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Remote VSWIR Imaging spectroscopy for Global Discovery and Conservation Science

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Objectives

This project applied advanced new imaging spectrometer algorithms for terrestrial ecosystem observations, advancing the science and practice of imaging spectroscopy for global conservation. Specifically, it aimed to demonstrate new measurement methods exploiting the entire visible infrared range to characterize functional diversity in tree species. This analysis included consideration of measurement accuracy, atmospheric correction, and controlling for variance due to canopy shading and substrate effects. Demonstrating robust retrieval of these parameters will be important for a range of future JPL-led NASA missions, including the Surface Biology and Geology investigation. We decided to focus this research effort on a case study involving characterization of an indigenous tree species, Metrosideros polymorpha, also known as Ohi'a, across the island of Hawai'i. Ohi'a shows significant variability and morphology and canopy chemistry, resulting from the pressures of local environmental conditions which vary widely over elevation and soil composition. We used this field experiment as a laboratory to explore the potential of imaging spectroscopy data for characterizing intra species trait variability, and the degree to which this variability manifests in diversity of spectra.

Background

Functional diversity, and specifically the variability in competitive strategies along the leaf economic spectrum – favoring fast growth, leaf longevity, or resistance to disturbance – is an important predictor of ecosystem productivity and resistance to disruption. This variability is hypothesized to manifest in measurable differences in the top-of-canopy reflectance signature measured remotely by visible-shortwave infrared spectrometers. This study shows the ability of imaging spectroscopy to map within-species variability, demonstrating a new level of sensitivity to plant variation. This raises the bar for the sensitivity and sophistication of ecosystem measurements that might be made by SBG.

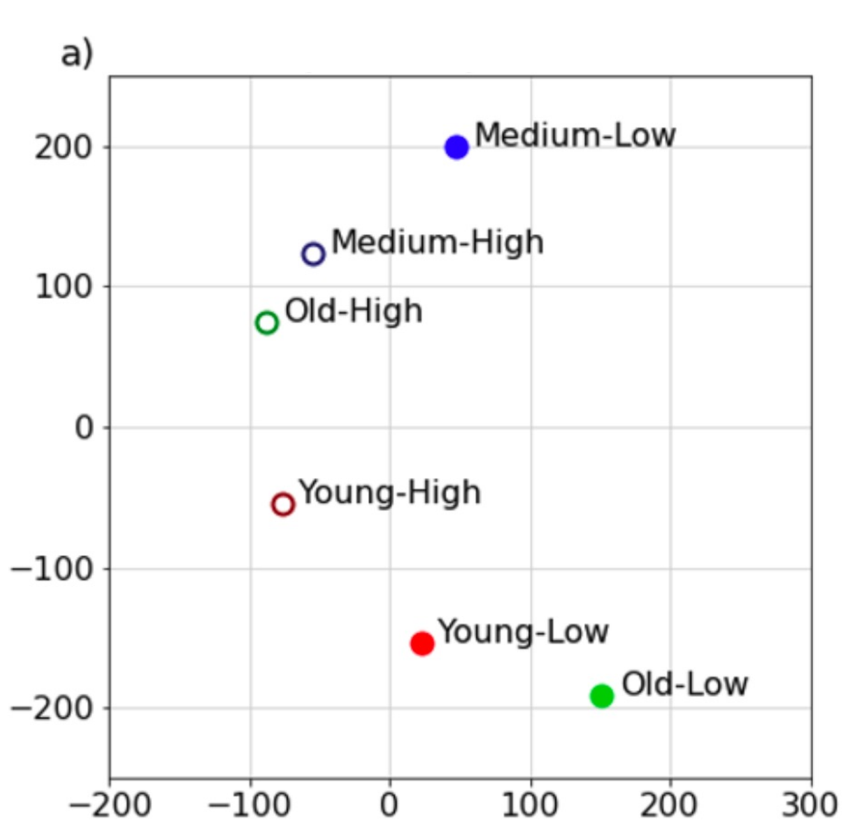

Figure: Euclidean distances between sites, projected into 2D space via multidimensional scaling.

