Estimating biodiversity of dry forests and coral reefs with hyperspectral data: a NASA EPSCOR project at UPRM

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PRYSIG December 11 2009

Outline

- Project goals
- Student education and research
- Study area
- Hyperspectral Image Processing
- Analysis and validation
- Anticipated Results

Objectives

- Develop spectrally-derived protocols for designing sampling schemes to estimate alpha-beta and gamma diversity
- Develop novel approaches integrating remote sensing and field data to assess and model components of ecosystem biodiversity
- Utilize hyperspectral image analysis techniques to estimate forest condition and reef condition

Education

- Train 6-8 graduate and 8-10 undergraduate students from underrepresented groups in remote sensing, advanced processing tools, hyperspectral imaging and terrestrial and coastal ecology

- Collaboration between faculty in Science, Agriculture and Engineering at UPRM and with NASA, GRC, GSFC, ARC and JPL, US Forestry service in PR and PR department of Natural Resources

What is ecosystem biodiversity ?

- Defined as variety of all forms of life from genes to broad scale of ecosystem
- Alpha diversity – diversity at a place or community
- Beta diversity – diversity between places or changes in alpha diversity
- Gamma diversity – overall diversity of a region; cumulative species of different communities

Estimators of biodiversity

- Estimates of similarity or difference of biodiversity from place to place – biodiversity surrogates (Sarkar, 2002)
- Difference in composition between places
- Species richness – total counts of species; is estimator surrogate for species diversity
- Other estimators – environmental parameter composition (NDVI and NPP), vegetation types, species composition
- Heterogeneity or spectral diversity in satellite imagery (Rocchini, 2009)

Previous Work

- Spatially estimate structure and diversity of forest using Hyperion imagery applying wavelet decomposition image processing methods (Kalackska, 2007)

- Retrieving vegetation cover using Hyperion and Quick Bird data (Huang et al, 2007)

- Estimating biodiversity at Yellowstone ecosystem using Landsat and GIS data (Debinski et al. 1999)

Study Area

- Coral reef – La Parguera (Enrique reef)
- Dry tropical forest - Guanica
- La Parguera ecosystem: shallow coral reef, sand, seagrass, mudflats, deeper areas of coral, sand and mud, deep offshore wall on western edge
- Guanica ecosystem: inland forest with zones of grassland, shrubs and cactus, mangrove forests.

Guanica forest

Benthic Habitat

Seagrass

Head coral

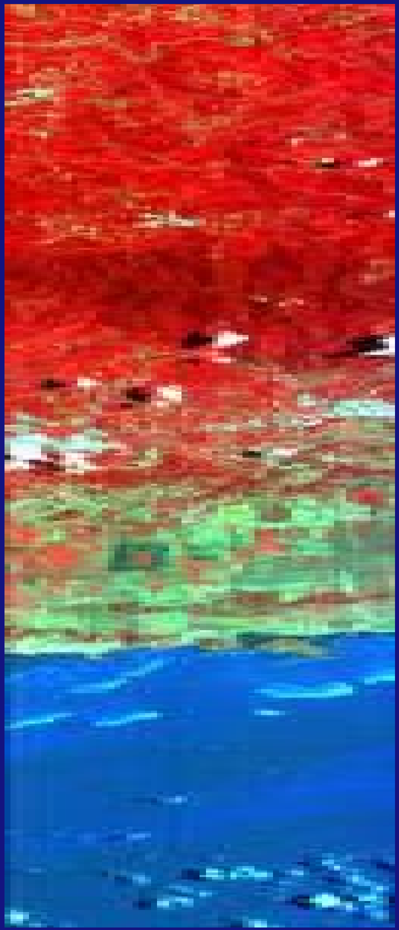
Algae and Coral

Aerial Image

Existing Data

- La Parguera: field data collected between 2001-2008 with a spectral library of benthic components
- 52 permanently marked study plots on tree growth, forest structure and phenology
- Hyperion hyperspectral imagery of both areas: 196 bands from 400 to 2500 nm at 10 nm spectral sampling interval. Spatial resolution 30 m

Hyperion Images of La Parguera



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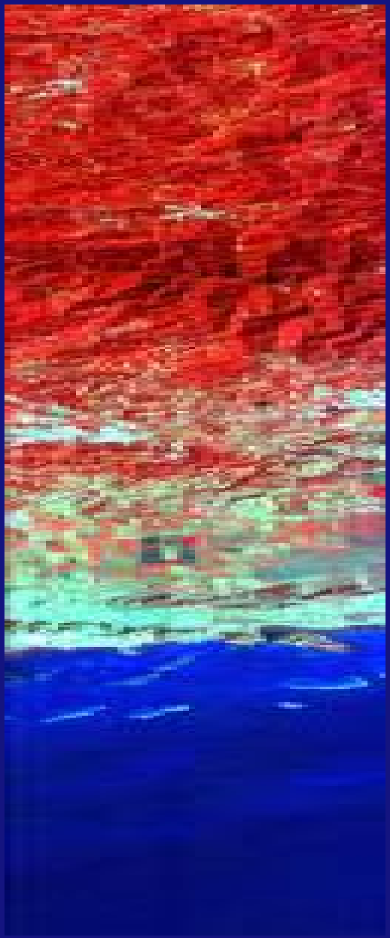

