Opportunistic Validation of Vegetation Indices from MODIS and VIIRS Using NEON AOP Hyperspectral Imagery

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Introduction

Vegetation Indices are one of the most widely derived and used satellite remote sensing products for studying the land surface vegetation composition, health, and productivity (with a record +12,000* publications). With a time series spanning more than 35 years at different spatial, temporal, spectral, and radiometric characteristics (AVHRR, MODIS, VIIRS) it becomes critical to characterize and regularly validate this invaluable data record.

While in-situ observations remain the most accurate validation approach, the associated footprint is very limiting. The alternative is to consider scaling opportunistic data and images from alternate sensors (hyperspectral, drones, etc.). Supported by statistical analysis techniques this should offer a reasonable approach.

* Google Scholar statistics

NEON AOP

The National Ecological Observatory Network (NEON), with its Airborne Observation Platform (AOP) collects annual hyperspectral imagery at very high spectral resolution from 20 eco-climatic domains located across the US. The hyperspectral data consists of 428 bands in the range 380 - 2510 nm at 1-meter spatial resolution. This offers great opportunity for validating higher order products and coarse and medium resolution based remote sensing data.

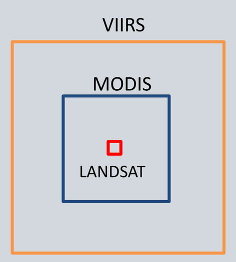
Objectives

This hyperspectral NEON AOP dataset presents a unique and long term opportunity for validation of coarser resolution sensors. However, working with these big data is challenging due to their size and the complex dataflow required (stitching, resampling, convolution, and post-processing, etc.). In this work we developed a workflow and set of tools aimed at assisting users take advantage of this rich data:

- Develop an application for the preprocessing of NEON hyperspectral data (mosaicking, spectral convolution and spatial resampling)
- Evaluate and use this data for validation of MODIS and VIIRS

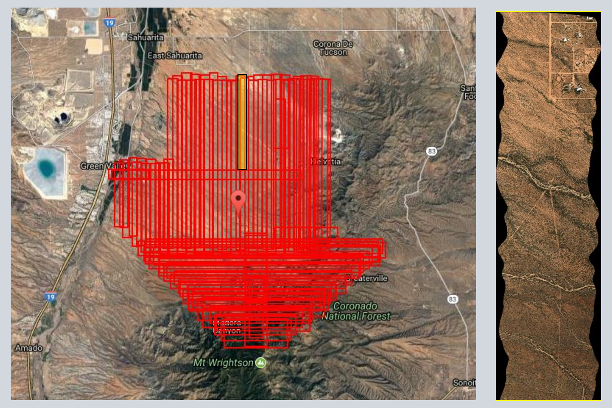
Sensors & Data specs

Sensor	RED (nm)	NIR (nm)	BLUE (nm)	Pixel Size
NEON AOP	Every 5nm (380-2510nm)			1 m
LANDSAT OLI	640-670	850-880	450-510	30 m
MODIS	620-670	841-876	459-479	250 m
VIIRS	600-680	846-885	436-454	375/750 m