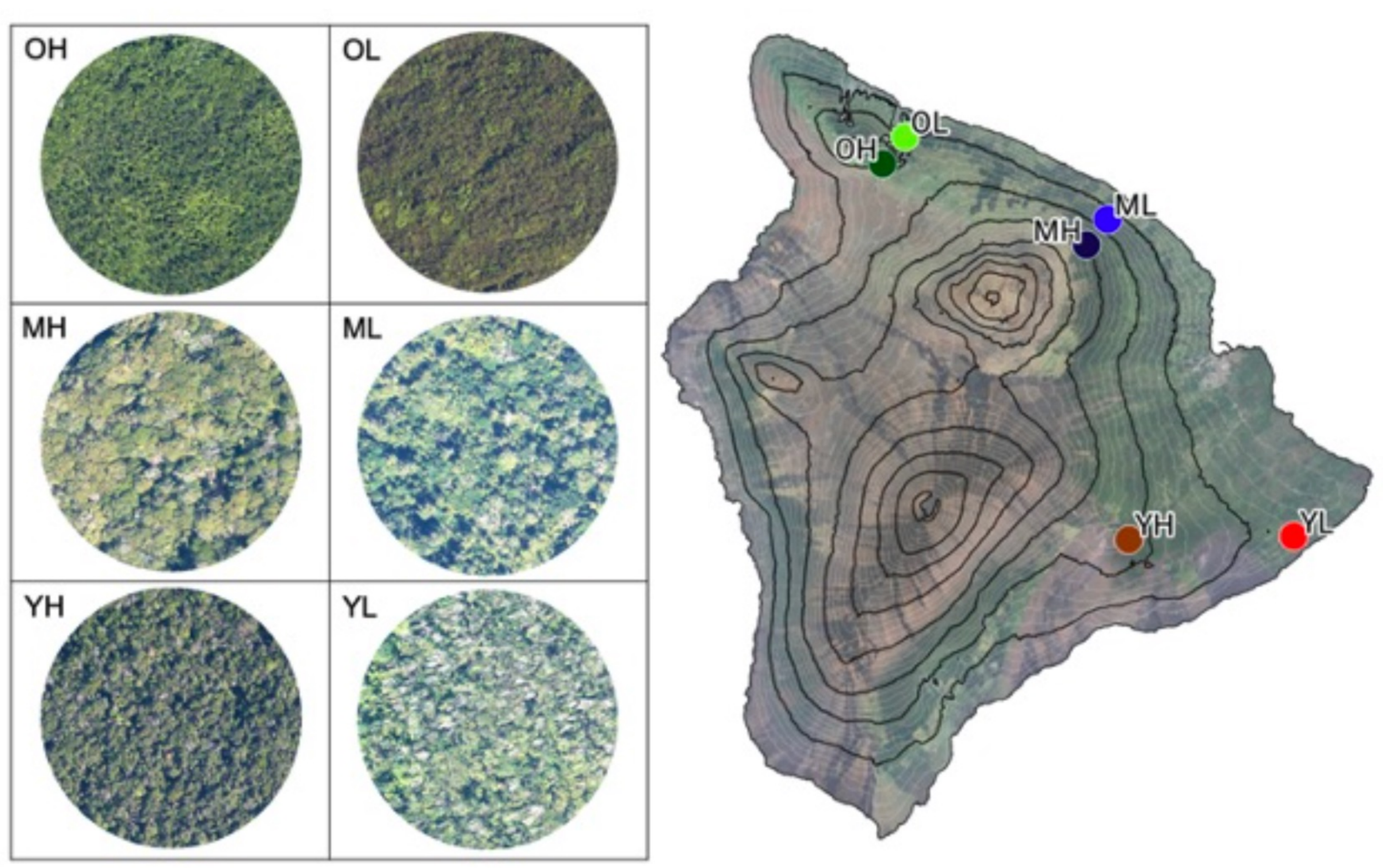

Figure: Global Airborne Observatory Digital Modular Areal Camera (DiMAC) imagery of six study sites in red, green, and blue (true color) composites (left). Locations of the sites on Hawai'i Island (right). The sites are located along soil substrate age (Y-young <200-750; M-medium 5,000-64,000; O-old 260,000-500,000) and elevation (L-low 200-900 m; H-high 1,100-1,500 m) gradients.

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Approach and Results

The spectra of closed canopy M. polymorpha forests were compared to assess the effect of environmental filtering on the functioning of a single species. We found that the spectra of six forest sites differed along soil substrate age and elevation gradients. These results are consistent with prior work describing heritable morphological differences between M. polymorpha populations at high and low elevations, as well as on lava flows of different ages. Inter-site variability was greatest across elevation gradients, as opposed to soil substrate age gradients, which supports other field-based work observing stronger phenological responses in M. polymorpha to elevation than soil substrate age. While elevation was a stronger driver of inter-site variability, soil substrate age was the primary determinant of intra-site variability. Coefficient of variation and intrinsic spectral dimensionality analyses demonstrate a clear hierarchical pattern of variation within each site, where the intra-site variation organized first by soil substrate age then elevation.

This application of imaging spectroscopy data to a model system demonstrated the potential for canopy reflectance data to address forest community assembly at large spatial scales. Observed differences in the reflectance spectra at the six sites were underpinned by variation in canopy leaf traits. The high spectral resolution of imaging spectroscopy has allowed canopy water content and foliar traits such as N, net primary productivity, and lignin, to be directly measured from aircraft. We have demonstrated the ability to assess intra-site and inter-site variability of canopy traits using canopy spectra and how the spectral variability follows a well-known model system. As imaging spectroscopy data become more widely available with the upcoming launch of spaceborne spectrometers, the ability to use these data to explore community assembly across even larger spatial scales will advance our understanding of forest functioning at a global level.