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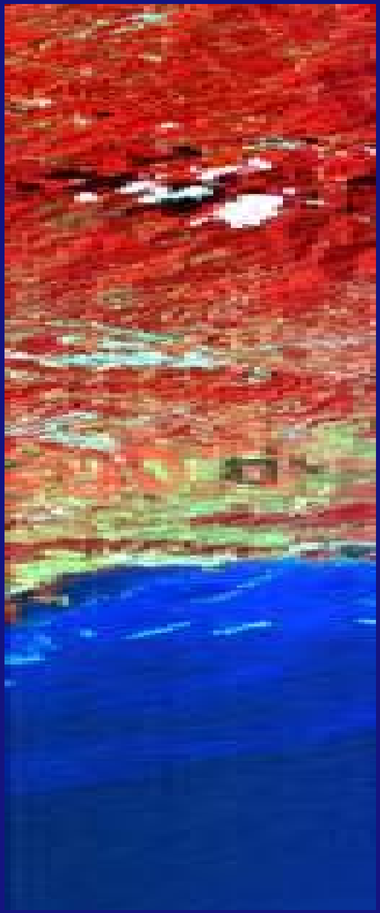

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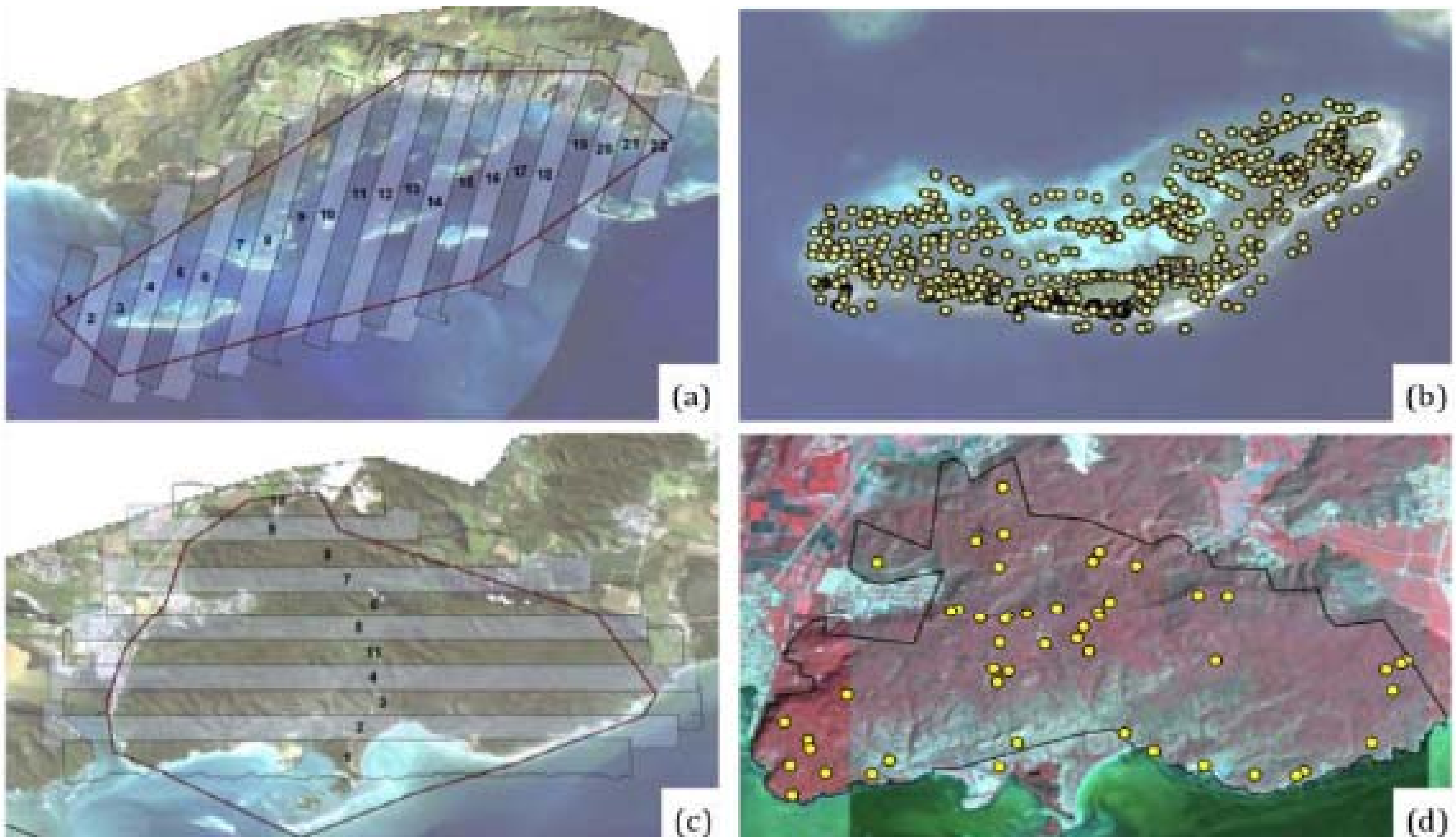
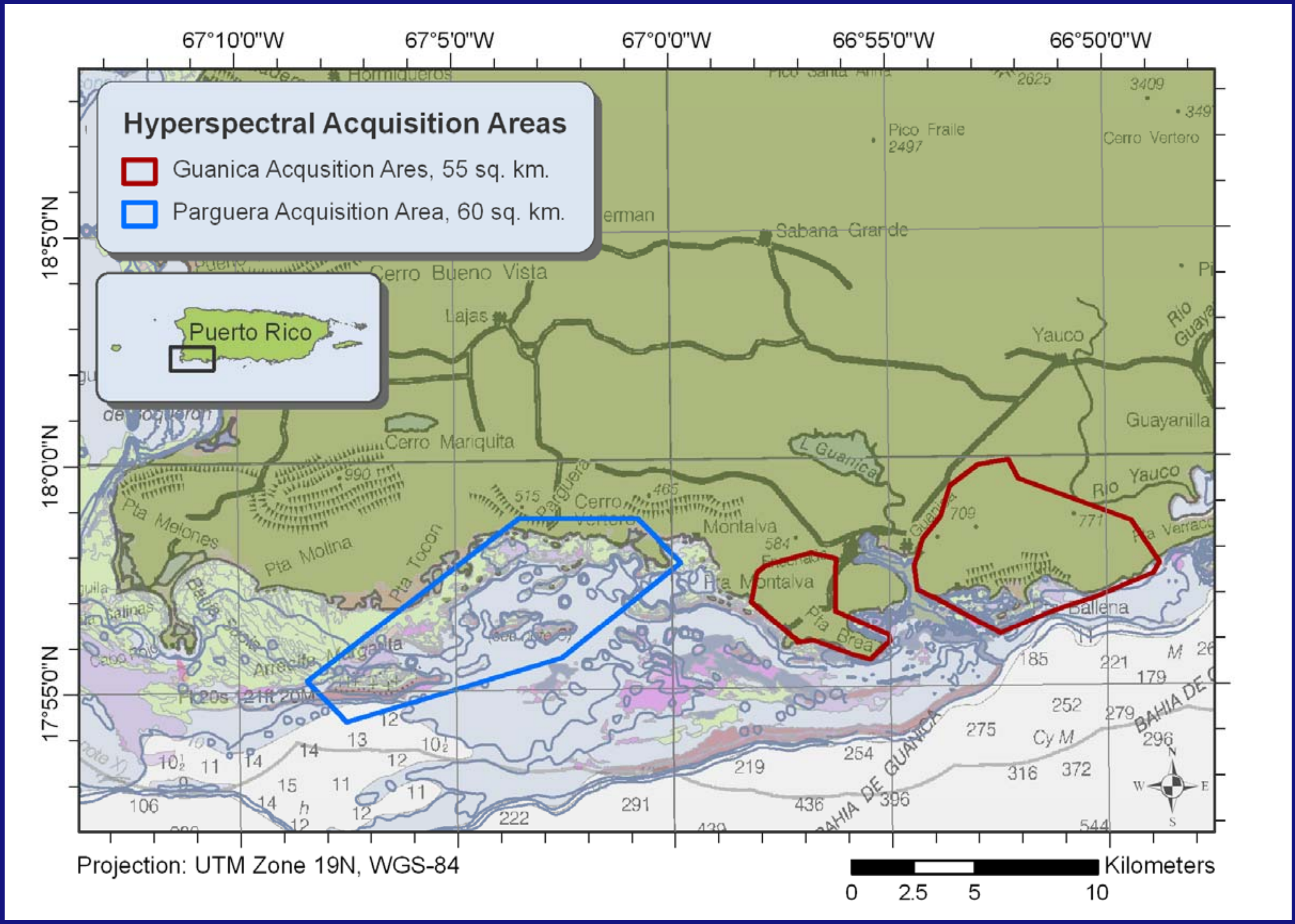
AISA Imagery of La Parguera, Guanica, December 2007

