum outliers that are below a cosine similarity threshold or outside 3 standard deviations from the mean

Two jump correction algorithms were available. The "hueni" algorithm follows (Hueni and Bialek, 2017) and is based off of Hueni and Bialek's characterization of the ASD performance over temperature. The "asdparabolic" is based off of the ASD processing software described in ASD (2016). However, the documentation for the ASD parabolic correction is as of this writing no longer openly available, so the "hueni" option was used for the data processing.

The processing code is provided so users can reprocess the raw data, if desired. The operation of the processing code is outlined below. A more general version of the code is also available here: https://github.com/fotxoa-geo/asd-processor

6. Data Access

These data are available through the Oak Ridge National Laboratory (ORNL) Distributed Active Archive Center (DAAC).

SHIFT: Pseudo-invariant Targets, ASD Field Spectrometer Measurements, 2022

Contact for Data Center Access Information:

- E-mail: uso@daac.ornl.gov
- Telephone: +1 (865) 241-3952

7. References

ASD. 2016. FieldSpec4 user manual. Analytical Spectral Devices Inc. (This manual is no longer available but see https://www.malvernpanalytical.com/en/products/product-range/asd-range for similar spectrometers.)

Hueni, A., and A. Bialek. 2017. Cause, Effect, and Correction of Field Spectroradiometer Interchannel Radiometric Steps. IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing 10:1542–1551. https://doi.org/10.1109/JSTARS.2016.2625043

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