Significance/Benefits to JPL and NASA

Imaging spectroscopy is a growing tool for understanding ecosystem functioning at large spatial scales, yet the application of this technology to assess intra-specific trait variation across environmental gradients had been poorly tested. Selection for specific genotypes via environmental filtering plays an important role in driving trait variation and thus functional diversity across space and time, but the relative contributions of intra-specific trait variation and species turnover are still unclear. By demonstrating species-specific variability across different elevational and soil gradients, this study helped to address this important question, and further demonstrated the utility of imaging spectroscopy for mapping intra-species variability.

Publications

Seeley, M., Martin, R. E., Vaughn, N., Thompson, D. R., Dai, J., & Asner, G. P. Quantifying the spectral variation of *Metrosideros polymorpha* canopies across environmental gradients. *Ecological Applications,* submitted.

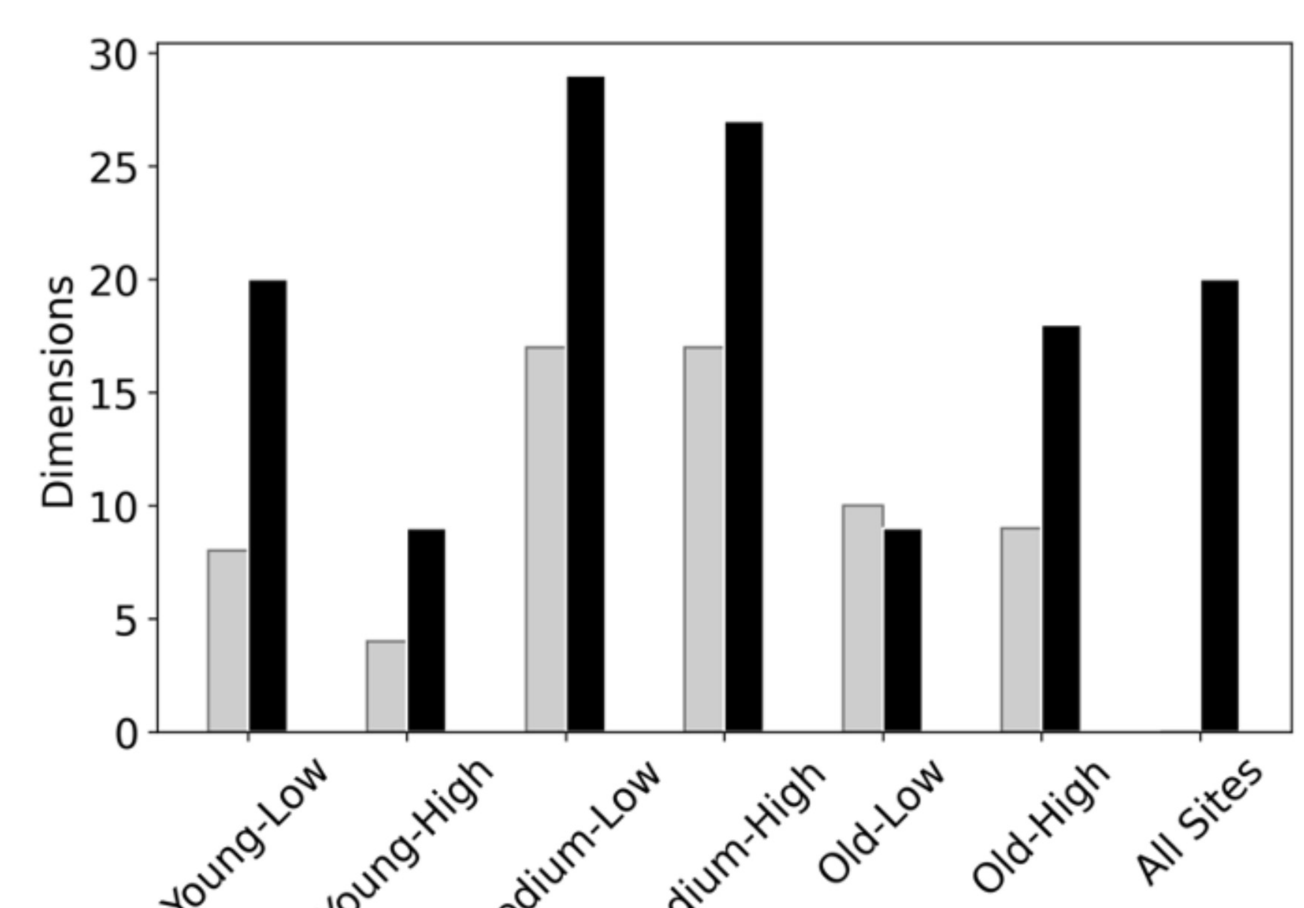

Figure: The intrinsic spectral dimensionality of each site calculated using both a local (grey) and global (black) principal component analyses (PCA) applied to the filtered reflectance data. The areal extent of each site was controlled, such that the area of each site used in the analysis was equivalent. The intrinsic spectral dimensionality was calculated for the "All" category used all the sites combined and only the global PCA.

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