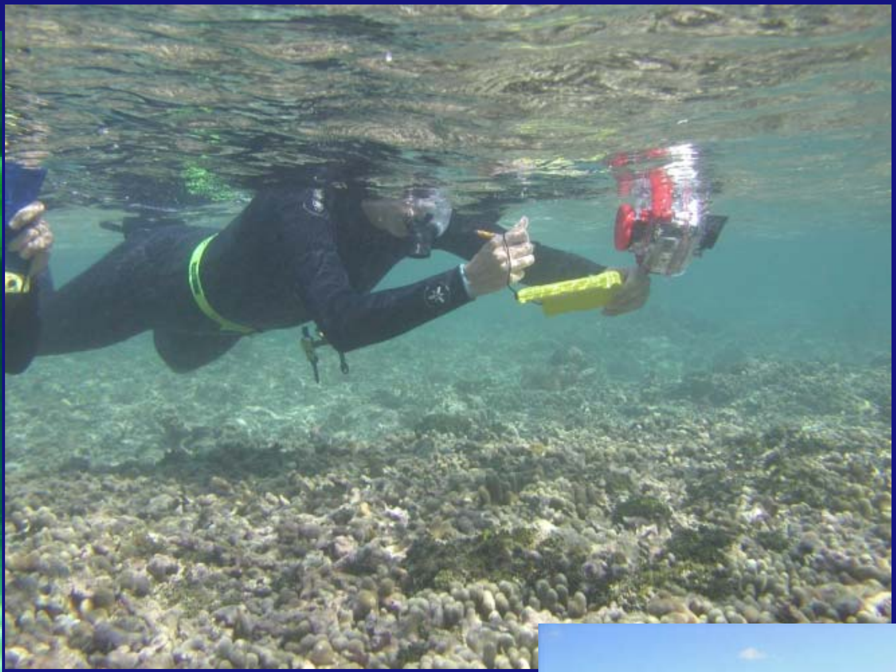


(a) 1m imagery of La Parguera, 22 flightlines (b) georeferenced photos For Enrique reef – 622 points (c) Guanica 11 flightlines, (d) georeferenced 51 plots

Data Acquisition: Jan 25 –Feb 3 2010



Field work

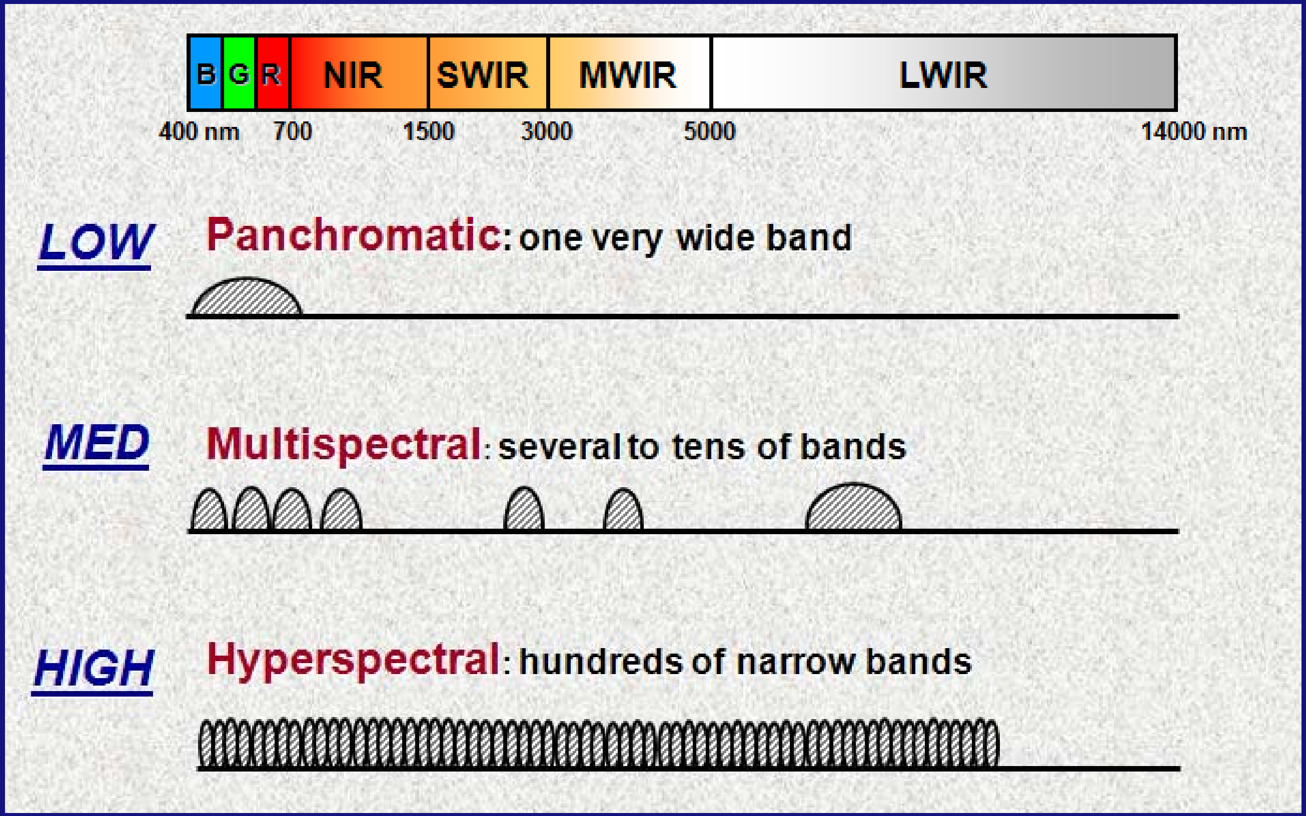


Remote Sensing using Hyperspectral Images

- Quantitative analysis of biodiversity using hyperspectral images
- Goal: Use high spectral resolution imagery to estimate the presence or abundance of different species by their spectral response patterns

