The 2011 NEON Airborne Pathfinder Campaign at the D17 Sites in California

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ABSTRACT

The National Ecological Observatory Network (NEON) conducted a series of airborne flights and supporting ground measurements at the three NEON sites located in NEON Domain 17 (Pacific Southwest). These sites extend over diverse ecological regions and elevational gradient ranging from open woodland at 200 to 520 m elevation dominated by oaks (blue and interior live oaks) and digger pine in the San Joaquin Experiment Range (NEON core site) to mixed conifer/deciduous forest at 1100 m elevation at Soaproot Saddle relocatable site, and red fir dominated forest at elevations above 2,300 at the Upper Teakettle relocatable site. This campaign took place during September 2011. The primary objectives of the combined airborne and field campaign were to prototype data collection approaches, evaluate data processing techniques, and obtain an initial data set that could support future spatial/temporal scaling studies potentially in conjunction with the NASA HyspIRI Preparatory Airborne Activities. The NASA AVIRIS-classic instrument provided the remote sensing measurements for this campaign since the NEON instrumentation slated for deployment on the AOP remote sensing payloads were not yet available. For this campaign, only airborne imaging spectrometer measurements were obtained. Supporting ground measurements that included vegetation spectra, plant species identification and key atmospheric variables measurements were made.

Keywords: Airborne remote sensing, imaging spectroscopy

Table of Contents

List of Tables

List of Figures

1 INTRODUCTION

The National Ecological Observatory Network (NEON) conducted a series of airborne flights and supporting ground measurements at the three NEON sites located in NEON Domain 17 (Pacific Southwest). These sites are in central California extending over a large elevational gradient (Fig. 1). The Domain 17 Core Site is located on the San Joaquin Experimental Range (SJER) located in the southern foothills of the Sierra Nevada at an elevation of 200 to 520 m. Overflights of the NEON Domain 17 Relocatable sites at Soaproot Saddle (1080 m) and Upper Teakettle (2300 m) were also conducted along with a long elevational transect extending from the SJER to Soaproot Saddle and then from Soaproot Saddle to Upper Teakettle. The D17 sites (SJER, Soaproot Saddle and Upper Teakettle) were chosen to study the effects of changing precipitation (from rain to snow-dominated) and ecosystem types across the elevational gradient. This campaign took place during September 2011. The primary objectives of the combined airborne and field campaign were to prototype data collection approaches, evaluate data processing techniques, and obtain an initial data set that could support future spatial/temporal scaling studies potentially in conjunction with the NASA HyspIRI Preparatory Airborne Activities[1]. The NASA AVIRIS-classic[2] instrument provided the remote sensing measurements for this pathfinder campaign since the NEON instrumentation slated for deployment on the AOP remote sensing payloads were not yet available. For this campaign, only airborne imaging spectrometer measurements were obtained. Supporting ground measurements that included vegetation spectra, plant species identification and key atmospheric variables measurements were made.

The San Joaquin site is in an experimental range operated by the US Forest Service. The site is located in the foothills of the Sierra Nevada, about 32 km north of Fresno, CA. According to te website http://www.fs.fed.us/psw/ef/san_joaquin/, the climate is Mediterranean, with about 486 mm of rain falling from October or November to April or May. Winters are cool and wet, with frequent frosts and monthly mean temperatures between 4 and 10 °C. Summers are hot and dry, with maximum daily temperatures commonly exceeding 38 °C and monthly mean temperatures ranging from 24 to 27 °C. San Joaquin contains open woodland dominated by oaks (blue and interior live oaks) and California Foothills, or grey pine (pinus sabiniana), with scattered shrubs and nearly continuous cover of herbaceous plants. Swales occur in low areas between rises. Since the pathfinder campaign took place in September, the site was quite arid and large areas of dry grasses were imaged.

[1] NASA Research Announcement "Research Opportunities in Space and Earth Sciences (ROSES) 2011" (NNH11ZDA001N) posted on the NASA research opportunity homepage at http://nspires.nasaprs.com/ (select "Solicitations" then "Open Solicitations" then "NNH11ZDA001N").

[2] http://aviris.jpl.nasa.gov/

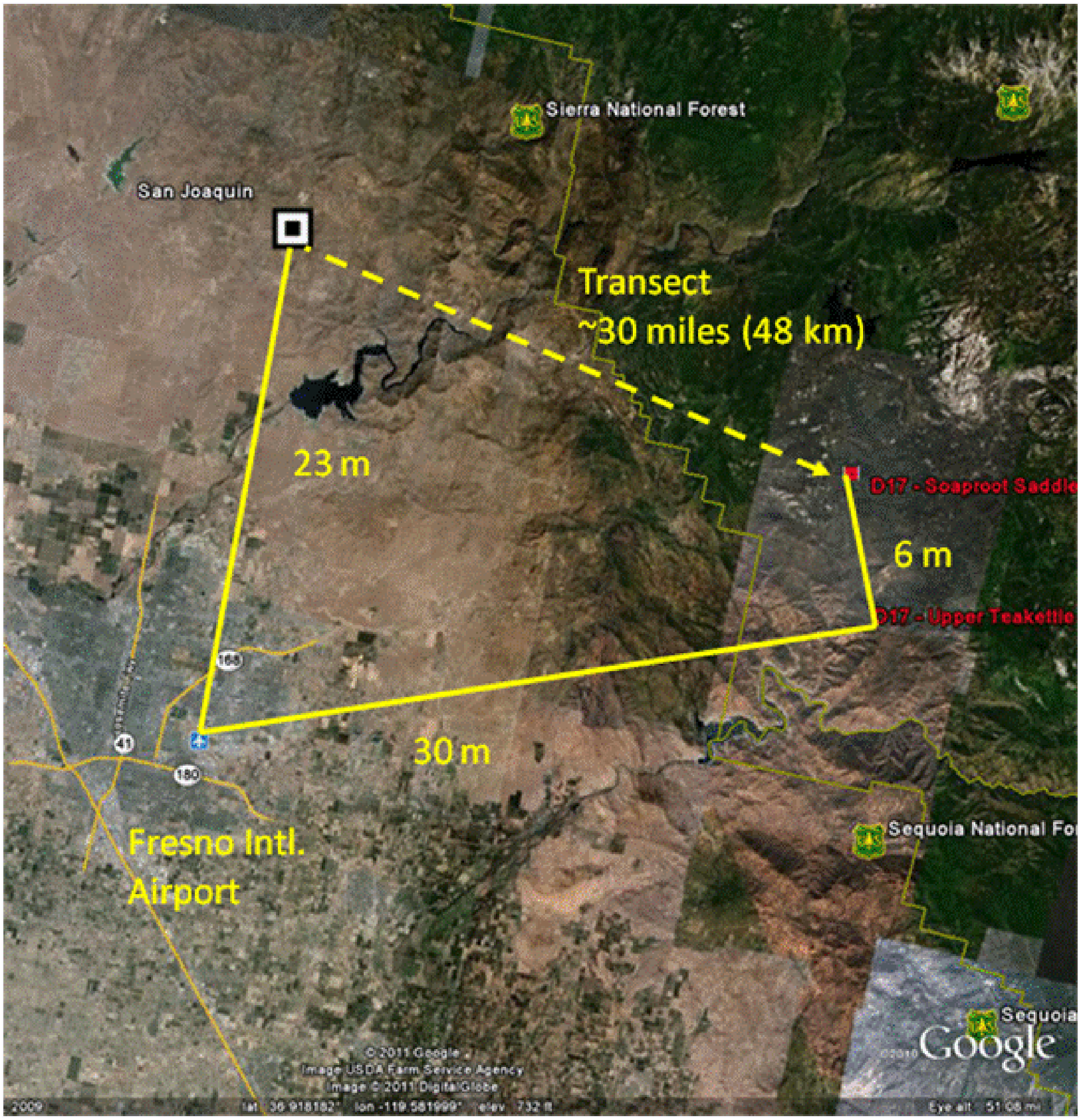


Figure 1: Domain 17 NEON Sites and distances from Fresno International Airport

The Soaproot Saddle site lies in an intermediate location along the elevational gradient from the San Joaquin Valley to the upper Sierra Nevada. The site is at approximately 1100 m in elevation on a lower steppe in the Sierras but at higher elevation than San Joaquin. The ecosystem is composed of a mixed deciduous/conifer forest that is dominated by Ponderosa pine with an open canopy, with various heights of trees and shrubs, and super dense floor cover dominated by sage. Topography is a complex terrain with coarse large hills and valleys. This site is expected to get 20% snow and 80% rain, and capture the snow-rain transition. The site is situated on the top of a knoll in the saddle area, thought the knoll itself is not the high point in elevation in the Soaproot Saddle area.

