Investigating the impact of spatially-explicit sub-pixel structural variation on the assessment of vegetation structure from imaging spectroscopy data: II Simulation approach

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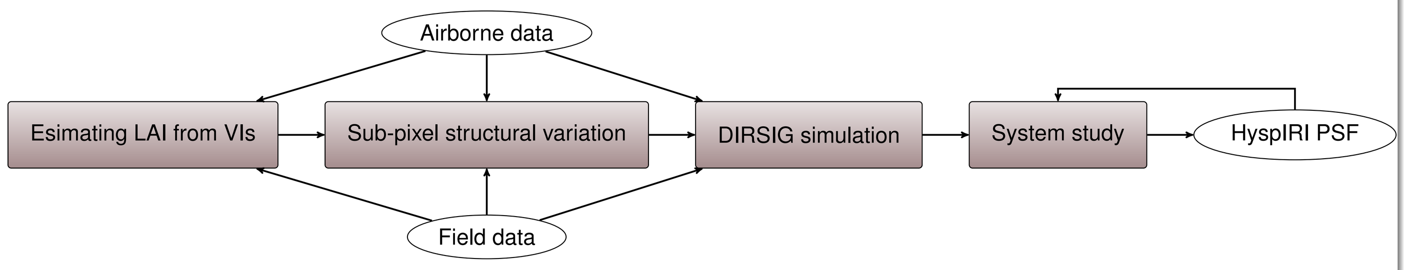
Abstract

Vegetation structure has been identified as a key input for the improvement of terrestrial ecosystem modeling. Therefore, consistent and scalable estimation of vegetation structural parameters from imaging spectroscopy is essential to remote sensing for ecosystem studies, over and above the more typical physiological assessments. The goals of this project thus were to (i) evaluate and confirm the links between structure and imaging spectroscopy, followed by (ii) an evaluation of the scalability of such assessments to the HyspIRI spatial scale.

Following last years work, we are building three virtual scenes, which correspond to the real vegetation structure of the National Ecological Observatory Network (NEON) Pacific Southwest site. Then we simulated HyspIRI data (60m GSD), AVIRIS data (15m GSD), and NEONs high-resolution spectrometer data (1m GSD). We also simulated our field sensor that measures leaf area index (LAI) in order to better understand the spatial variation in one such structural parameter (LAI). We are confident about our simulation results, since the geometric parameters and physical models were verified by the AVIRIS data, NEONs data, and field sensor measurements. More details will be presented at the workshop.

Project outline

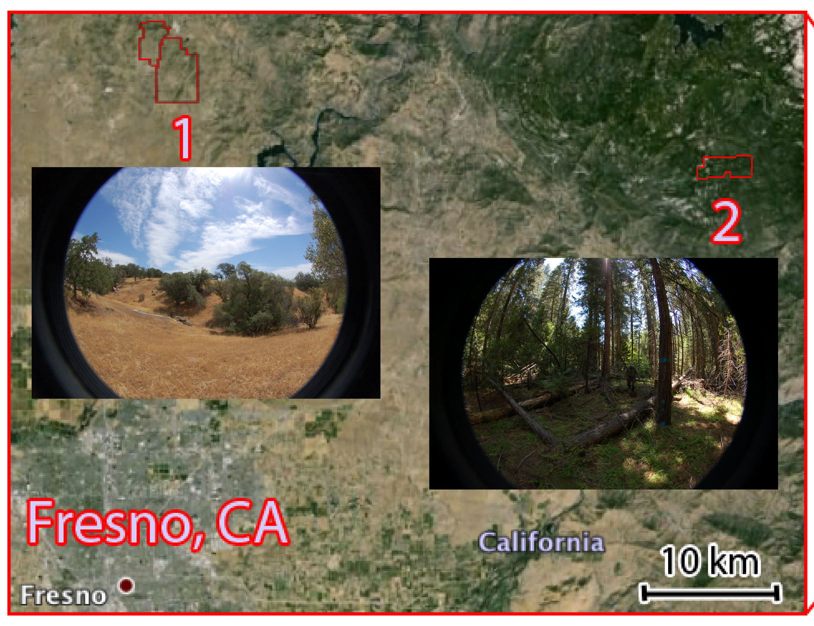
Our project consists four stages. In 2013 (Stage 1), we worked on data collection and estimating LAI from AVIRIS-based vegetation indices (VIs). In 2014, we focused on stages 2 & 3: Sub-pixel structural variations were assessed from airborne and ground data, in tandem with the construction of virtual scenes, based on these data, followed by performing a series of DIRSIG simulations. Stage 4 will conclude with results from the simulation.