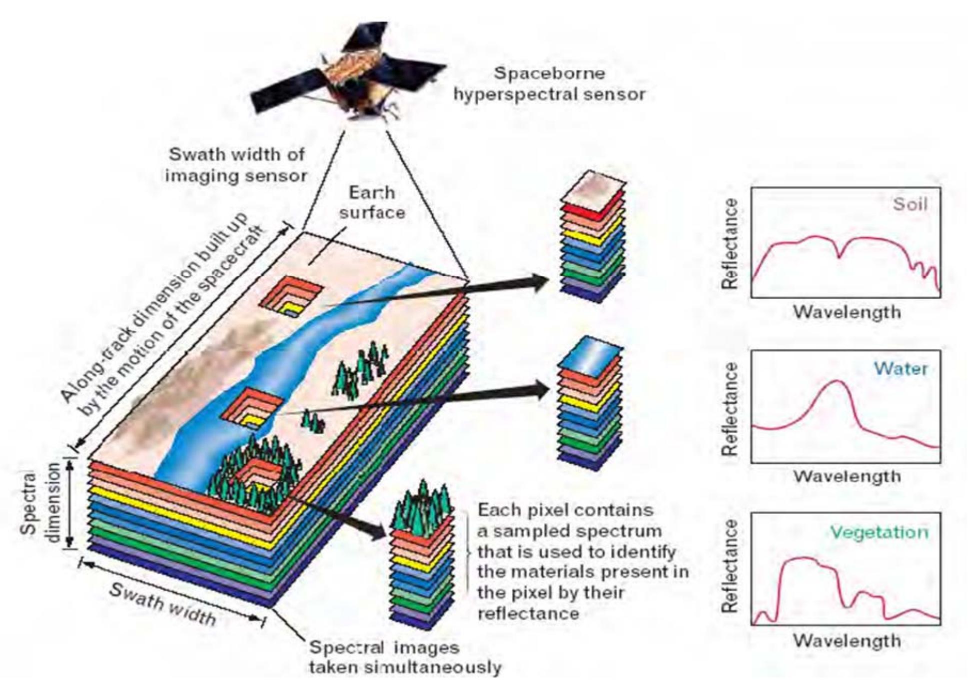
Spectral Resolution

- Number and dimension of specific wavelength intervals, referred to as bands or channels.