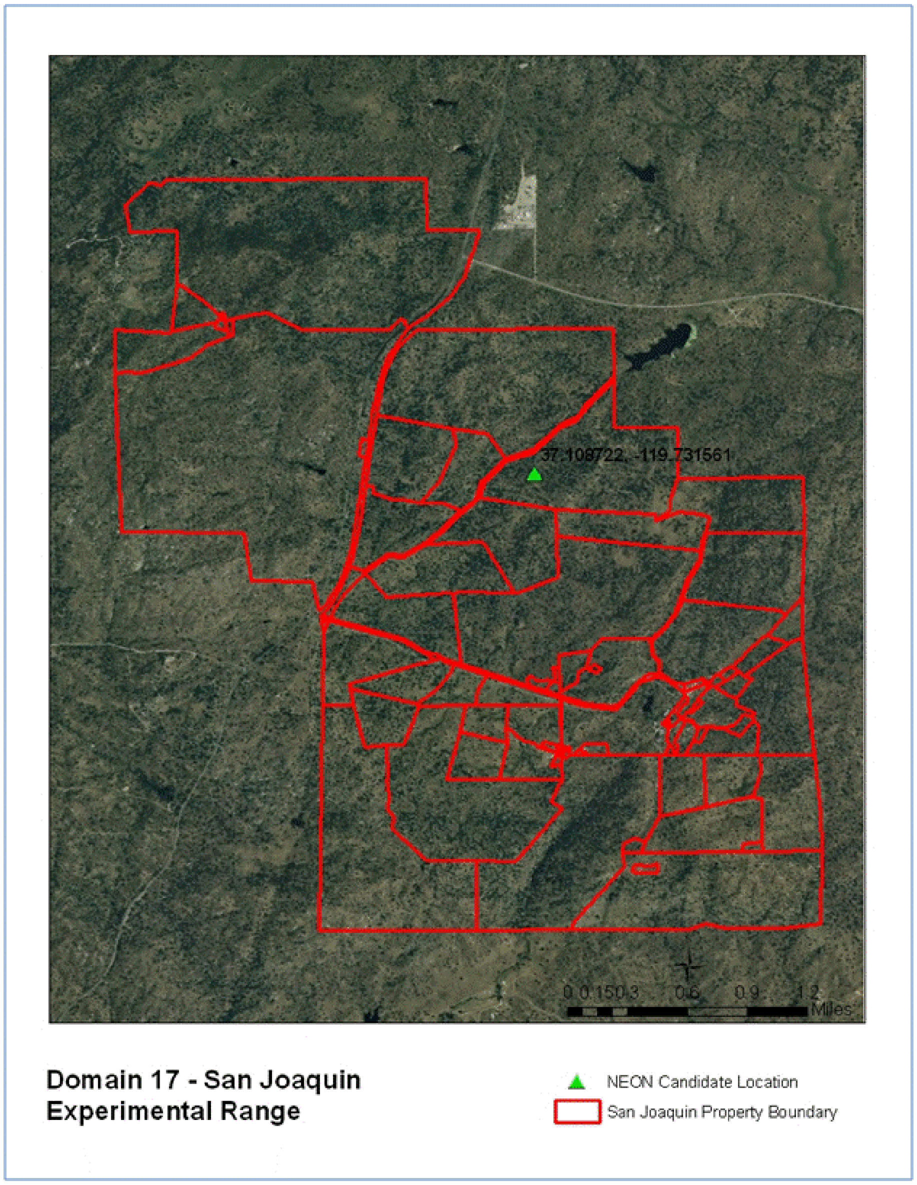


Figure 2: San Joaquin Experimental Range Site with boundaries

The Upper Teakettle is located on an upper steppe, at higher altitude (~2165 m) than the Soaproot Saddle relocatable site. Topography in the immediate area is relatively flat with 3-5 m gentle rises. Granite outcrops are 30 -50 m in height and 5-10 km away. This area is expected to receive 80% snow and 20% rain in the annual precipitation. The ecosystem at the immediate area around the planned tower site and in the tower airshed is a natural regenerating stand, very diverse with a mix of red fir, ponderosa and Jeffery's pine, and white fir. Age structure is also very diverse. Mean canopy height is ~ 35 m. Some individual trees are emergent with ~>50 m in height, and 2 other lower co-dominant canopies range from 25 – 37 m. The canopy is extremely rough and ~ 25-30% open with the understory being dominated by numerous cohorts of different species.

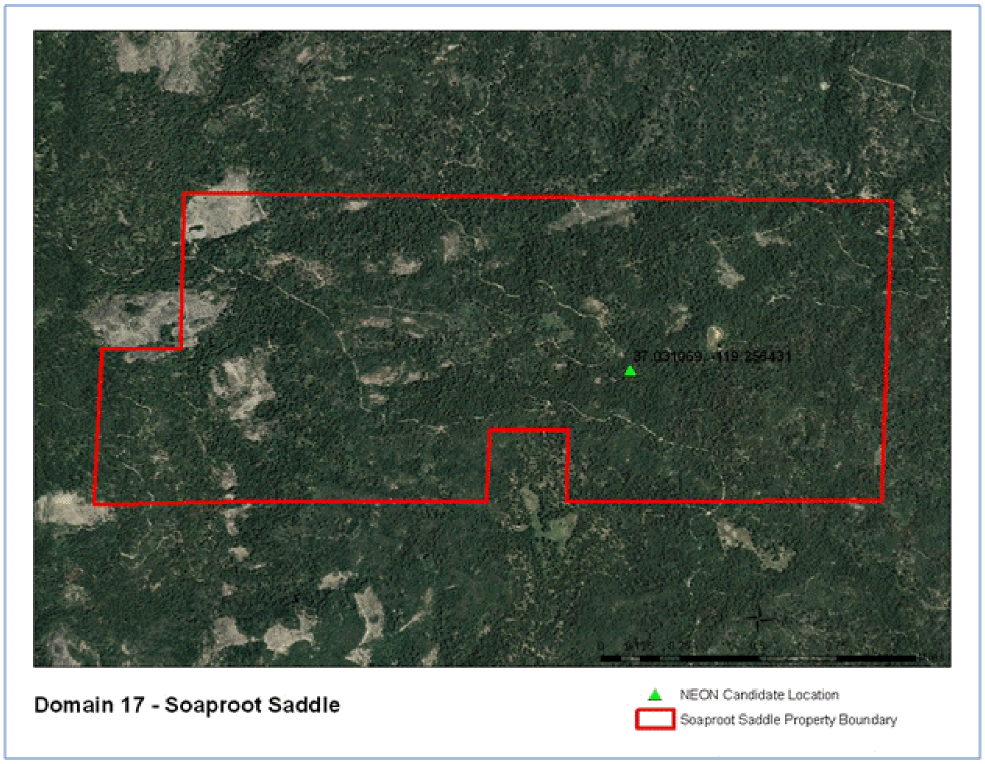


Figure 3: The Soaproot Saddle Relocatable Site and boundaries

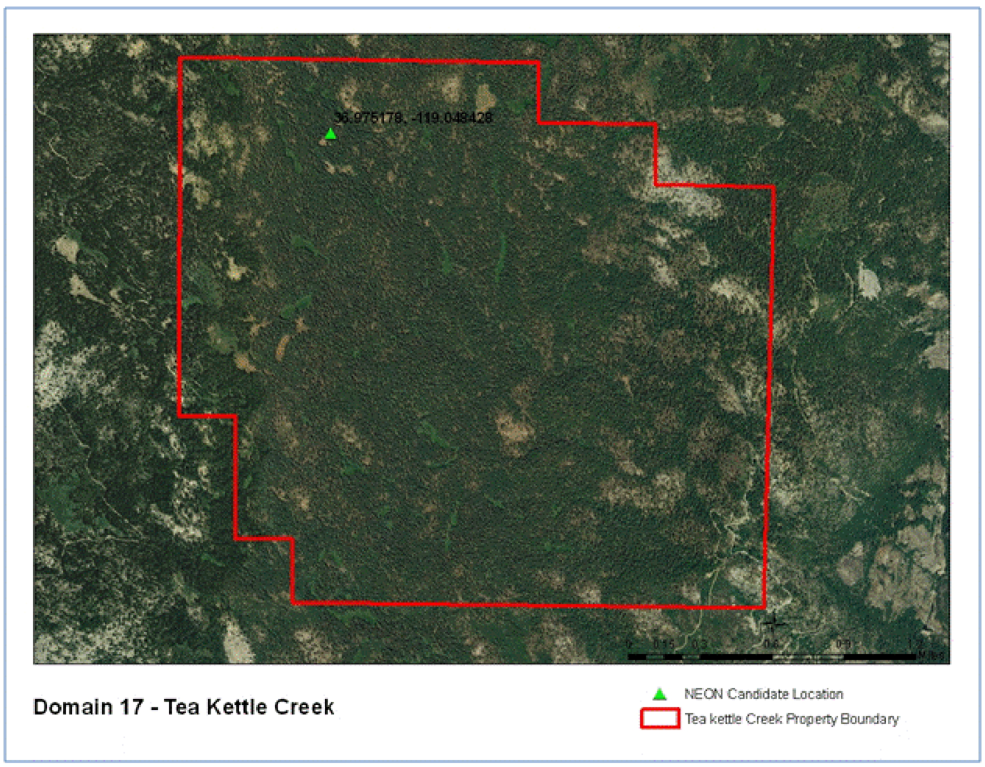


Figure 4: The Upper Teakettle Relocatable site with boundaries

The major objectives of this campaign were 1) to obtain operational flight and ground sampling experience in a distinctly different ecosystem from what was experienced during the 2010 Domain 3 Pathfinder Campaign at the Ordway-Swisher Biological Research Station[3], 2) develop a spectral database for vegetation species in the Domain 17 sites, 3) obtain an early set of spectroscopic data for the Domain 17 sites to assist in developing an approach for scaling studies in conjunction with the HyspIRI Preparatory Airborne Activities in subsequent years, and 4) conduct a transect airborne acquisition across an elevational gradient.

2 AIRCRAFT DEPLOYMENT

Since the instruments making up the NEON Remote Sensing Payload were not available at the time of this campaign, we elected to fly an imaging spectrometer with similar acquisition parameters to the NEON imaging spectrometer. The AVIRIS-classic instrument operated and managed out of NASA's Terrestrial Ecology Program was flown aboard a Twin Otter DeHavilland DHC-6-300 aircraft owned and operated by Twin Otter International.

The airborne measurements collected over the San Joaquin Experimental Range and surrounding regions provide a data set for NEON to begin the development of science data products and algorithms for NEON imaging spectrometer. By mapping the different vegetation types that exist in the diverse ecosystems at the Domain 17 sites, we begin to build up a data set to begin evaluating algorithms for a variety of different geophysical algorithms across a variety of ecosystems. By performing these measurements in a well-characterized region with supporting ground measurements, we have the opportunity to conduct direct comparisons to assess and characterize the sources of error in the airborne imaging spectrometer measurements. Sampling vegetation communities, ranging from simple to complex, with the spectrometer alongside ground-based validations allows provides the opportunity for a first look at useful spectral characterization schemes.

In addition to the site surveys for each of the NEON sites, a long transect was flown across the elevational gradient extending from SJER to Soaproot Saddle and then to the Upper Teakettle site. This transect is shown in Figure 5.

The nominal flight parameters for flights with the AVIRIS-classic instrument are shown in Table 1. These parameters were maintained for all flights with the exception of the elevational transect flights. In this case, one flight was conducted at a constant altitude (18,000 ft) and the second flight had a variable flight altitude adjusted to maintain a near-constant flight altitude above ground (13,800 ft to 16,400 ft). Flights were conducted on the 24th and 26th of September 2011. The flight on September 25th was aborted due to excessive cloudiness over the sites.

Table 1: General flight parameters

Percent overlap	30%
Ground Speed	90 knots
Flight Altitude	13,000 ft (4000 m) AGL
Nominal Ground Resolution	4 m
Expected Time of Day	Flights between 10 am and 2 pm whenever possible (flexible)

[3] Kampe, T.U., et al., NEON Technical Memo 002, "The NEON 2010 Airborne Pathfinder Campaign in Florida," 2012 (available at http://www.neoninc.org/documents/technical-memorandum-series)

Figure 5: Path of transect flown by AVIRIS across the elevational gradient extending from the San Joaquin Experiment Range to Soaproot Saddle.

The nominal flight parameters for all AVIRIS-classic flights are described in the following sections.

Figure 6 shows the flight lines over the San Joaquin Experimental Range and nominal flight parameters are listed in Table 2.

Figure 7 shows the nominal flight lines over the Soaproot Saddle relocatable site, and the nominal parameters for these flight lines are listed in Table 3.

Figure 8 shows the flight lines for the Upper Teakettle relocatable site and nominal flight parameters are listed in Table 4.

Figure 9 shows the nominal flight path for the elevational gradient flight lines along with a plot of the elevational change along the flight path. Figure 10 shows an AVIRIS Quicklook view of the transect between Soaproot Saddle and Upper Teakettle. Table 5 lists the nominal flight parameters for this flight line.