Study area

The National Ecological Observatory Network (NEON) Pacific Southwest site is located in the central part of California.

1. San Joaquin Experimental Range (core site)
2. Soaproot Saddle (relocatable site)



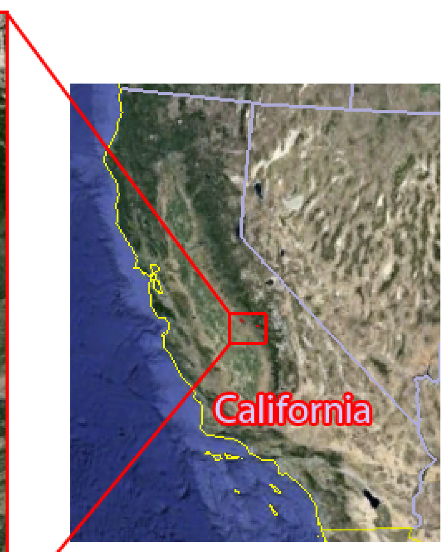
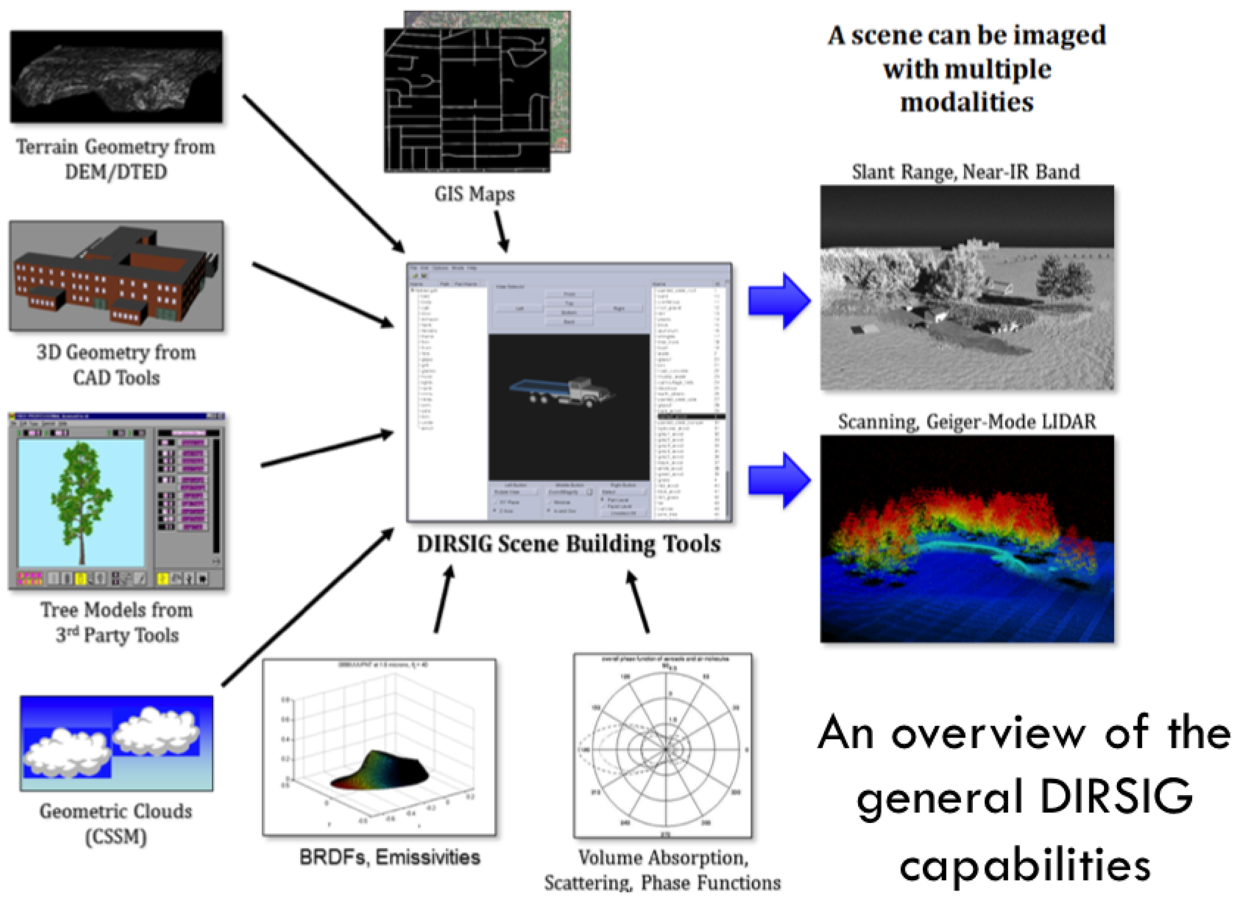