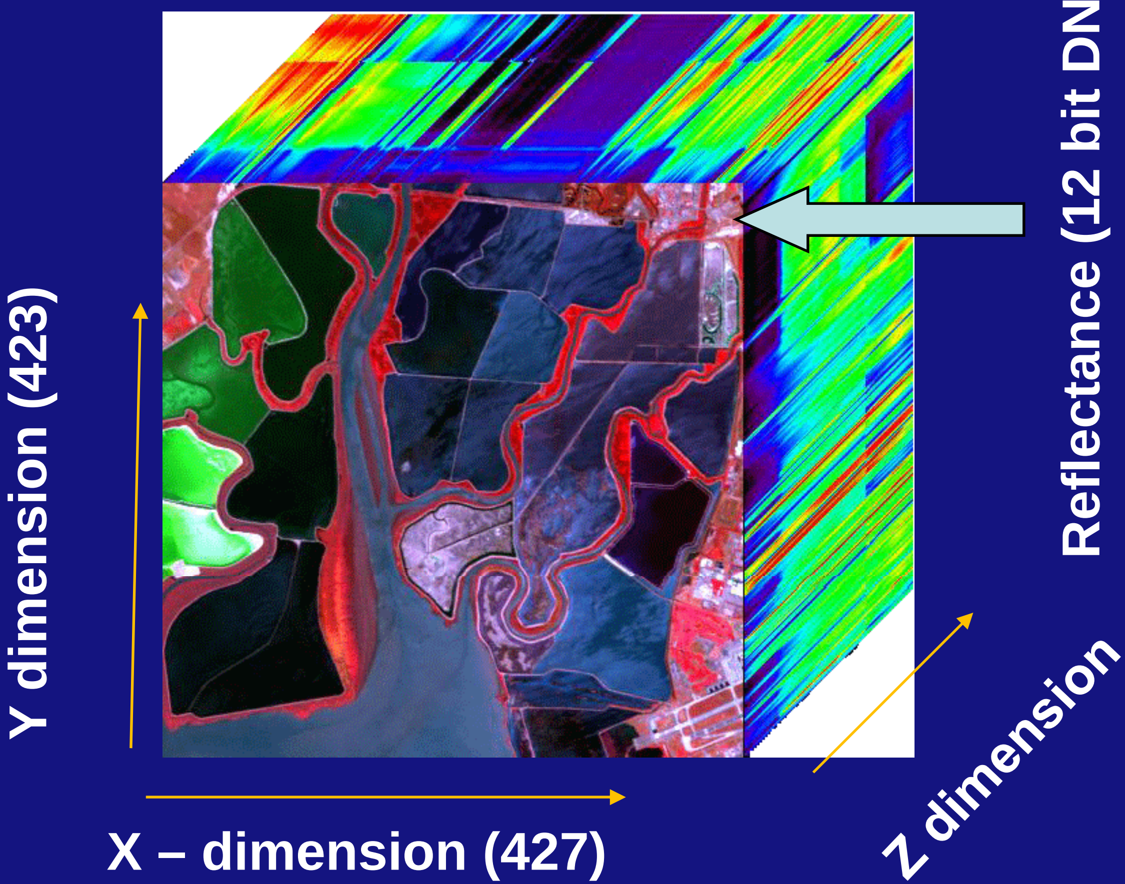


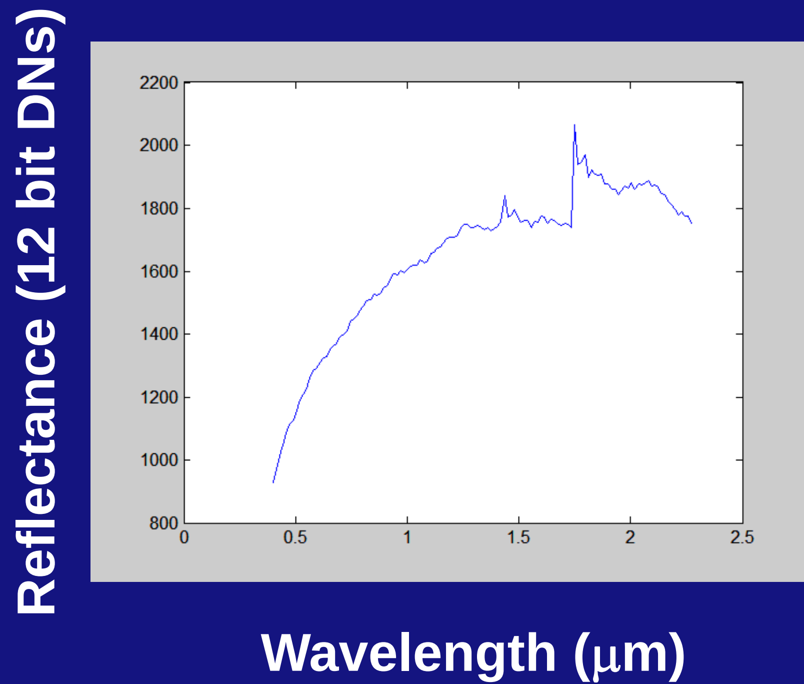
Hyperspectral Images

- Large amounts of data taken at narrow and contiguous spectral bands.
- Helps to discriminate better between different objects.
- Frequently used
  - Land cover classification
  - Detection and target recognition
  - Search and rescue operations
  - Biomedical applications