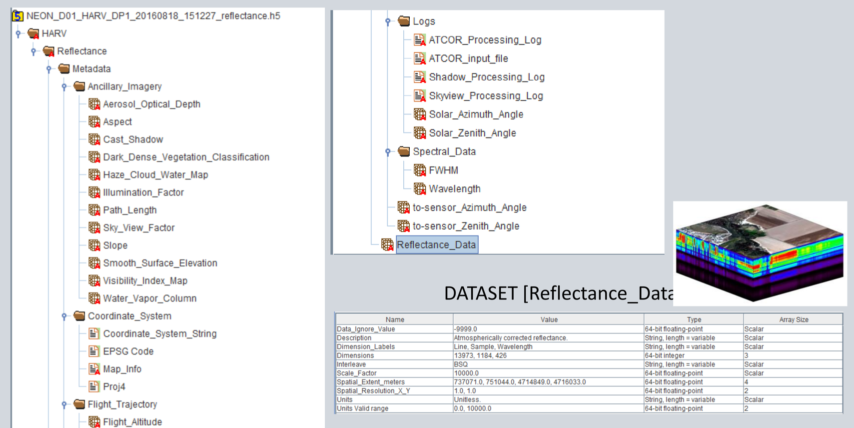
Pixel Size

NEON – AOP Dataset



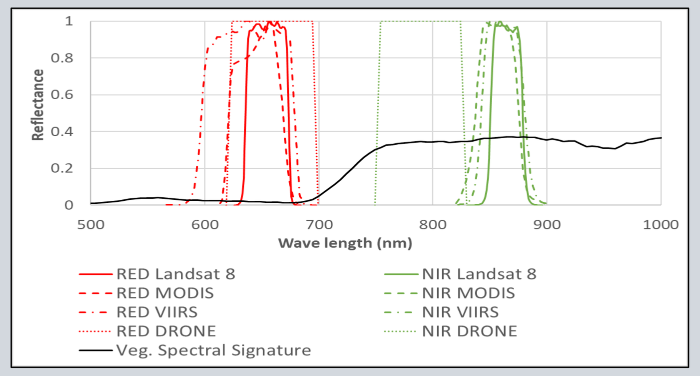
NEON AOP datasets are collections of separate files. Each file represents a flight strip containing 428 spectral bands and ancillary information.

Data File Structure



NEON Hyperspectral data is available as HDF5 files, in the UTM projection and each granule/strip is between 4-10 GB in size. A site requires a total of ~500 GB.

Relative Spectral Responses (RSR)

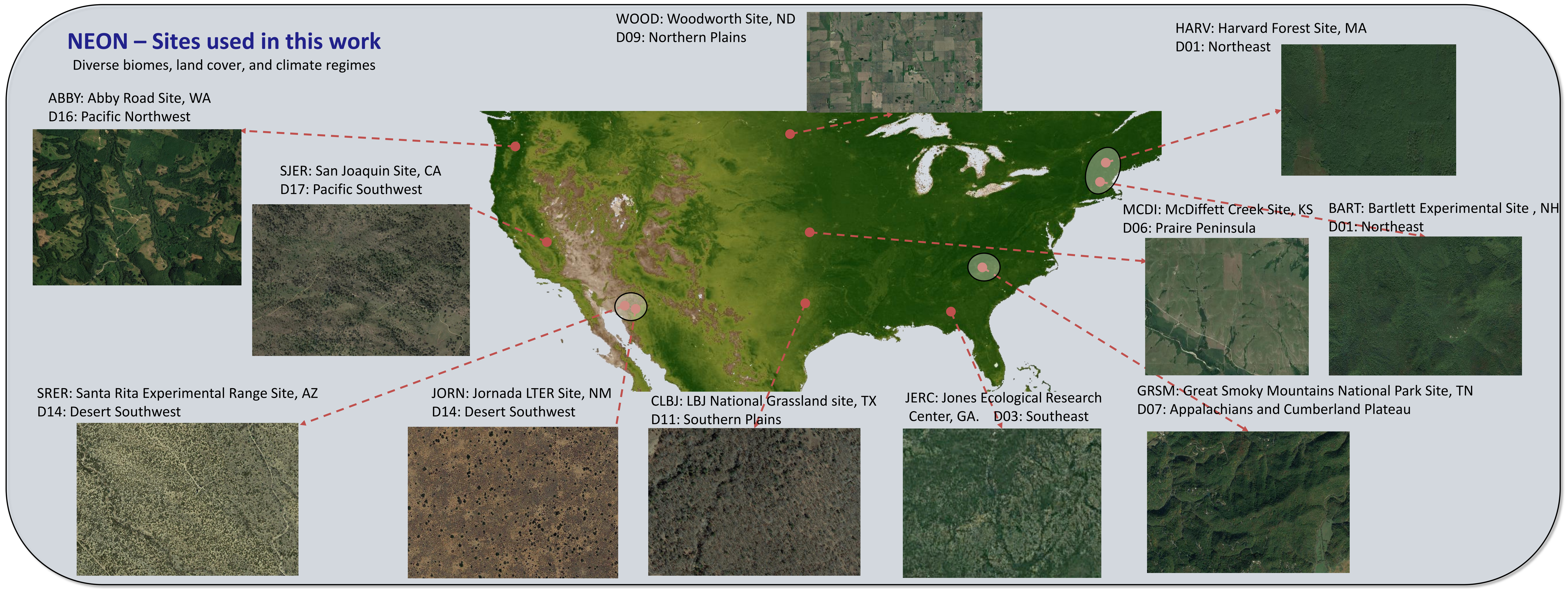


RSR measurements are assumed to be constant for all detectors covered by a common filter and are normalized to unity at peak response .