Figure from Google Earth

DIRSIG

The *D*igital *I*maging and *R*emote *S*ensing *I*mage *G*eneration (DIRSIG) model is a first principles based synthetic image generation model developed by the Digital Imaging and Remote Sensing Laboratory at Rochester Institute of Technology. The model can produce passive single-band, multi-spectral or hyper-spectral imagery from the visible through the thermal infrared region of the electromagnetic spectrum. The model also has a mature active laser (LIDAR) capability and an evolving active RF (RADAR) capability. The model can be used to test image system designs, to create test imagery for evaluating image exploitation algorithms and for creating data for training image analysts.

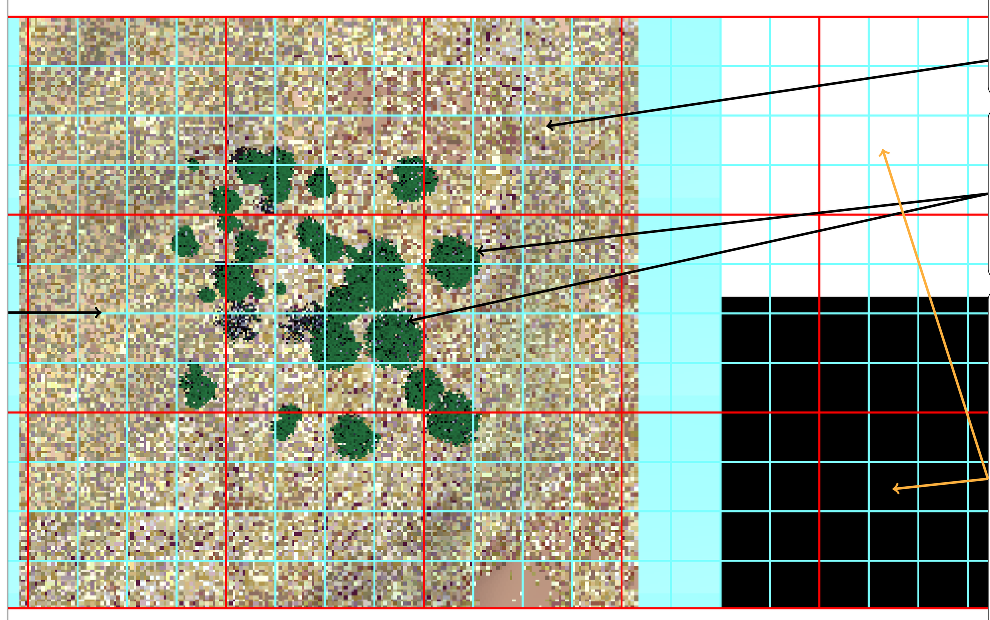


An overview of the general DIRSIG capabilities

Methodology

Three virtual scenes were first constructed, which correspond to the actual vegetation structure of our study area.

Virtual scene
The size of the virtual terrain is 180 × 180 meters, which corresponds to 3 × 3 HyspIRI pixels (60m GSD, red grid) or 12 × 12 AVIRIS pixels (15m GSD, cyan grid). The center 80 × 80 meters area corresponds to the actual vegetation structure of our study area.



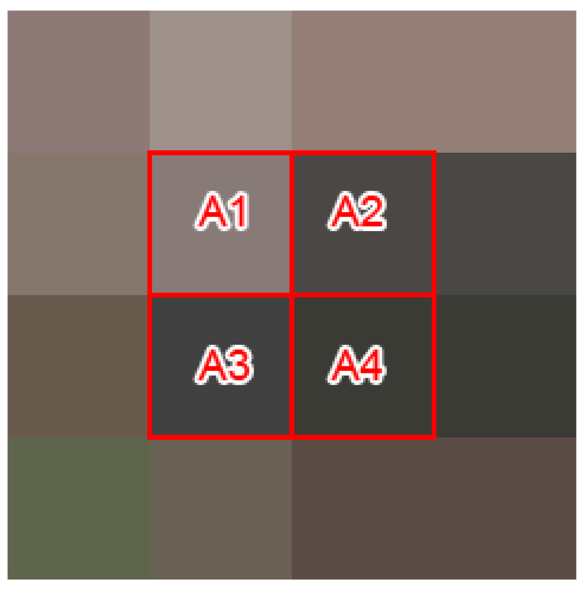
Terrain
Elevation is derived from the airborne lidar data.

Tree
3D tree models are generated by OnyxTREE.