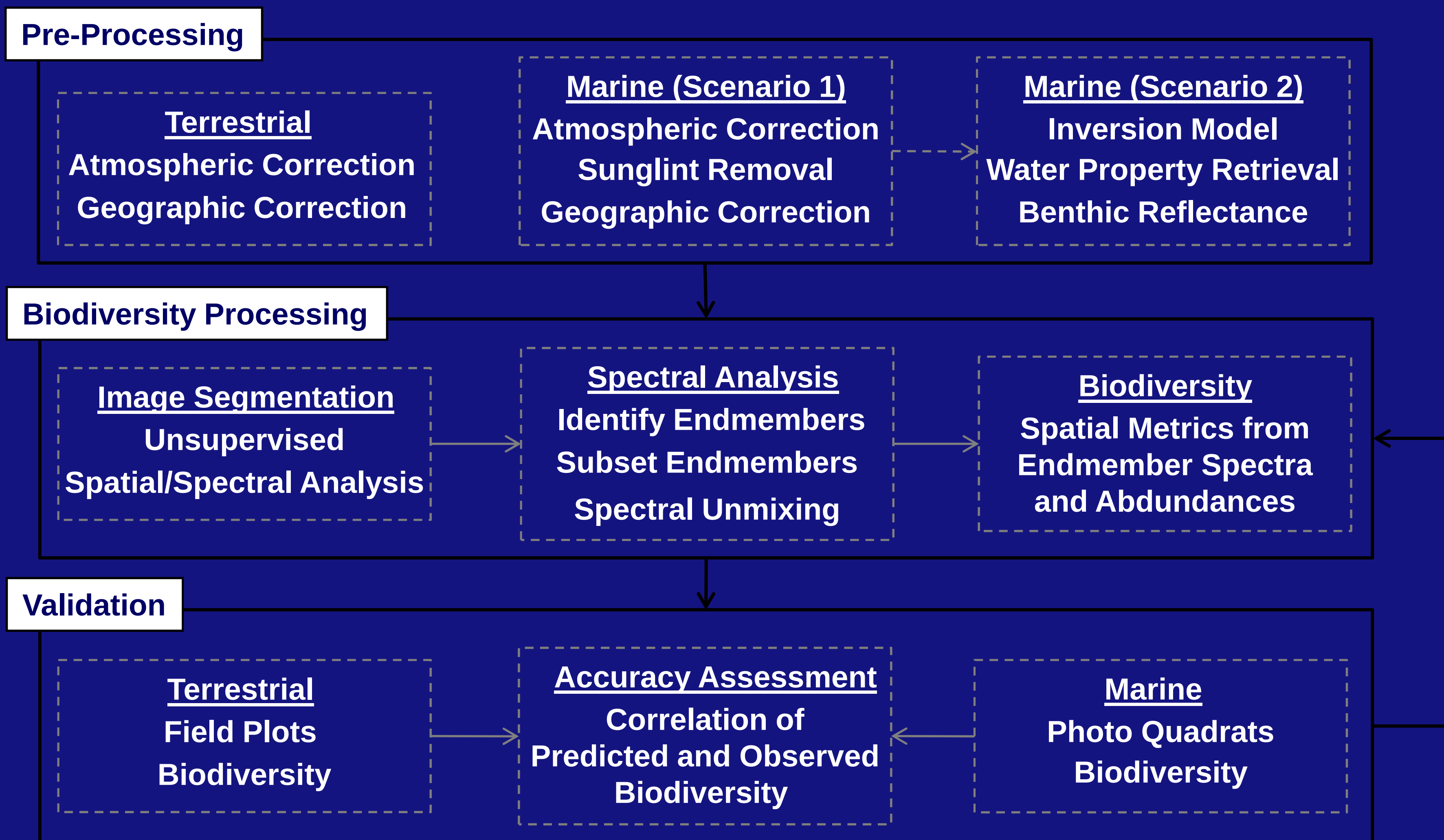
Example of Hyperspectral Image





AVIRIS data-224 spectral Bands 0.4-2.4 μm with 20m spatial resolution

Hyperspectral Image Processing Approach



Hyperspectral Image Processing

- Goal: utilize available spectral, spatial and temporal information
- Data Pre-processing: atmospheric correction using FLAASH, sunglint removal, reduce striping, improve SNR
- Apply inversion model of Lee to derive bathymetry and water properties for every pixel