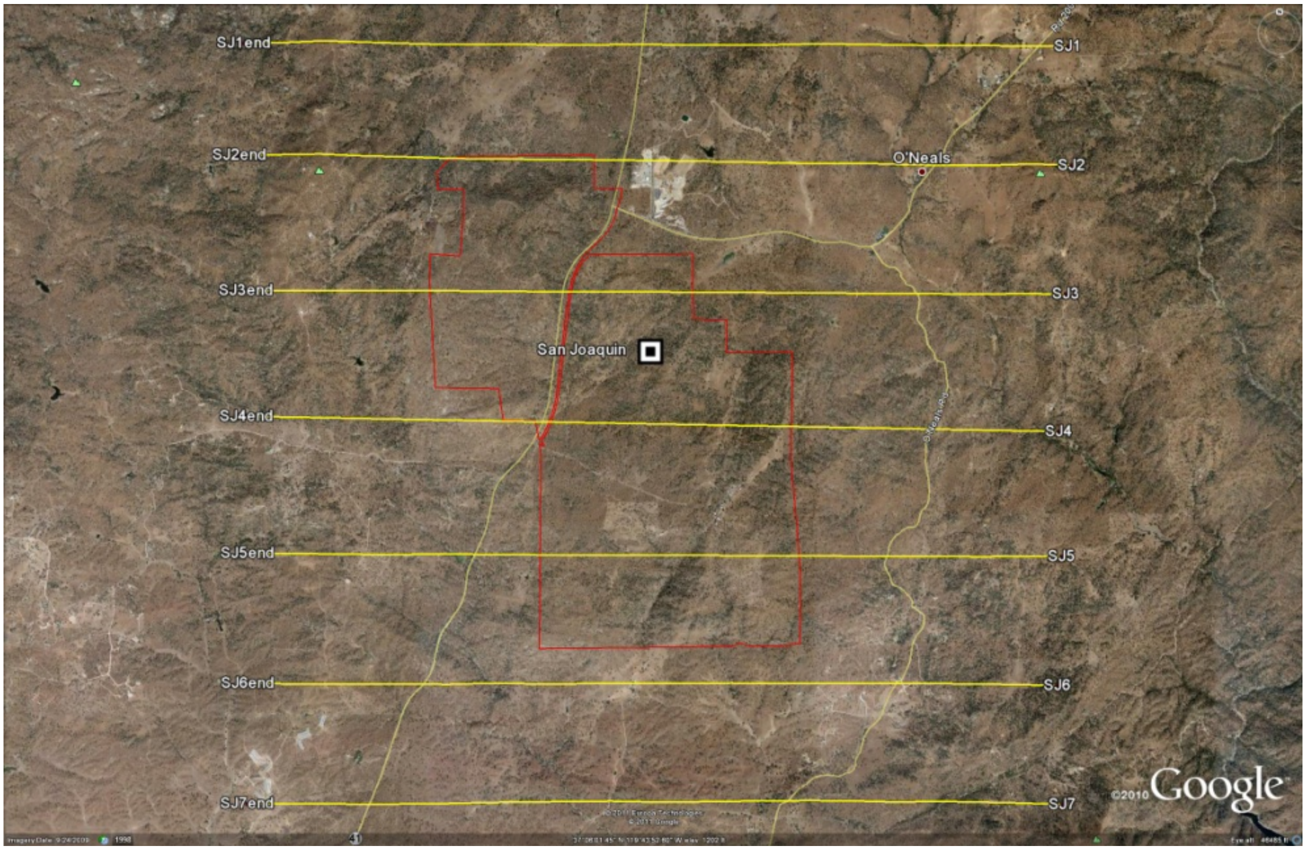


Figure 6: Flight lines for San Joaquin Experimental Range Flights

Table 2: Flight lines for the AVIRIS flight over the San Joaquin Experimental range. Flight lines are approximately 10 km in length. The area covered is approximately 100 square km.

San Joaquin(10x10km)

Line	Start			End		
	Latitude	Longitude	Elevation (ft)	Latitude	Longitude	Ele (ft)
SJ1	37°08'30.47" N	119°40'28.33" W	1517	37°08'33.21" N	119°47'17.08" W	1150
SJ2	37°07'43.51" N	119°40'27.02" W	1674	37°07'48.29" N	119°47'18.18" W	1326
SJ3	37°06'53.51" N	119°40'28.06" W	1326	37°06'54.74" N	119°47'14.58" W	1450
SJ4	37°05'59.12" N	119°40'30.55" W	1027	37°06'05.18" N	119°47'16.12" W	1057
SJ5	37°05'09.45" N	119°40'29.20" W	1039	37°05'10.42" N	119°47'16.67" W	752
SJ6	37°04'18.27" N	119°40'31.75" W	1110	37°04'18.15" N	119°47'17.08" W	673
SJ7	37°03'31.62" N	119°40'29.95" W	1273	37°03'29.70 N	119°47'17.57" W	587

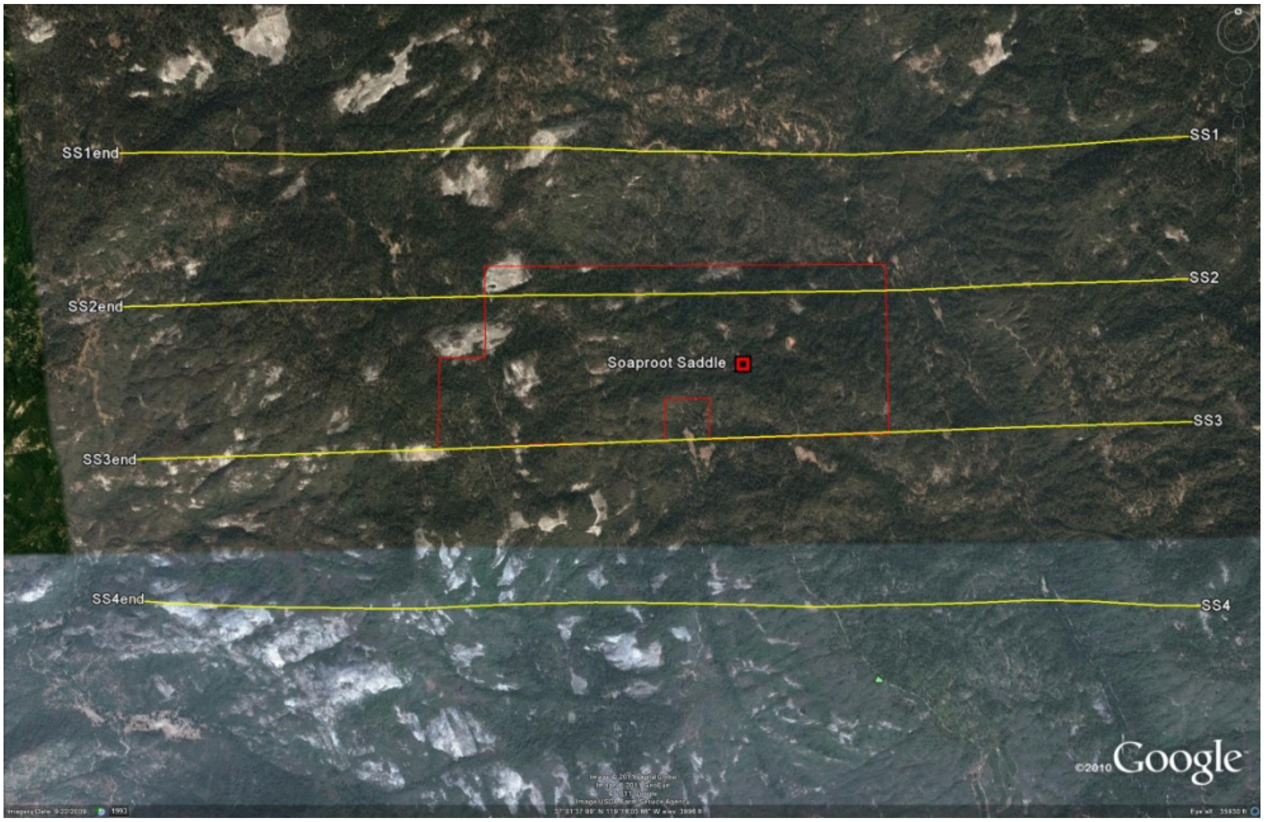


Figure 7: Flight lines for Soaproot Saddle Relocatable Site

Table 3: Flight lines for Soaproot Saddle in the Sierras. Flight lines are approximately 10 km in length. The area covered is approximately 50 square km.

Soaproot Saddle (10x5km)

Line	Start			End		
	Latitude	Longitude	Elevation (ft)	Latitude	Longitude	Elevation (ft)
SS1	37°02'53.66" N	119°12'44.61" W	5357	37°02'51.26" N	119°19'14.41" W	4925
SS2	37°02'15.00" N	119°12'40.18" W	4550	37°02'08.78" N	119°19'17.62" W	4058
SS3	37°01'34.31" N	119°12'37.42" W	4314	37°01'24.16" N	119°19'19.08" W	2969
SS4	37°00'41.31" N	119°12'34.81" W	4468	37°00'41.31" N	119°19'20.41" W	2251

