# Mapping Plant Species and Plant Functional Types from the West Coast to the Gulf

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# Research Questions

- **How separable are plants at the species and plant functional type (PFT) level using imaging spectrometry?**
- **How does the ability to discriminate species/PFTS vary as a function of**
  - **Spatial resolution (4 to 60m)?**
  - **Spectral sampling (Broad band to imaging spectrometry)?**
  - **Seasonality?**
- **How does separability vary across multiple ecosystems?**

# Terrestrial Ecology Study Sites


**Additional sites include Sierra Nevada and Jasper Ridge**

# How do you Quantify Spectral Separability?

- **Spectral distance measures**
  - **Jeffries-Matsusita**
  - **Bhattacharyya distance**

$$B = \frac{1}{8}[\mu_1 - \mu_2]^T \left[\frac{\Sigma_1 + \Sigma_2}{2}\right]^{-1} [\mu_1 - \mu_2] + \frac{1}{2} \mathrm{Ln} \frac{\left|\frac{1}{2}[\Sigma_1 + \Sigma_2]\right|}{\sqrt{|\Sigma_1||\Sigma_2|}}$$

**(μ - mean value | ∑ - Covariance)**

- **Statistical**
  - **t-test**
- **Classification**
  - **Least Squares Analysis of Absorption Features (MICA)**
  - **Linear Discriminant Analysis**
  - **Spectral Angle Mapper**
  - **Multiple Endmember Spectral Mixture Analysis**
    - **Extension of simple mixing model**
    - **Number and type vary per pixel**
    - **2 em case**

# Selecting Optimal Endmembers for MESMA

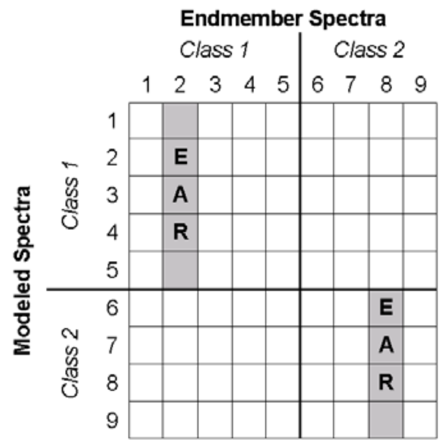
- **Objective**
  - **Select the smallest subset of spectra that has the least confusion between classes**
- **Approaches**
  - **Count-Based Endmember Selection (COB)**
  - **Endmember Average RMS (EAR)**

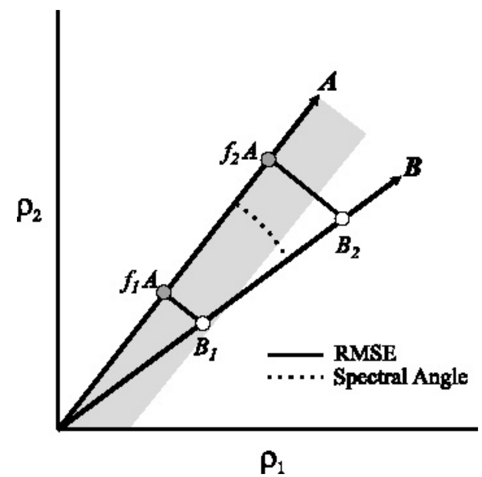
$$\mathrm{EAR}_{A_i,B} = \frac{\sum_{j-1}^{n} \mathrm{RMSE}_{A_i,B_j}}{n-1}$$