Unmixing

- The measured spectrum of a pixel is decomposed into a collection of spectra, or endmembers and a corresponding set of fractions or abundances
- Separations of different components in landscapes with mixed communities and variable plant densities
- Linear Mixing Model: $x = Sa + w$
- Positive Matrix Factorization (Masalmah and Velez-Reyes, 2008)

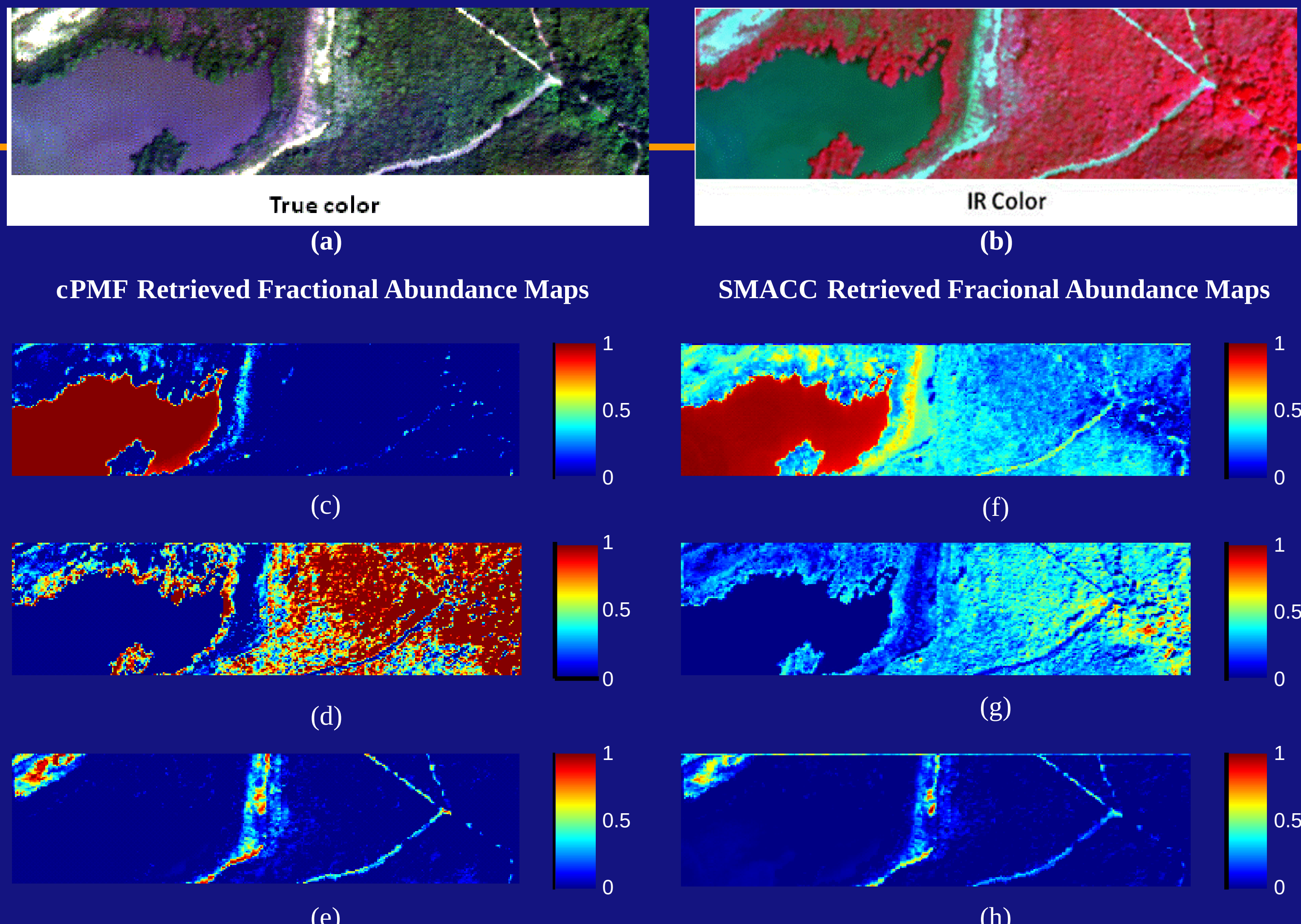
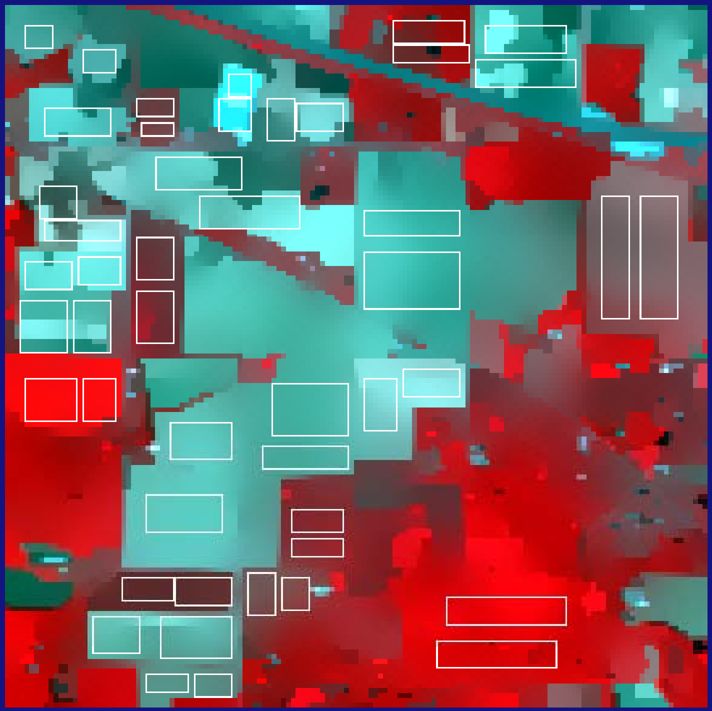