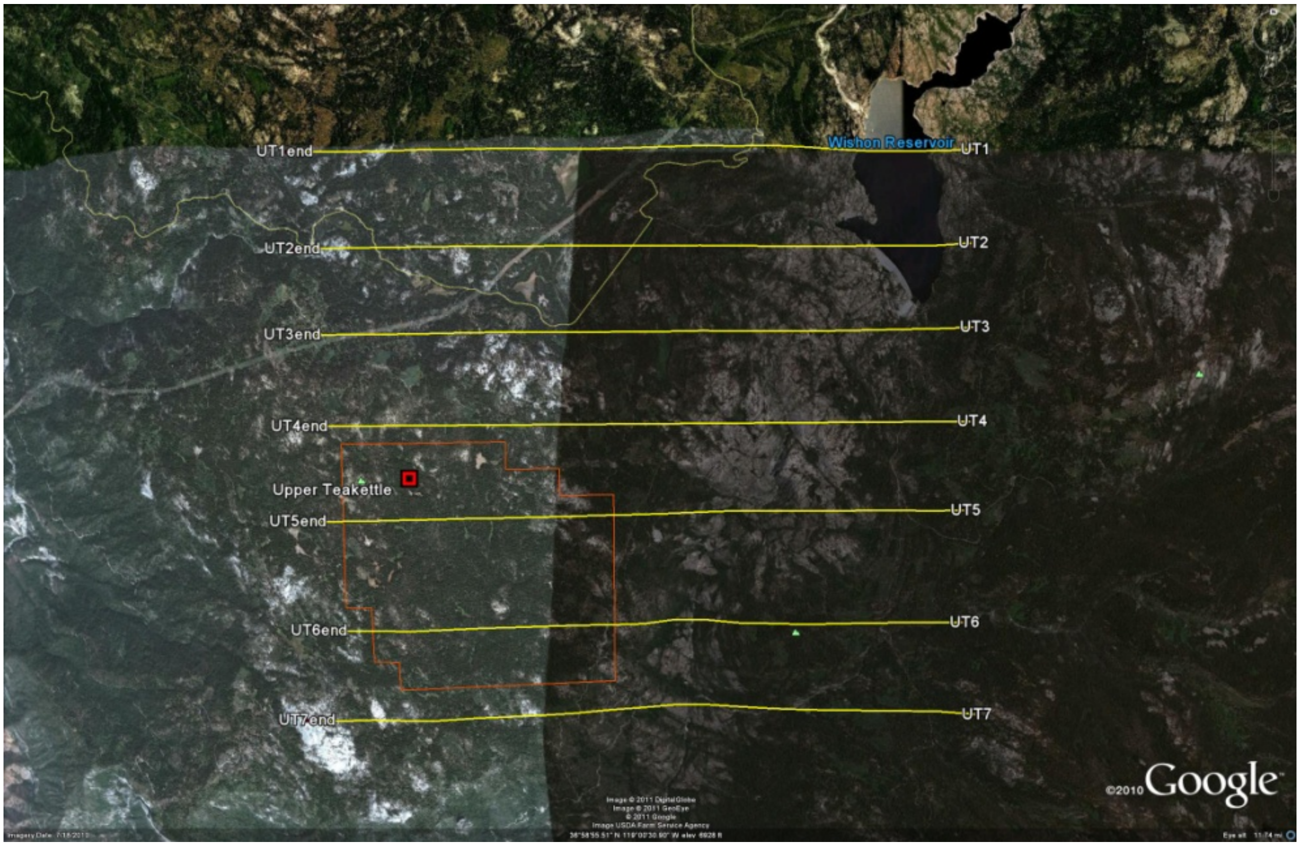


Figure 8: Flight lines for Upper Teakettle Relocatable Site

Table 4: Flight lines for the Upper Teakettle site. Flight lines are approximately 10 km in length. The area covered is approximately 100 square km.

Upper Teakettle(10x10km)

Line	Start			End		
	Latitude	Longitude	Elevation (ft)	Latitude	Longitude	Elevation (ft)
UT1	37°01'07.07" N	118°57'12.27" W	6832	37°01'08.20" N	119°04'11.46" W	7019
UT2	37°00'21.11" N	118°57'15.60" W	7248	37°00'21.48" N	119°04'08.27" W	6761
UT3	36°59'40.38" N	118°57'15.72" W	7454	36°59'39.28" N	119°04'06.16" W	7381
UT4	36°58'55.23" N	118°57"18.41" W	7607	36°58'55.20" N	119°04'01.18" W	7661
UT5	36°58'12.50" N	118°57'22.22" W	7468	36°58'09.65" N	119°04'02.90" W	7553
UT6	36°57'17.67" N	118°57'21.44" W	6870	36°57'16.87" N	119°03'51.67" W	7284
UT7	36°56'34.72" N	118°57'16.73" W	7536	36°56'33.36" N	119°03'59.85" W	7131

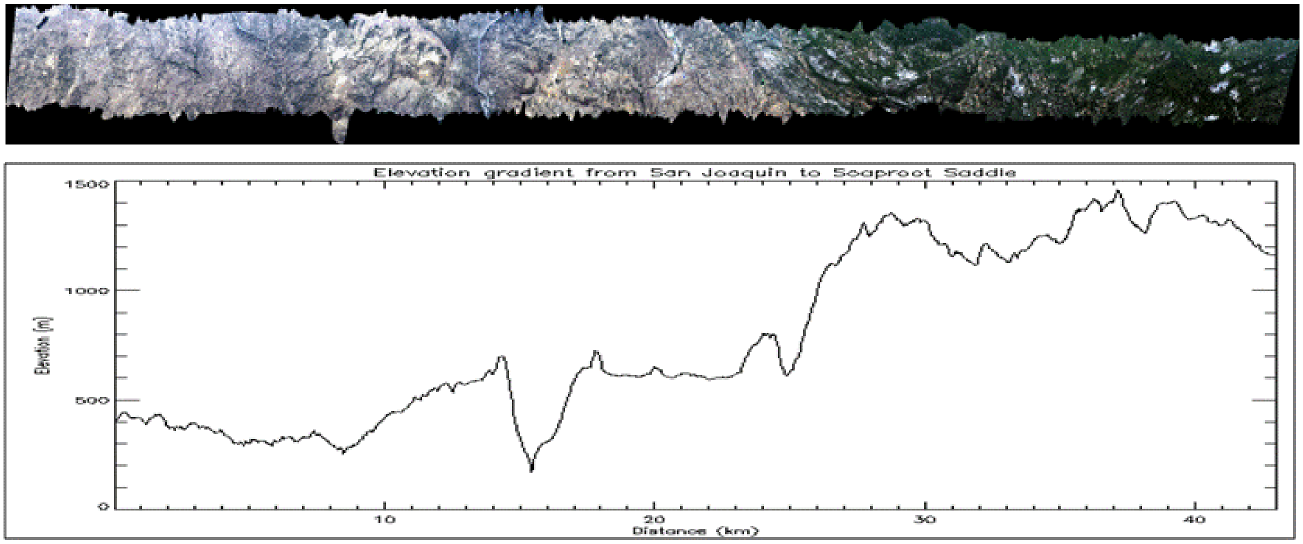


Figure 9: AVIRIS Quicklook data (top) for the elevational transect extending from SJER (left) to Soaproot Saddle (right). The lower figure shows a plot of elevation across the elevational gradient.

Figure 10: AVIRIS Quicklook data for transect extending from Soaproot Saddle to Upper Teakettle.

Table 5: Flight line for the elevation gradient flight line from the San Joaquin Experimental Range to the Soaproot Saddle relocatable site and return flight. The flight line is approximately 43 km in length.

Elevational Gradient

Line	Start			End		
	Latitude	Longitude	Elevation (ft)	Latitude	Longitude	Elevation (ft)
EG1*	37°06'25.59" N	119°43'54.95" W	1317	37°01'49.03" N	119°15'23.40" W	3858

* *Flown twice*

Table 6 lists the actual flight parameters for all flight lines flown by AVIRIS-classic as part of this campaign. This information is also available from the AVIRIS web site, (http://aviris.jpl.nasa.gov/cgi/flights_11.cgi?step=view_all_flights).

Table 6: Flight Line Parameters for AVIRIS-classic flights during 2011 Domain 17 Flight Campaign

AVIRIS Flt & Run ID	Site Name	NASA Log No.	Start Lat	Start Long	Stop Lat	Stop Long	Start GMT	Stop GMT	Comments
110924t01 P00_r04	San Joaquin 1	11T012	37.12970278	-119.7037028	37.13019167	-119.7691694	1838	1842	E to W; 14.5kFt; 80-85 kts SOG
110924t01 P00_r05	San Joaquin 2	11T012	37.11508056	-119.7030583	37.11488056	-119.7686278	1847	1852	E to W; 14.5kFt; 80-85 kts SOG
110924t01 P00_r06	San Joaquin 3	11T012	37.09760556	-119.7002	37.09827222	-119.7668306	1856	1900	E to W; 14.5kFt; 80-85 kts SOG
110924t01 P00_r07	San Joaquin 4	11T012	37.082675	-119.6992	37.08343056	-119.76755	1906	1910	E to W; 14.5kFt; 80-85 kts SOG
110924t01 P00_r08	San Joaquin 5	11T012	37.06935278	-119.6983972	37.06983333	-119.7652833	1971	1921	E to W; 14.5kFt; 80-85 kts SOG
110926t01 P00_r02	Relocatable Site 1, CA	11T012	36.964925	-118.97845	37.05230556	-119.2867111	1848	1901	18,900Ft 89SOG
110926t01 P00_r03	Relocatable Site 2, CA	11T012	37.03866389	-119.2918222	36.95214167	-118.9896611	1904	1916	19,000Ft 94SOG
110926t01 P00_r06	Relocatable Site 3, CA	11T012	36.93666111	-118.9971028	37.02322222	-119.2985806	1925	1938	19,00Ft 86SOG
110926t01 P00_r07	Elevational Gradient 1, CA	11T012	37.03028611	-119.2565	37.10710833	-119.7319306	1948	2007	18,000Ft 82SOG
110926t01 P00_r09	Elevational Gradient 1, CA	11T012	37.10710833	-119.7319306	37.03028611	-119.2565	2020	2039	13,800Ft to 16,400Ft 81SOG
110926t01 P00_r10	San Joaquin 5, CA	11T012	37.06935278	-119.6983972	37.06983333	-119.7652833	2049	2053	14,500Ft 78SOG
110926t01 P00_r11	San Joaquin 4, CA	11T012	37.08343056	-119.76755	37.082675	-119.6992	2055	2059	14,500Ft 78SOG

3 FIELD SAMPLING GOALS AND METHODS

Between the 23rd and 24th of September, 2011, field teams collected ground data at San Joaquin Experimental Range (Fig. 11-12). On September 25th, 2011, ground measurements were taken at the Soaproot Saddle (Fig. 13) and Upper Teakettle sites. The primary goals associated with these ground collections were to: 1) develop field training and data collection protocols; 2) collect ground-based data useful for validation of remotely-sensed data collected by the NEON airborne sensors from the same land area; and, 3) better constrain the time-frame in which ground data must be collected for airborne data validation purposes.

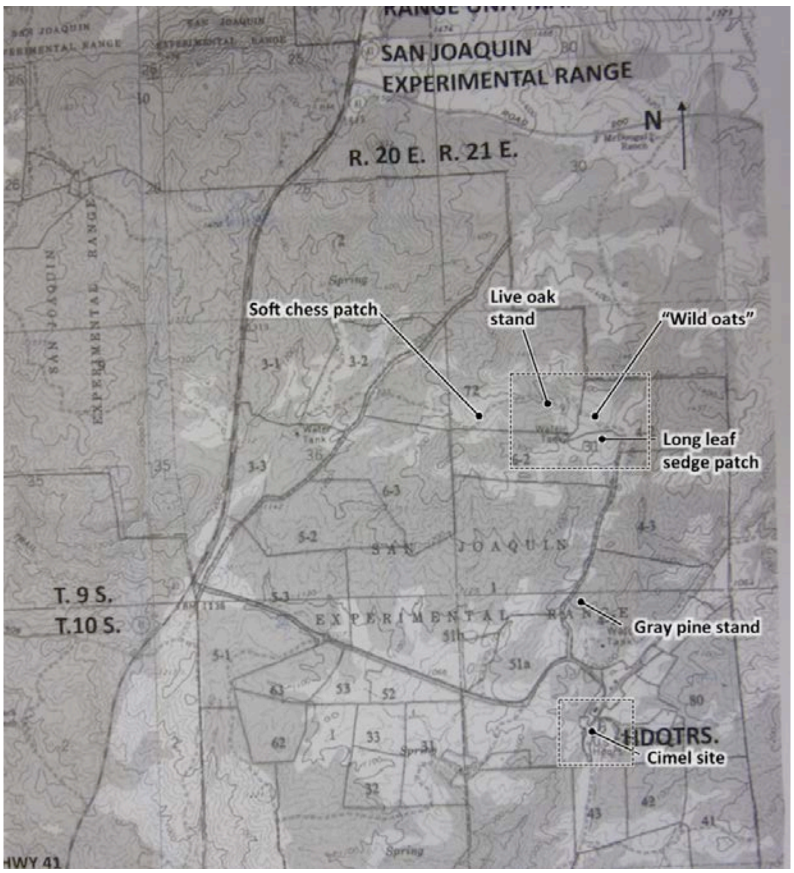


Figure 11. Regional map of the San Joaquin Experimental Range area showing locations of individual plant specimens used to obtain spectral measurements and Cimel sun photometer location.