  - **Minimum Average Spectral Angle (MASA)**

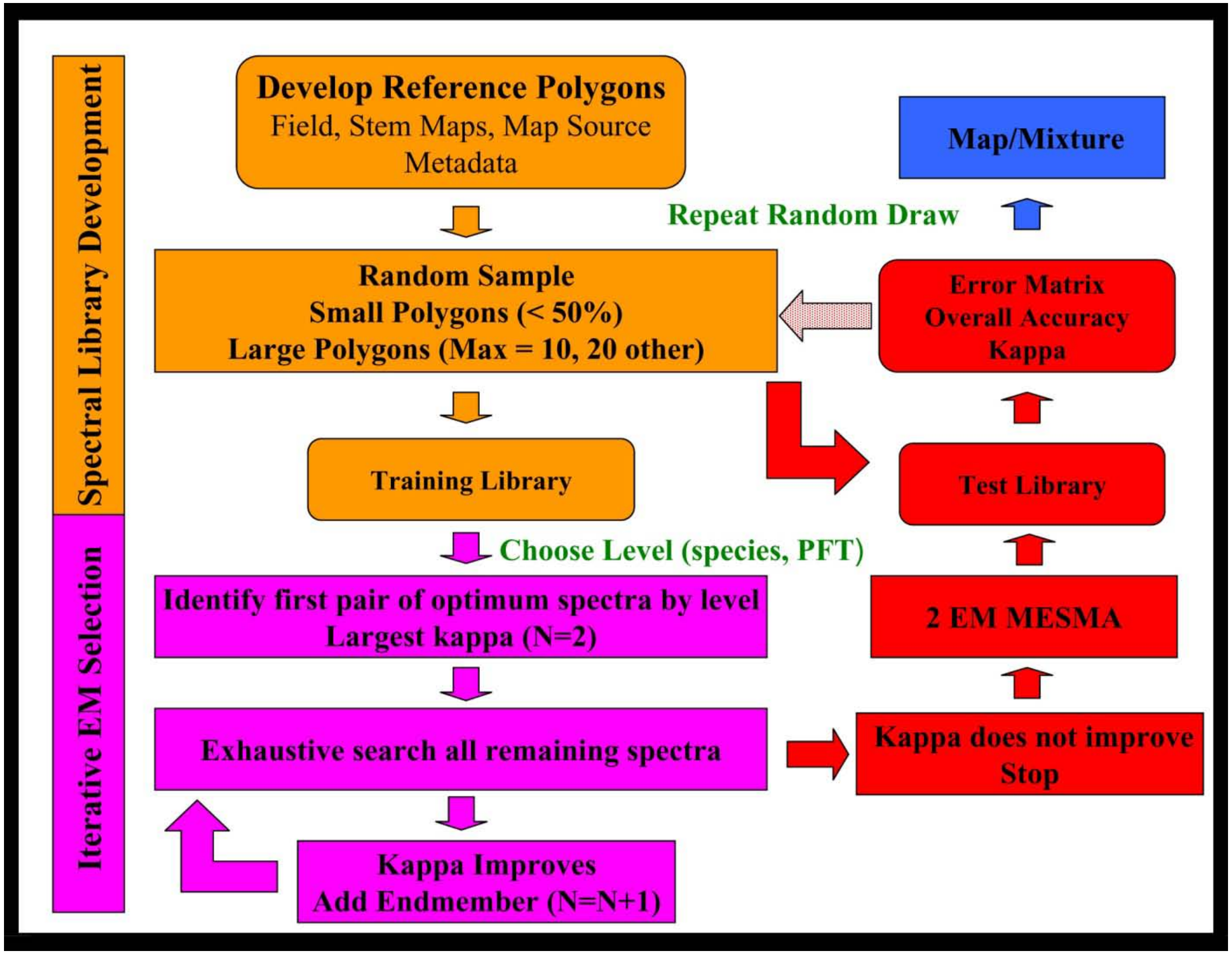
$$\bar{\theta}_{A_i,B} = \frac{\sum_{j-1}^{n} \theta_{A_i,B_j}}{n-1}$$

- **Limitations**
  - **Difficult to evaluate relative merits of each approach and standardize**
  - **May not capture important em variability**
  - **Does not evaluate relative merits of individual ems or optimize accuracy**



# Iterative Endmember Selection and Random Selection



# Gulf Study Site: In Detail


Louisiana Gulf (modified from Google Earth)

Coarse Resolution AVIRIS
May 6, 2010


1650, 831, 645 RGB

R1

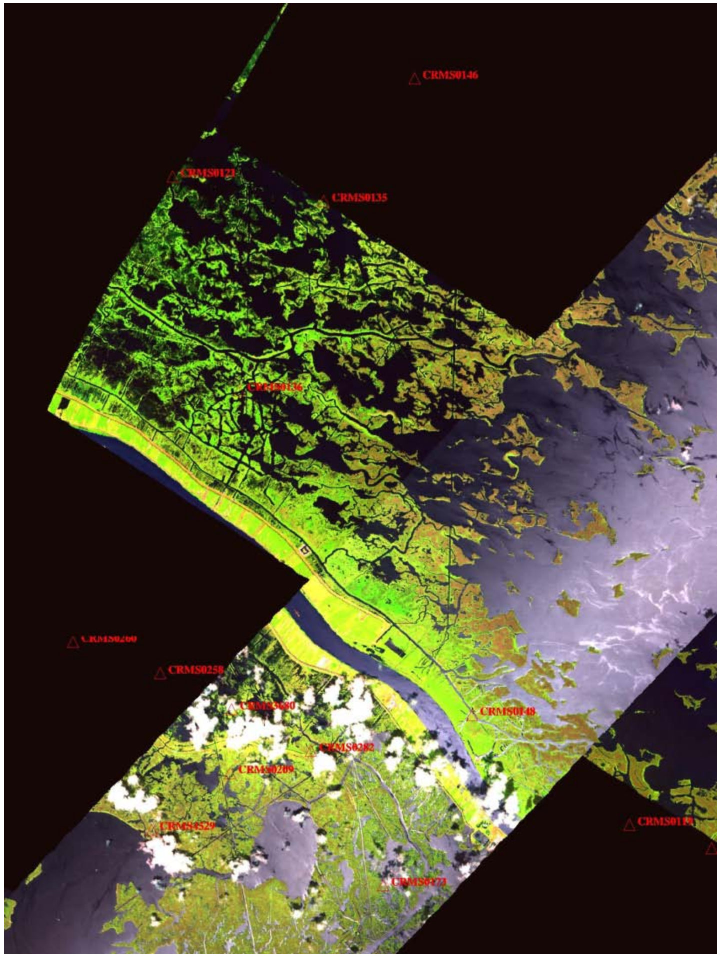
645 nm

High Resolution AVIRIS
July 10, 2010

# Building a Spectral Library: Examples from the Gulf

- **Identify suitable reference data for training and validation**
  - **CRMS (Coastal Reference Monitoring System)**
  - **NWRC (National Wetland Research Center)**
- **Extract spectra, construct metadata, sample training and test libraries**
- **Select optimum spectra**