Relative Spectral Responses (RSR) are used to simulate any sensor data (i.e. VIIRS, MODIS, TM, OLI) from the hyperspectral images. This allows the simulation of any sensor spectrally and spatially. We assume that NEON-AOP, flying at 1km Above Ground Level, is the ground truth (due to the high fidelity, resolution, and lack of atmosphere. NEON data is corrected for Atmosphere using the ATCOR model).

NEON – Sites used in this work

Diverse biomes, land cover, and climate regimes

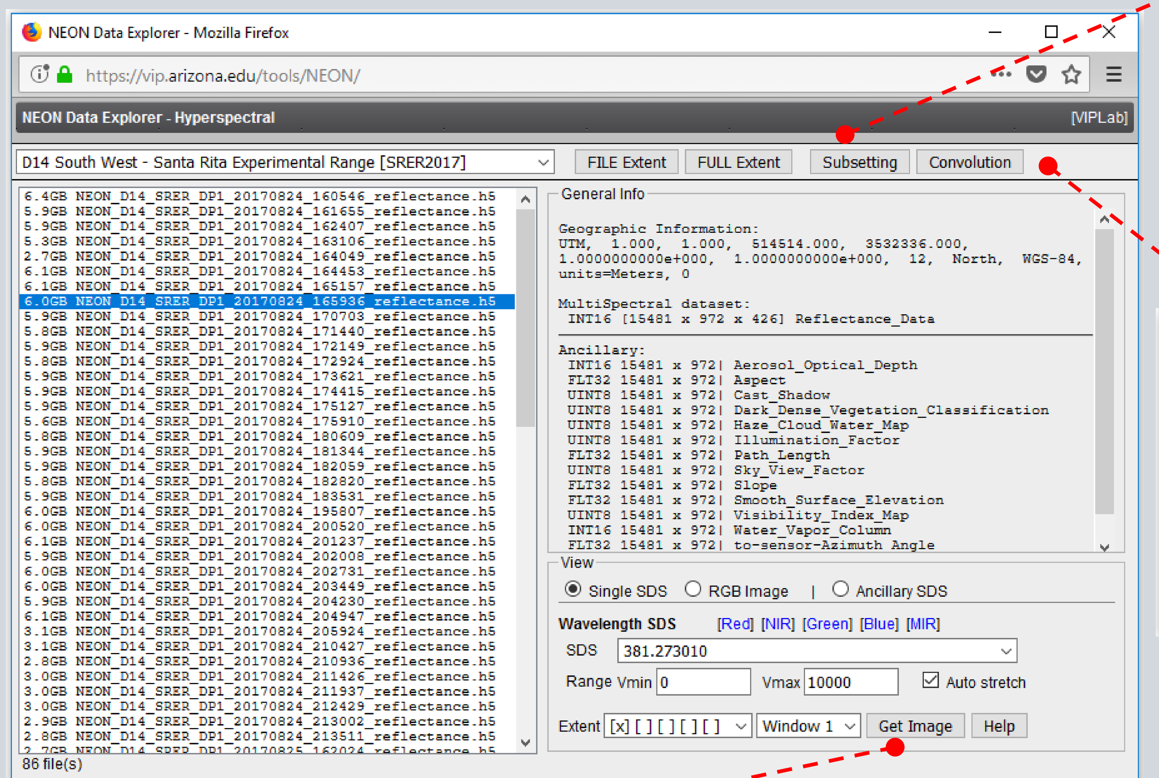


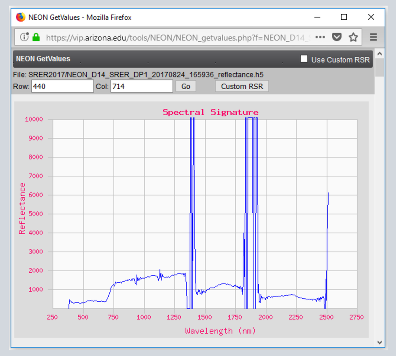
VIP NEON-AOP DataExplorer

We developed an online tool for the exploration and preprocessing of NEON AOP hyperspectral data. The tool main features are:

- Data file access and metadata browsing
- Visualization: Single band, Composites, FCC, True color, and Ancillary
- Pixel spectral signature extraction
- Mosaicking to custom spatial extent
- Spectral convolution using default sensors RSR or custom user defined SRS
- Spatial resampling and Subsetting
- Output reformatting

Main Window Application

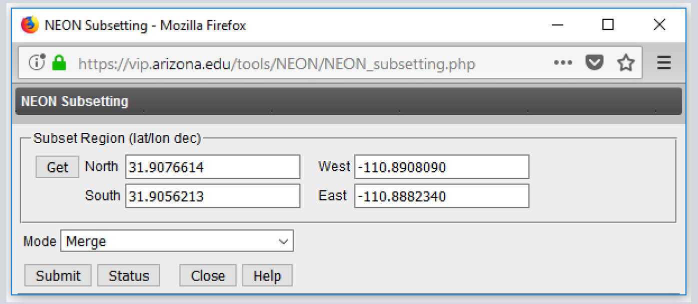




Pixel Spectral Signatures

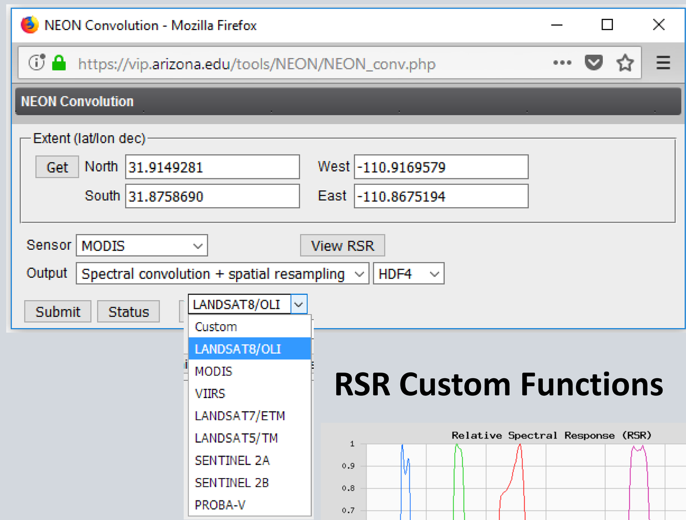
Different Visualization Modes

Dataset Subsetting



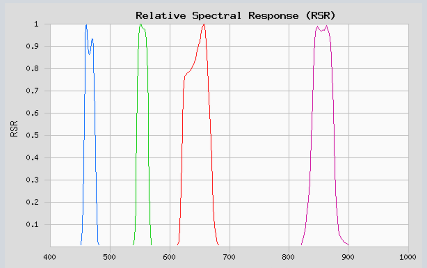
For a given extent the data files are subsetted and or merged while conserving the same data structure as input.

Spectral and Spatial Convolution



Using RSR functions, NEON bands are convolved to create a synthetic output. Spatial resampling is also applied to match the desired sensor pixel size. File formats are hdf4, hdf5, and geotiff.

RSR Custom Functions

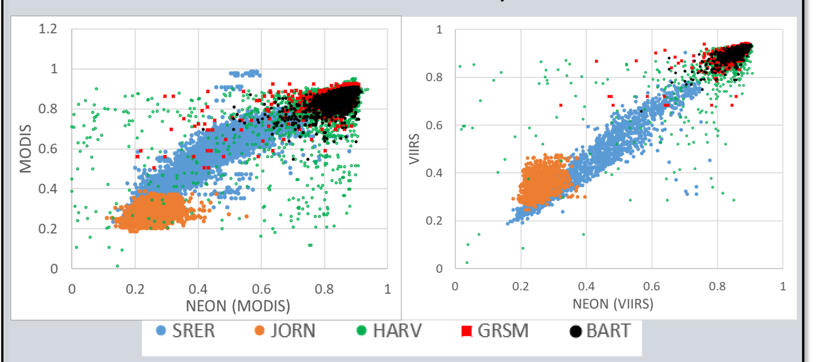


Default RSR of current sensors are directly available. The user can specify custom SRS , useful especially for drone cameras, and other sensors.