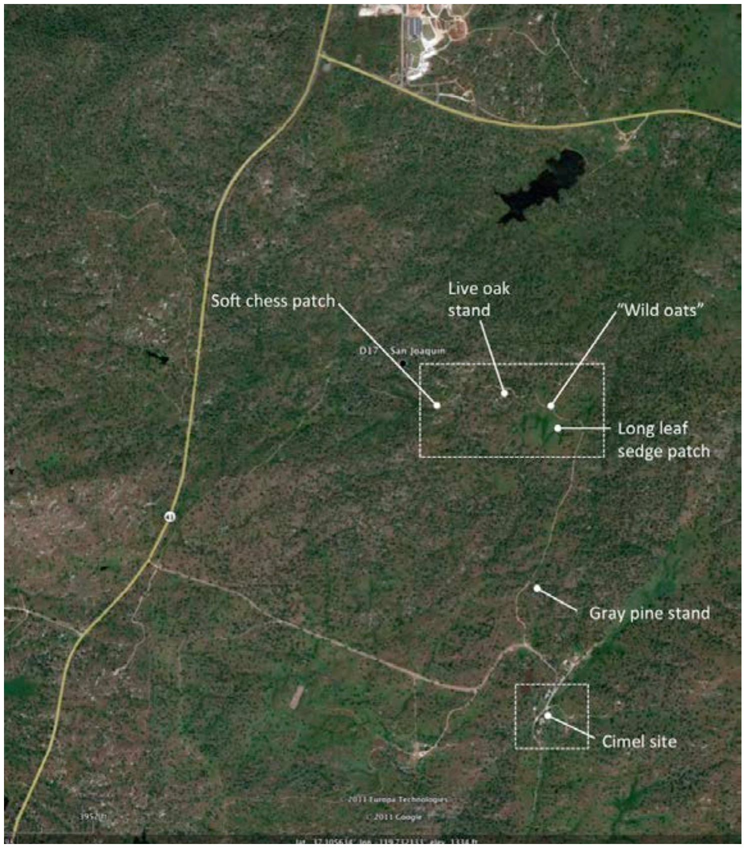


Figure12. Goggle Map image of the San Joaquin Experimental Range area showing locations of individual plant specimens used to obtain spectral measurements and Cimel sun photometer location.

NEON AOP staff members collected field spectrometer measurements of dominate vegetation species at the sites. Representative spectra taken with the ASD FieldSpec 3 Spectroradiometer obtained at the San Joaquin Experimental Range is shown in Figure 14. These data sets are also available on the NEON prototype web portal.

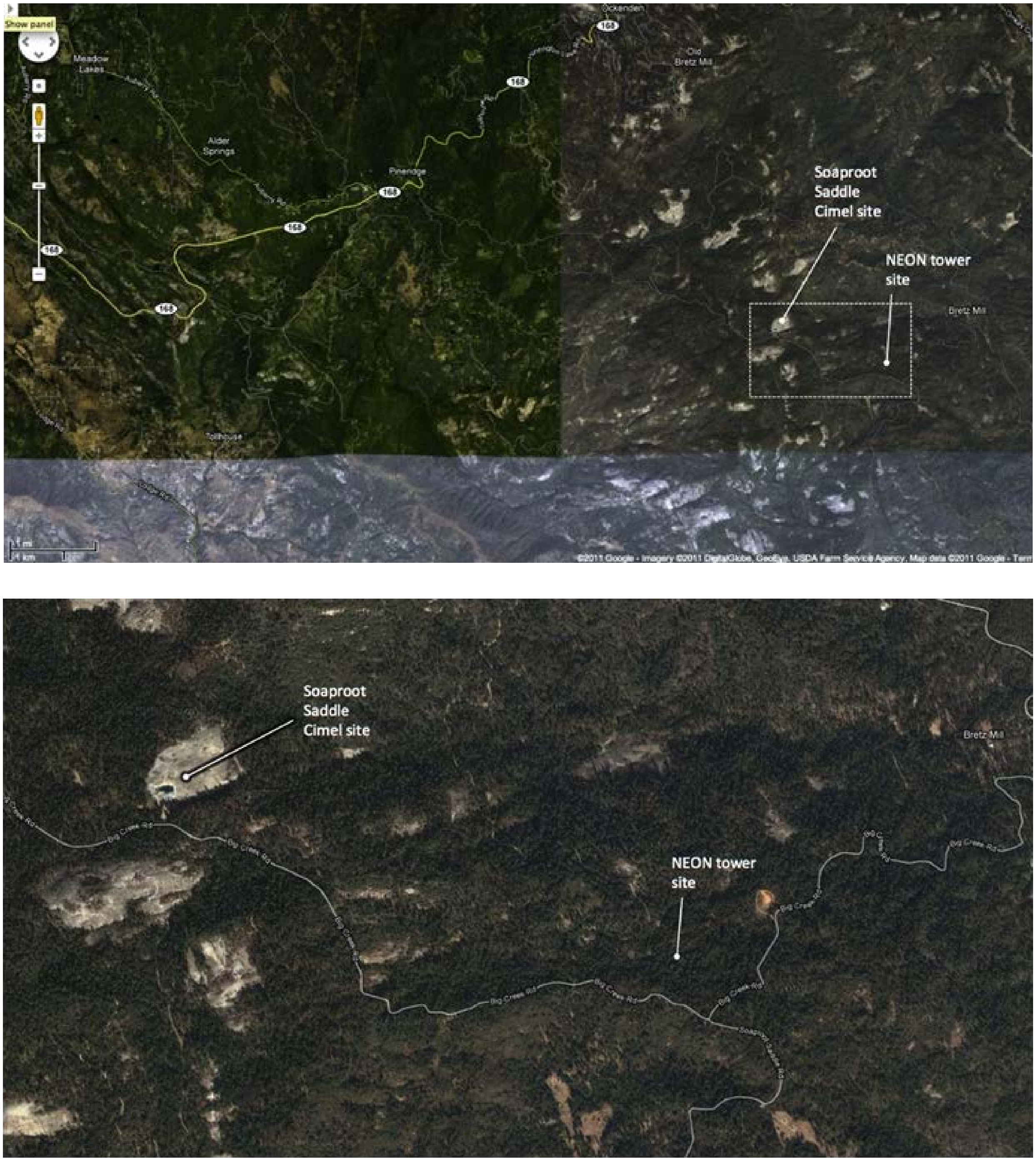


Figure 13: Soaproot Saddle location and location of Cimel sun photometer site and proposed site for the NEON flux tower. A close-up is shown in lower figure.

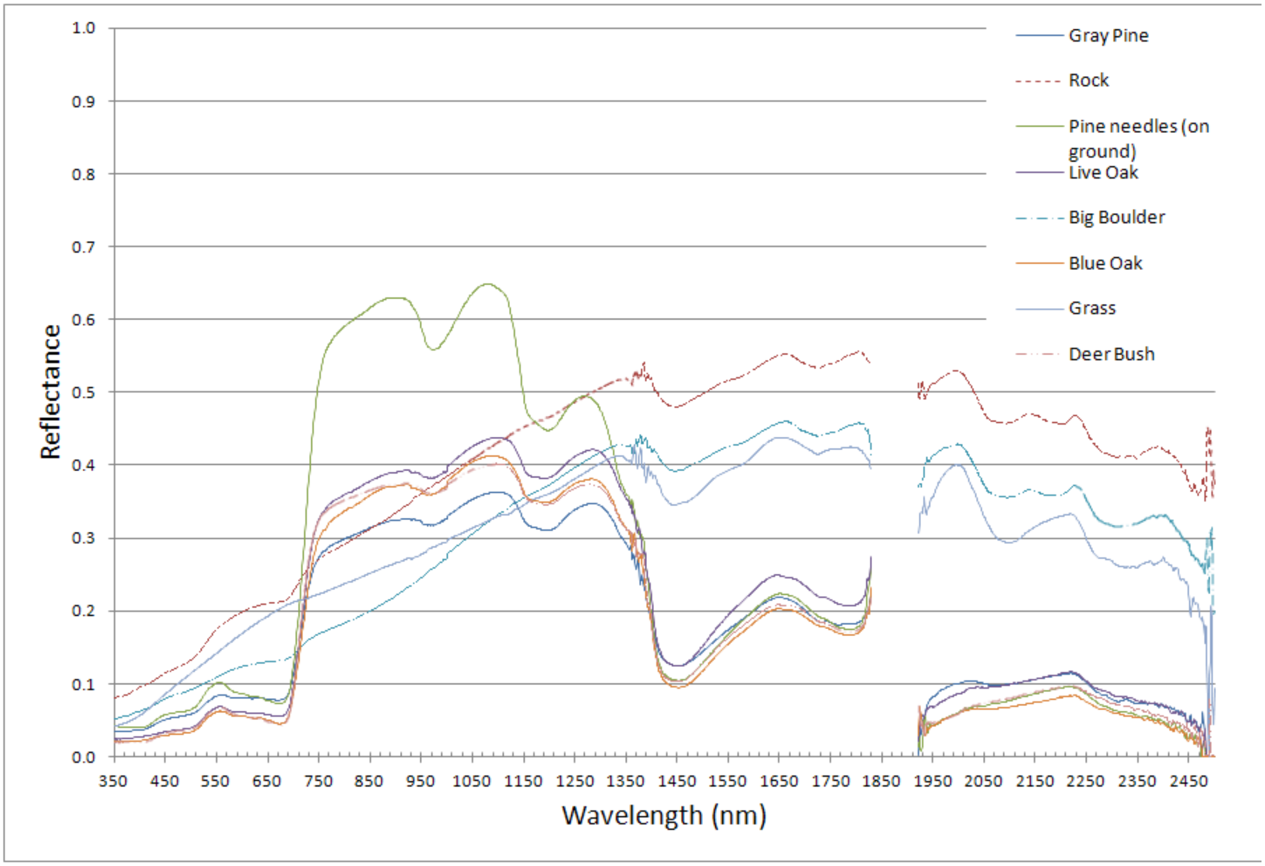


Figure 14: Representative spectra obtained with field spectrometer measurements at the San Joaquin Experimental Range site coincident with the airborne measurements.