Figure 2. Comparison between SMACC and cPMF of retrieved fractional abundance maps : (a) true color composite, and (b) color infrared composite for the for the Vieques image; cPMF retrieved fractional abundance maps for (c) water , (d) forest, and (e) dry soil endmembers; SMACC retrieved fractional abundance maps for (f) water, (g) forest, and (h) dry soil endmembers .

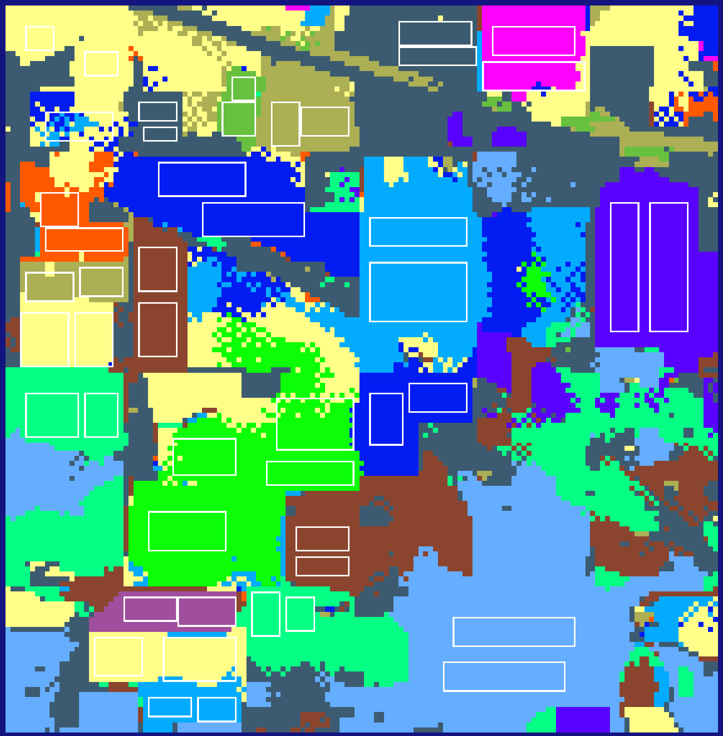
Geometric PDFs for Hyperspectral Imagery

- Nonlinear anisotropic diffusion (NAD) reduces variability in regions of similar spectral characteristics and enhances borders
- Improves classification and contrast enhancement (Duarte –Carvajalino, 2007, 2008)

NAD PDE Application to Classification



Training & testing Samples NW Indian Pines Image



Classification map, smoothed image, 93.7% overall accuracy

Measures of Spectral Variability

- Measure jointly spectral and spatial variability using texture metrics to assess biodiversity in hyperspectral images
- Some metrics to be computed using weighted spatial-spectral kernels are kurtosis, homogeneity, skewness and entropy (Velasco-Forero and Manian, 2009)

Anticipated Results

- Provide new methods to assess biodiversity
- Assess spatial and temporal changes in biodiversity
- Develop test and validate algorithms for fully automated spectral unmixing using PMF and of new indices to predict species richness using hyperspectral images
- Educate underrepresented students in NASA related areas