Results

We tested the tools and used the data from 5 sites to validate MODIS and VIIRS data. The NEON dataset were spectrally and spatially convolved to create a simulated MODIS/VIIRS dataset for the selected sites. We assessed the correlation between these sensors for NDVI/EVI2 and surface reflectance data.

NDVI Correlation Analysis



	MODIS					VIIRS				
	r^2	Slope	Std Error	Lower 95%	Upper 95%	r^2	Slope	Std Error	Lower 95%	Upper 95%
NDVI SRER	0.9817	1.24856	0.00191	1.24482	1.25231	0.9905	1.07493	0.00236	1.07029	1.07957
NDVI JORN	0.9754	1.08757	0.00242	1.08282	1.09233	0.9804	1.36308	0.00534	1.35260	1.37356
NDVI HARV	0.9891	0.99543	0.00121	0.99306	0.99781	0.9910	1.04187	0.00228	1.03740	1.04633
NDVI GRSM	0.9984	1.01703	0.00054	1.01596	1.01809	0.9988	1.05798	0.00099	1.05604	1.05992
NDVI BART	0.9984	1.00032	0.00071	0.99893	1.00172	0.9993	1.05234	0.00102	1.05033	1.05435
EVI2 SRER	0.9668	1.07389	0.00223	1.06952	1.07826	0.9863	1.17492	0.00311	1.16883	1.18102
EVI2 JORN	0.9777	1.14355	0.00242	1.13879	1.14830	0.9828	1.26085	0.00462	1.25179	1.26992
EVI2 HARV	0.9713	0.93144	1.01120	1.00725	1.01514	0.9778	0.93144	0.00322	0.92513	0.93775
EVI2 GRSM	0.9911	1.00044	0.00128	0.99792	1.00295	0.9726	0.90041	0.00407	0.89242	0.90840
EVI2 BART	0.9722	1.04057	0.00313	1.03444	1.04670	0.9765	0.91986	0.00509	0.90986	0.92986
RED SRER	0.9725	0.63693	0.00120	0.63458	0.63929	0.9876	1.04936	0.00264	1.04418	1.05454
RED JORN	0.9837	1.02237	0.00185	1.01875	1.02599	0.9830	0.71848	0.00262	0.71334	0.72362
RED HARV	0.8550	0.97542	0.00465	0.96631	0.98454	0.9358	0.62247	0.00374	0.61514	0.62980
RED GRSM	0.9315	0.79472	0.00291	0.78901	0.80042	0.9007	0.47716	0.00427	0.46878	0.48554
RED BART	0.9179	0.99505	0.00532	0.98462	1.00548	0.9283	0.55502	0.00551	0.54420	0.56583
NIR SRER	0.9812	0.83489	0.00130	0.83235	0.83743	0.9915	1.14130	0.00237	1.13665	1.14595
NIR JORN	0.9936	1.09360	0.00124	1.09118	1.09602	0.9942	0.89738	0.00190	0.89366	0.90110
NIR HARV	0.9664	0.86347	0.00313	0.85733	0.86961	0.9756	0.86347	0.00313	0.85733	0.86961
NIR GRSM	0.9847	0.97225	0.00164	0.96903	0.97546	0.9486	0.81341	0.00510	0.80340	0.82342
NIR BART	0.9564	1.04332	0.00398	1.03551	1.05112	0.9607	0.83419	0.00602	0.82237	0.84602

The cross-plots between MODIS/VIIRS VI/SR data and NEON simulated data indicate a high degree of correlation (R^2>=95 and p=~0, α close to 1). The Red band analysis indicates lower correlation over mostly densely vegetated forest, likely due to the S/N ratio (red values are very low).

Overall the tools was very useful in supporting the validation of these sensors and considering the potential 30-year plan for NEON these data and sites could become a valuable validation resource.

Conclusions

The high spectral and spatial resolution of NEON AOP data provide useful and accurate ground truth data to support validating synoptic coarse resolution remote sensing. While NEON data is only available once a year, during peak growing season, it does provide additional and dense field data to support the design of a solid validation protocol.

Our effort aimed primarily at reducing the tasks and resources required to process the NEON AOP data and provided an rich online environment directed at serving the land products validation community. We plan to improve this tool and make it open to the public.

http://vip.arizona.edu

http://www.neonscience.org/

vegetation index & phenology lab. ...Understanding a piece of the Earth system

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