4 ATMOSPHERIC CHARACTERIZATION

Atmospheric characterization relied on measurements of a Cimal sun photometer in coordination with the NASA Aerosol Robotic Network (AERONET)[7]. The Cimel sun photometer, shown in Figure 15, is a ten spectral channel radiometer designed to measure solar irradiance and sky radiance. The spectral channels span the visible to near-infrared portion of the solar-reflective spectrum and are specifically located at 340, 380, 440, 500, 675, 870, 1020, and 1640 nm. Measurements were made on September 24th at San Joaquin Experimental Range (Fig. 15). Measurements at Soaproot Saddle, scheduled to coincide with the September 25th, 2011 overflights, were unsuccessful due to instrument issues.

One goal of the measurement is to use the derived atmospheric information to improve the atmospheric correction of the AVIRIS-classic spectrometer data, in this case, the AVIRIS-classic flights over San Joaquin Experimental Range on September 23 and 24, 2011.

Direct solar irradiance measurements from a well-calibrated radiometer can provide total optical depth that can be broken out into separate components as follows:

$$\delta_{\text{total}}(\lambda) = \delta_{\text{Rayleigh}}(\lambda) + \delta_{\text{aerosol}}(\lambda) + \delta_{\text{absorption}}(\lambda) \quad (1)$$

The Rayleigh component, also known as molecular scattering, is accurately predicted with known of atmospheric pressure[4]. The remaining aerosol and absorption components are subsequently derived in the Cimel processing[5]. Spectral aerosol optical thickness measured by the Cimel sun photometer on September 23 and 24, 2010 is shown in Figure 16. In order to characterize aerosol effect across the full spectrum, a power law[6] is assumed with a functional form:

$$\delta_{\text{aerosol}}(\lambda) = \delta_{\text{aerosol}}(\lambda_o)\left(\frac{\lambda}{\lambda_o}\right)^{-\alpha} \quad (2)$$

where α is the Ångstöm exponent and $\delta_{aerosol}(\lambda)$ is the aerosol optical depth at reference wavelength λ_0. The Ångstöm exponent corresponding to each of the aerosol optical depth measurements in Figure 16 is shown in Figure 17. These data are available from the NEON prototype data sharing site (http://neoninc.org/pds/) and can also be obtained from the AERONET site (http://aeronet.gsfc.nasa.gov/new_web/index.html).

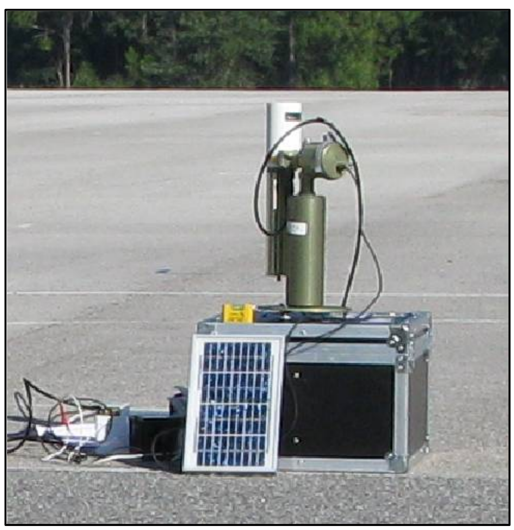


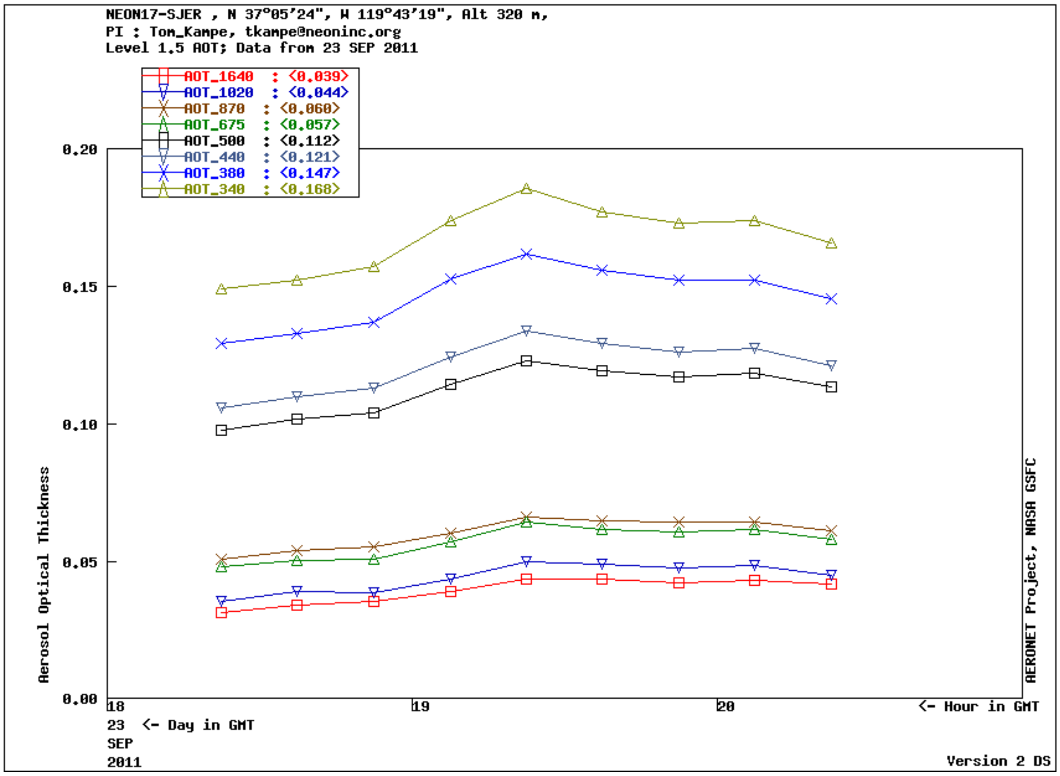
Figure 15: Cimel sun photometer

[4] Hoyt, D.V., "A redetermination of Rayleigh optical depth and its application to selected solar radiation problems," J. Appl. Meteorol., Vol. 16, pp. 432-436, (1977)

[5] Holben, B.N., T.F. Eck, I. Slutsker, D. Tanre, J.P. Buis, A. Setzer, J.A. Reagan, Y.J. Kaufman, T. Nakajima, F. Lavenu, I. Jankowski, A. Smirnov, "AERONET - A federated instrument network and data archive for aerosol characterization," Rem. Sens. of Env., Vol. 66, No. 1, pp. 1-16, (1998).

[6] Ångström, A., "On the atmospheric transmission of sun radiation and on dust in the air," Geografiska Annaler, Vol. 11, pp. 156-166, 1929.

Figure 15: Cimel Sun photometer location relative to San Joaquin Experimental Range Headquarters Building



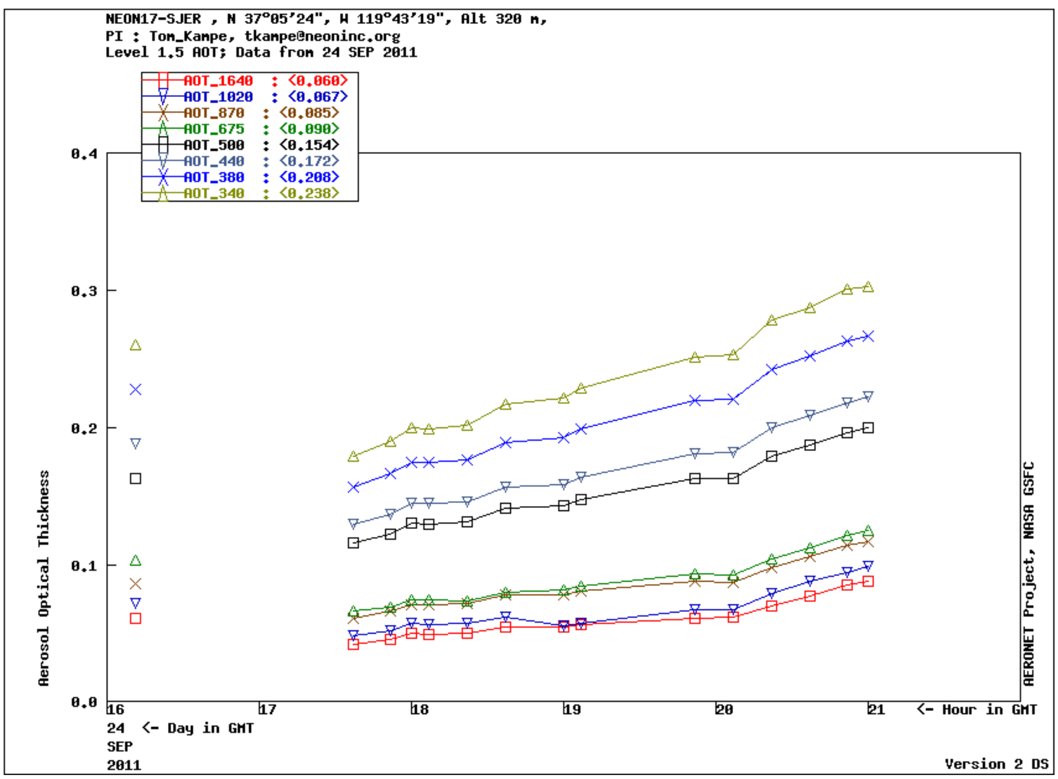
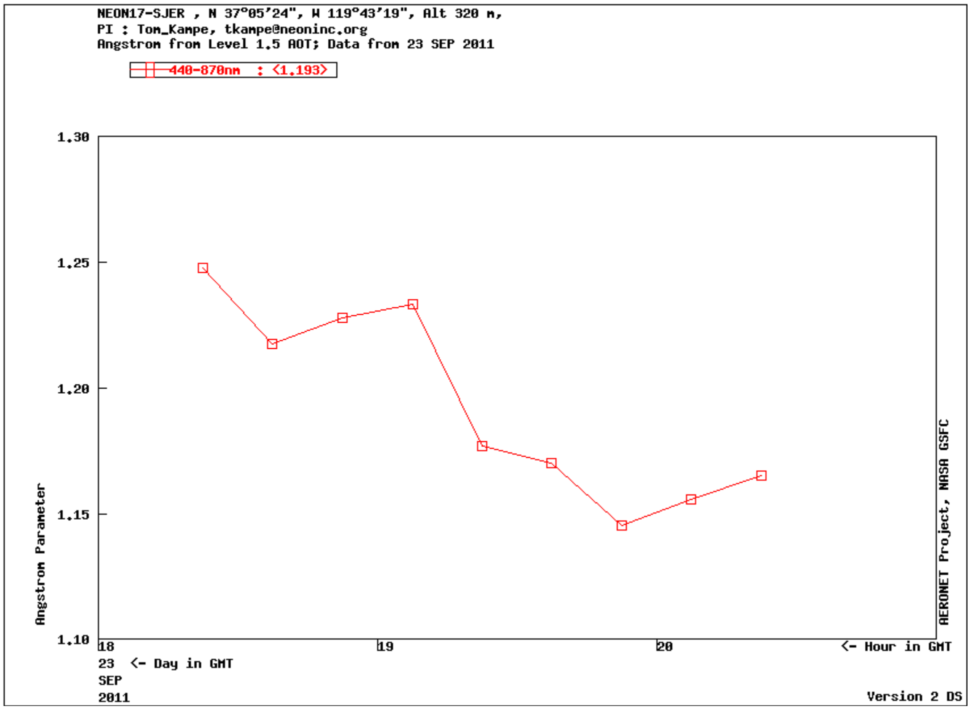


Figure 16: Aerosol optical thickness calculated from measurements with the Cimel sun photometer at the San Joaquin Experimental Range on September 23, 2011 (top) and September 24, 2011 (bottom).