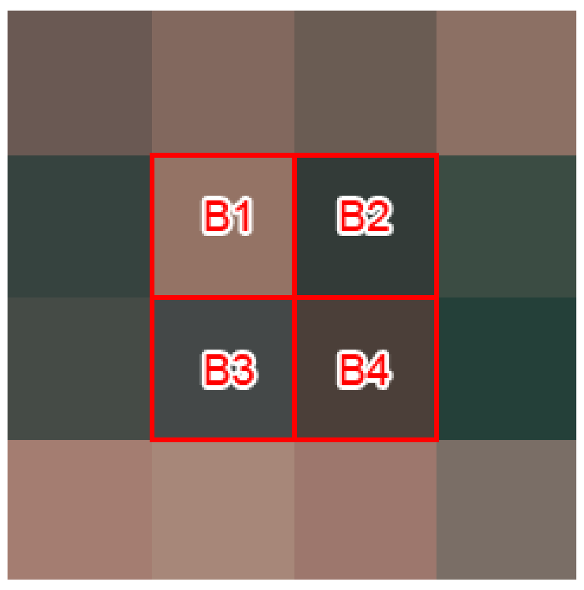
Calibration panels
Two black panels and two white panels are placed at the corners and used as reference objects for empirical line method(ELM) atmospheric compensation.

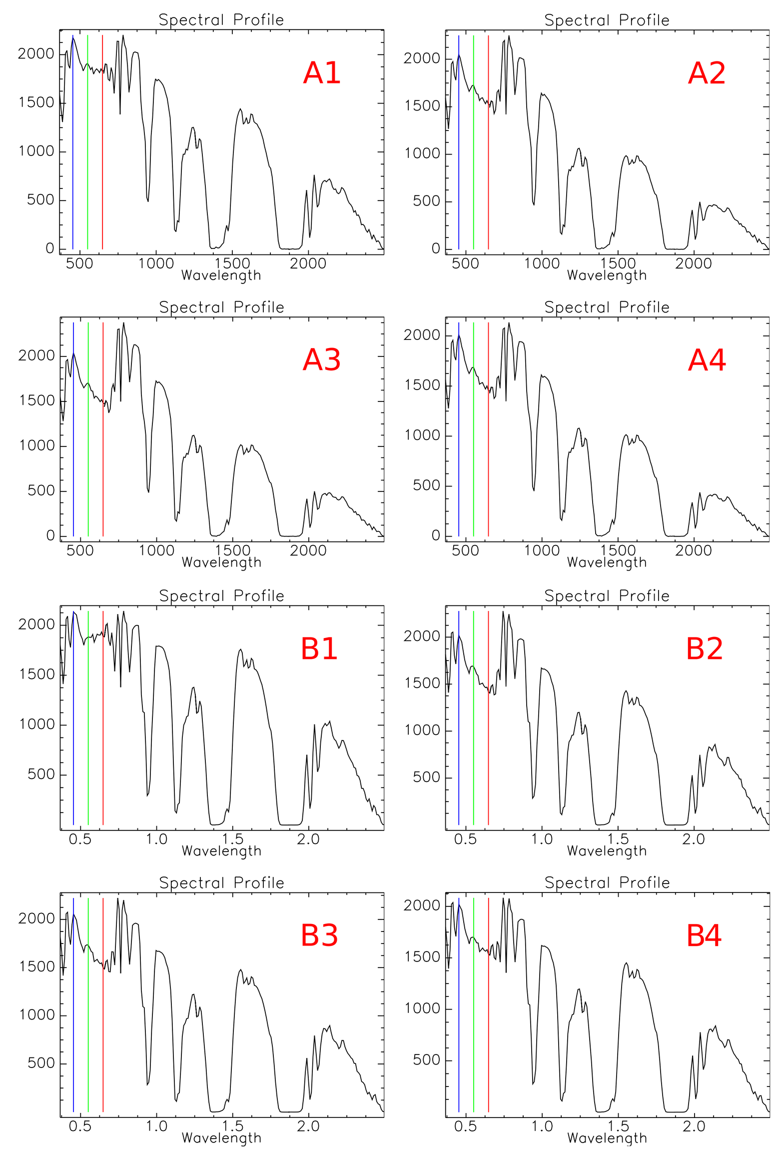
Secondly, the HyspIRI data (60m GSD), AVIRIS data (15m GSD), and NEONs high-resolution spectrometer data (1m GSD) were simulated via DIRSIG. AVIRIS and NEONs high-resolution spectrometer data were used to verify the geometric parameters and physical models. The figures below show the AVIRIS radiance spectra and simulated spectra of AOP site 116.