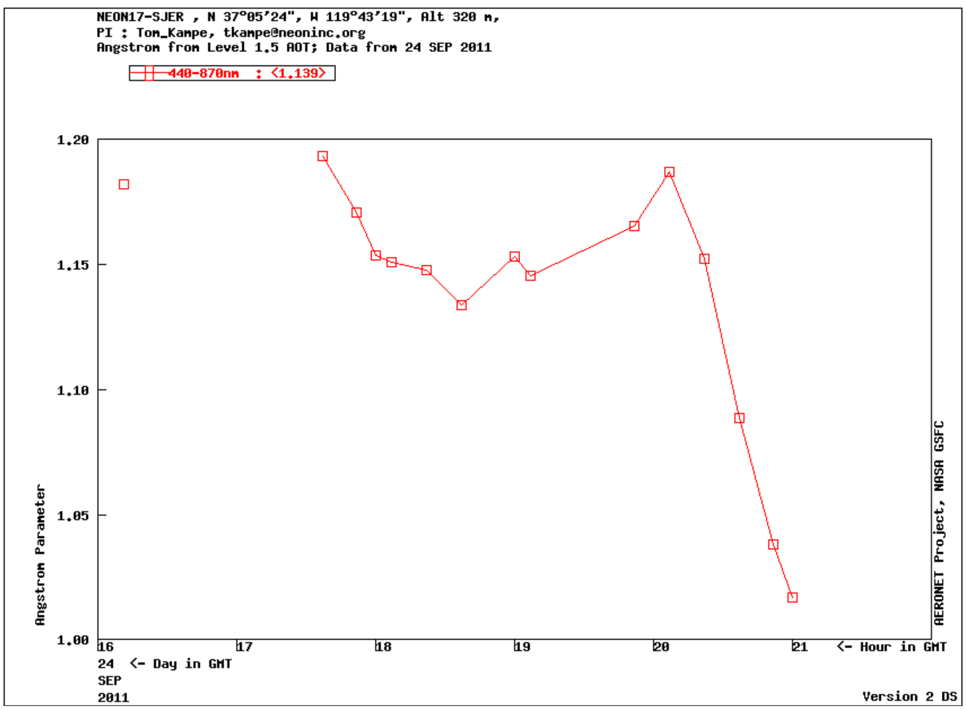


Figure 17. The derived Angstrom exponent for each of the aerosol optical depth measurements shown in Figure 17 over the course of the day on September 23, 2011 (top) and September 24, 2011 (bottom).

Atmospheric water vapor will have a significant impact on the atmospheric transmission spectra. This can be seen in the modeled atmospheric transmission spectra with the water vapor component highlighted as shown in Figure 18. Column water vapor is calculated from the 940 nm spectral channel of the sun photometer. Results for September 24, 2011 are shown in Figure 19.

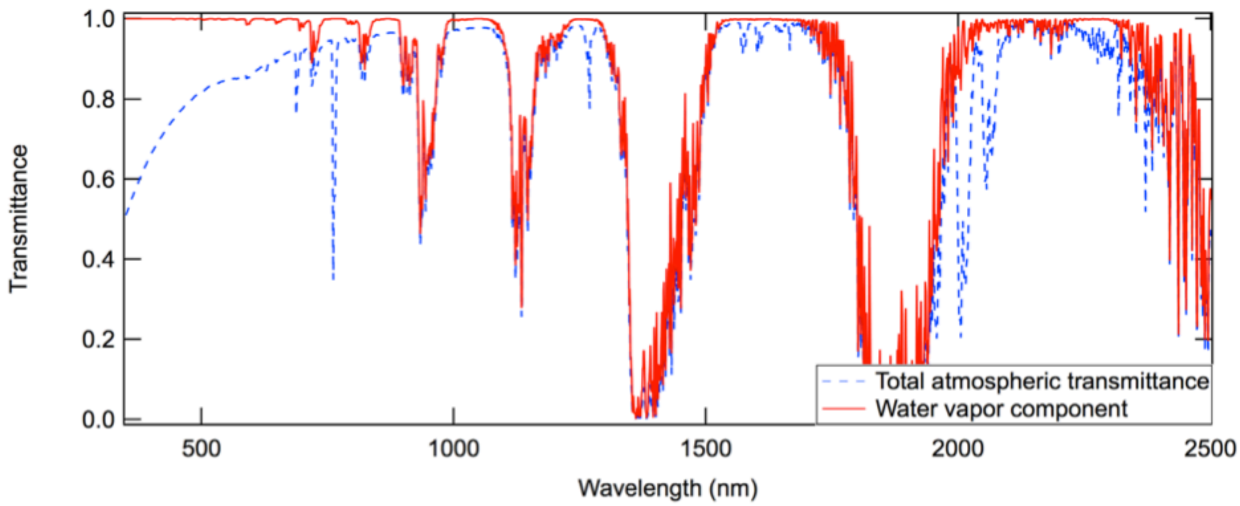


Figure 18. Total atmospheric transmittance also showing the component due to water vapor absorption

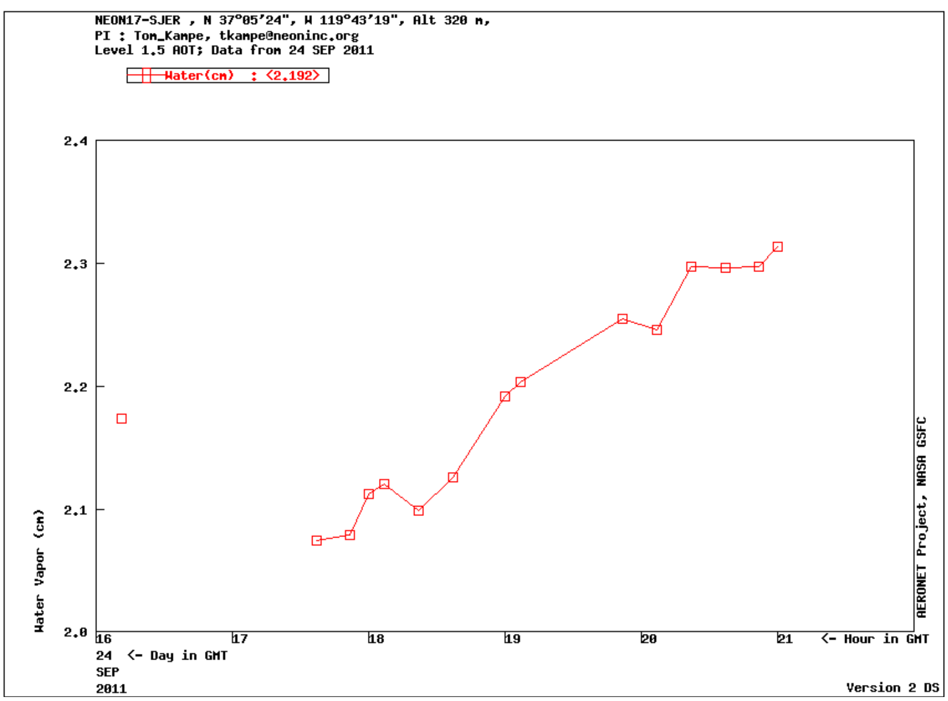


Figure 19. Column water vapor as measured on September 24, 2011

A Kestrel 4500 Pocket Weather Tracker portable weather station was used to collect temperature, pressure, relative humidity, and wind speed and direction. Measurements were made on September 23 through 24, 2011. This data is also available on the NEON prototype data web site (http://neoninc.org/pds/).

5 PRELIMINARY SCIENCE RESULTS

5.1 Airborne and ground reflectance retrieval comparisons

Ground spectral measurements of individual vegetation species can help to inform interpretation of information retrieved by the airborne spectrometer over a sample region containing those species. It can be helpful to take the measurements from above the canopy tops so they are similar to the measurements taken by the airborne spectrometer in that the leaves are in a similar orientation to the aircraft retrieval and the surrounding environment and ground is included in the measurement. During this campaign, measurements were made exclusively from the ground using an ASD FieldSpec 3 Spectroradiometer to make spectral reflectance measurements of several vegetation species over the 400-2500 nm wavelength range (Fig. 14). Measurements of reflectance of several species including Grey Pine, Blue Oak, Live Oak, and grasses were collected at San Joaquin Experimental Range. Measurements of ponderosa pine, Manzanita, deer brush, live oak, and cedar were made at the Soaproot Saddle site. Measurements of red fir, white fir, Manzanita, and elderberry were made at Upper Teakettle. GPS coordinates were recorded for each reflectance measurement in order to help locate the plants in the AVIRIS imagery.

Spectral datasets for individual plant species have been generated and have been made available to the public via the NEON web portal (http://neoninc.org/pds/). Two files are provided for each spectral reflectance dataset, a jpeg image and an ASCII text file. The jpeg shows a preview of the data including a description of the object being measured, information about the date and time of the collection, the GPS coordinates of the object, a photograph to provide context about the object, and a quick look of the reflectance spectrum and standard deviation of the measurement. The text file contains the reflectance measurement data as 3 columns: wavelength (nm), reflectance (mean of several measurements), standard deviation of the measurement.

5.2 Atmospheric Correction

The JPL AVIRIS data are processed at JPL using the standard AVIRIS processing approach[25]. The spectral radiance data are then processed by NEON using the ATCOR-4 (Atmospheric & Topographic Correction program; http://www.rese.ch/products/atcor/atcor4/index.html) and the data from the Cimel sun photometer to perform an atmospheric correction to determine surface spectral reflectance. This code is designed with Modtran®-5 (DISORT, 8 stream option) to provide physical understanding behind its mathematical assumptions[7].