AVIRIS data

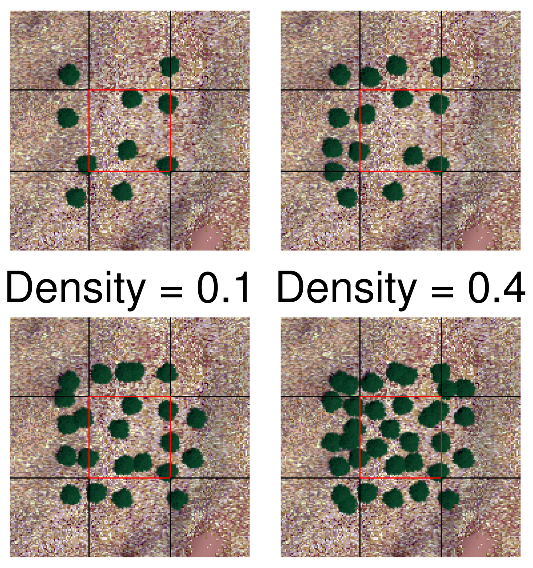


Simulated data



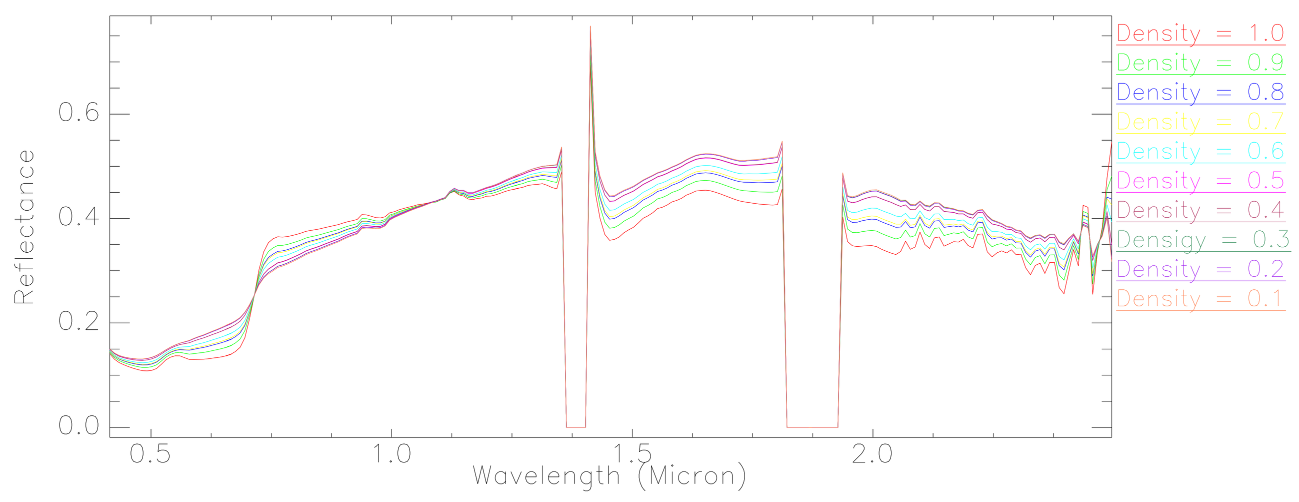


Thirdly, multiple simulated HyspIRI data sets were generated by varying within-pixel structural variables, such as the density of the “forest”, the position and distribution of trees, the height of trees, and the crown size. The figures below show a series of simulations with different forest densities and corresponding HyspIRI spectra.



Density = 0.1 Density = 0.4

Density = 0.7 Density = 1.0



Conclusion

Early results indicate that HyspIRI is sensitive to sub-pixel vegetation structural variation in the blue and red spectral regions due to pigment concentration changes, as well as the SWIR region due to water content variation. Therefore, the system's suitability for consistent global vegetation structural assessments could be improved by adapting calibration strategies to account for this variation in sub-pixel structure.

Future work

Next year, we plan to increase the number of simulations to investigate the impact of spatially explicit sub-pixel structural variation on the spectroscopy data. We then will employ statistical methods (e.g., wavelength pair-wise comparisons, derivative analyses, etc.) to verify our hypotheses:

1. Fine-scale, within-pixel structural assessments can be used to improve our understanding of HyspIRI-based estimates of leaf area, leaf area index (LAI), and vegetation biomass;
2. From a systems perspective, the spatially explicit within-pixel structural variations are quantifiable when it comes to their impact on the HyspIRI systems response (point spread function);
3. An improved understanding of (1) and (2) will lead to proper calibration of HyspIRI based vegetation structure estimates.

Acknowledgements

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