The basic overview of the ATCOR-4 processing is as follows:

- Use of an IDL code to create a scan angle file as well as extract pixel size, solar zenith, solar azimuth from the AVIRIS *flightline*_obs_ort file
- Georeferencing and creation of acceptable format of the digital elevation model (DEM) in ENVI
- Smoothing and atmospheric correction in ATCOR

Where *flightline* is the radiance file name in this format: fYYMMDDt01p00r##rdn_a/b/c.

The files needed in this process are:

Table 1. Files and data needed for ATCOR processing.

File/data type	Description and use
*flightline*_obs_ort	Used to create *flightline* _obs_ort_sca.bsq (scan angle file)
flightline _ort_igm	Band 3 of this is georeferenced for DEM
flightline _ort_glt	Used to georeference band 3 of *flightline* _ort_igm, create DEM
flightline _obs	Extract slope and aspect files from this
flightline _ort_img	BIP image file, which is converted to BSQ in ATCOR
flightline.info	Contains flight info like altitude, start/end lat/long, etc.
flightline.gain	Used to create *.cal file for sensor definition
flightline.spc	Used to create *.wvl file for sensor definition
CIMEL data (Water vapor, AOD, α)	AOD and α used for visibility, water vapor used for atmosphere

Parameters and selections used in the processing of this data are listed in the following tables:

[7] Anderson, G.P., Alexander Berk, Prabhat K. Acharya, Michael W. Matthew, Lawrence S. Bernstein, James H. Chetwynd, Jr., H. Dothe, Steven M. Adler-Golden, Anthony J. Ratkowski, Gerald W. Felde, James A. Gardner, Michael L. Hoke, Steven C. Richtsmeier, Brian Pukall, Jason B. Mello and Laila S. Jeong, "MODTRAN4: radiative transfer modeling for remote sensing", Proc. SPIE 3866, 2 (1999b), doi:10.1117/12.371318.

Table 2. ENVI georeferencing parameters.

Description	Value
Band math expression to convert ENVI data type	FLOAT(b1)
Band to set as b1 (to be georeferenced)	Band 3
Image from which Band 3 will be georeferenced	*flightline*_ort_igm
Input geometry lookup file for georeferencing	*flightline* _ort_glt
Output georeferenced DEM file	*flightline* _ort_igm_ele.bsq
File containing slope and aspect	*flightline*_obs
Spectral subset to georeference (slope)	slope.*flightline*_obs
Spectral subset to georeference (aspect)	aspect.*flightline*_obs
Georeferenced slope file	*flightline*_ort_igm_slp.bsq
Georeferenced aspect file	*flightline*_ort_igm_asp.bsq

Table 3. ATCOR DEM input parameters.

Description	Value
Input DEM file	*flightline* _ort_igm_ele.bsq
Pixel size	Pulled from *flightline*_obs_ort using IDL scan angle code
DEM height unit	m
Solar zenith and azimuth	Pulled from *flightline*_obs_ort using IDL scan angle code
Smoothing filter for DEM (# pixels)	5 x 5
Smoothed DEM output file	*flightline* _ort_igm_sm_ele.bsq
Smoothed slope output file	*flightline* _ort_igm_sm_slp.bsq
Smoothed aspect output file	*flightline* _ort_igm_sm_asp.bsq
Smoothed Skyview output file	*flightline* _ort_igm_sm_sky.bsq

Table 4. Image conversion in ATCOR (BIP to BSQ).

Description	Value
BIP image to convert	*flightline*_ort_img
Converted image	*flightline*_ort_img_img.bsq

Table 5. ATCOR 4: rugged terrain correction input parameters.

Description	Value
Input Image File	*Path\flightline*_ort_img_img.bsq
Date	Date of flight
DEM Path	*Path\flightline*
DEM height unit	m
Shadow file	Use pre-calculated shadow file
Selected Sensor	avirisYYYY (2010 for Ordway Swisher, 2011 for SJER)
Calibration file	avirisYYYY.cal

Scan angle file	*flightline*_obs_ort_sca.bsq
Nadir pixel size	Pulled from *flightline*_obs_ort using IDL scan angle code
Flight Altitude	Found in *flightline*.info
Flight heading	Found in *flightline*.info
Solar zenith and azimuth	Pulled from *flightline*_obs_ort using IDL scan angle code
Atmospheric file	Rural; need to know flight altitude and water vapor
Visibility estimate	Calculated using CIMEL AOD and α

Table 6. ATCOR Image processing selections.

Description	**Selections**
Select Processing Option window	Yes: Variable Water Vapor
Select Region(s) for Water Vapor Algorithm window	940 nm and 1130 nm; water vapor retrieval without band regression
Empirical BRDF Correction window	No BRDF correction

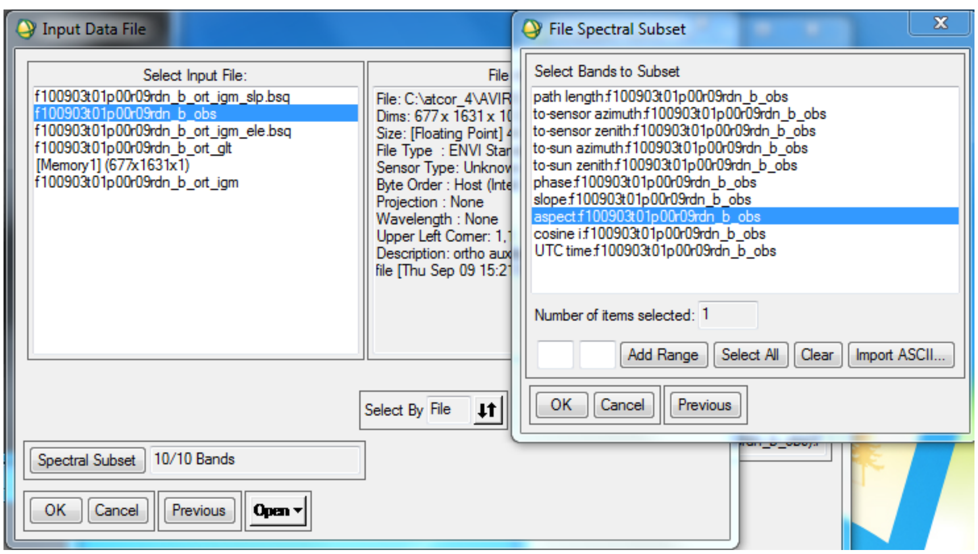


Figure 1. Spectral Subset to select slope and aspect files for georeferencing in ENVI.

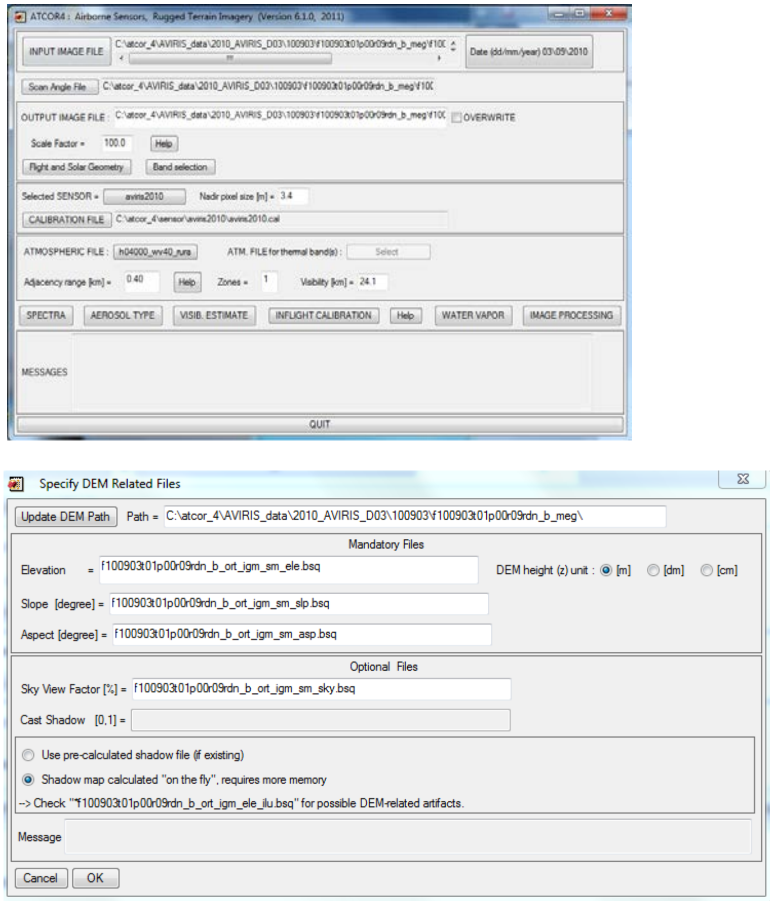


Figure 2. ATCOR rugged terrain atmospheric correction windows.

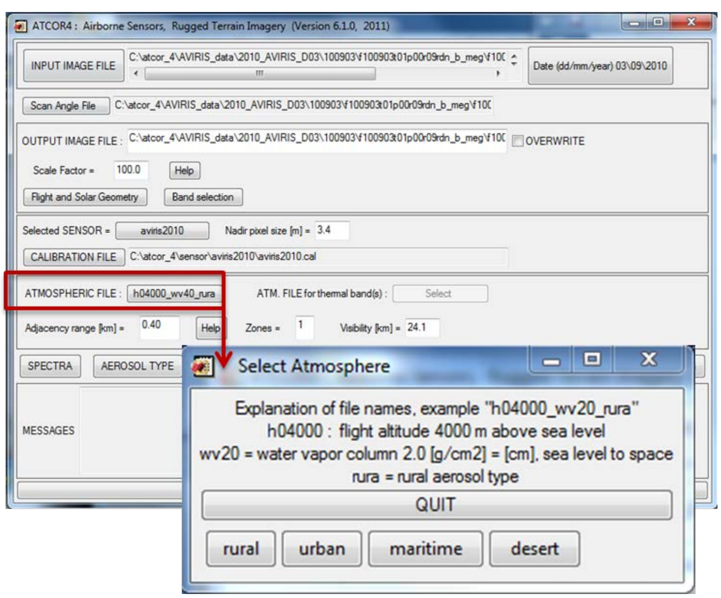


Figure 3. Atmospheric file selection explanation in ATCOR atmospheric correction.

6 CONCLUSION

The 2011 Domain 17 Pathfinder Campaign completed in September 2011. This campaign has provided pathfinder data sets that are being used effectively by the NEON Science teams to develop methods and protocols for ground site sampling, comparison between ground-based and airborne data, and data product development. This campaign has provided a baseline for establishing flight and ground-based operations in subsequent NEON airborne campaigns in Domain 17, including potential coincident flights of the new NEON airborne remote sensing payload in conjunction with HyspIRI-like data collections from AVIRIS-classic onboard the NASA ER-2 aircraft. Prototype data from the 2010 NEON Pathfinder Campaign are available from the NEON Pathfinder data website http://neoninc.org/pds/.

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