**Challenges:**
**•Clouds, water, glint, tides**
**•Limited sites**
**•Limited species sampled**




**May 6, 2010**

# Endmember Selection: EAR, MASA, COB

- **Spectra selected from complete library**
- **Classification accuracy evaluated with test library**

| | disp | dwtr | glint | juro | mwtr | phau | spal | sppa | vilu | users |
|---|---|---|---|---|---|---|---|---|---|---|
| disp | 4 | 0 | 0 | 0 | 0 | 5 | 14 | 1 | 0 | 16.67% |
| dwtr | 0 | 39 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 100.00% |
| glint | 0 | 0 | 53 | 0 | 0 | 0 | 0 | 0 | 0 | 100.00% |
| juro | 0 | 0 | 0 | 1 | 0 | 0 | 40 | 1 | 0 | 2.38% |
| mwtr | 0 | 31 | 0 | 0 | 48 | 0 | 0 | 0 | 0 | 60.76% |
| phau | 0 | 0 | 0 | 0 | 0 | 80 | 47 | 8 | 6 | 56.74% |
| spal | 0 | 0 | 0 | 1 | 0 | 12 | 178 | 9 | 2 | 88.12% |
| sppa | 1 | 0 | 0 | 0 | 0 | 26 | 36 | 17 | 1 | 20.99% |
| vilu | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.00% |
| Producers | 80.00% | 55.71% | 100.00% | 50.00% | 100.00% | 65.04% | 56.51% | 47.22% | 0.00% | 63.54% |
| Kappa | 0.536 | | | | | | | | | |
| Kappa v | 0.00052 | | | | | | | | | |

- **26 spectra selected, including 1 disp (*Distichlis spicata*), 4 water, 3 glint, 1 juro (*Juncus roemerianus*), 5 phau (*Phragmites australis*), 6 spal (*Spartina alterniflora*), 3 sppa (*S. patens*) and 3 vilu (*Vigna luteola*)**
- **Classification accuracy is reasonable, but certain classes (juro,sppa and vilu) were poor**
- **Two classes (disp and juro) are poorly represented**

# Iterative Endmember Selection

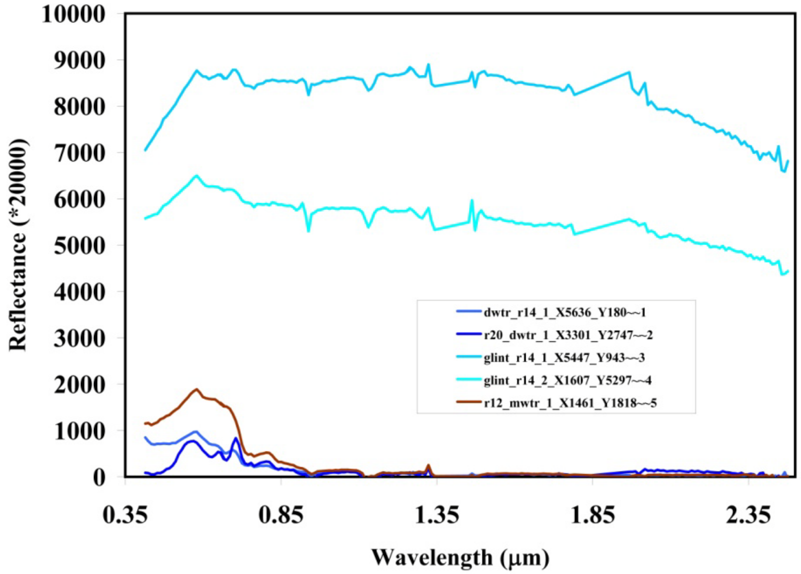
- Spectra selected from one training library
- Classification accuracy evaluated with remaining spectra (test library)

| | disp | dwtr | glint | juro | mwtr | phau | spal | sppa | vilu | users |
|---|---|---|---|---|---|---|---|---|---|---|
| disp | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.00% |
| dwtr | 0 | 70 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 100.00% |
| glint | 0 | 0 | 53 | 0 | 0 | 0 | 1 | 0 | 0 | 98.15% |
| juro | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.00% |
| mwtr | 0 | 0 | 0 | 0 | 48 | 0 | 0 | 0 | 0 | 100.00% |
| phau | 0 | 0 | 0 | 0 | 0 | 121 | 26 | 9 | 6 | 74.69% |
| spal | 5 | 0 | 0 | 2 | 0 | 15 | 303 | 20 | 3 | 87.07% |
| sppa | 0 | 0 | 0 | 0 | 0 | 4 | 6 | 11 | 0 | 52.38% |
| vilu | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 8 | 7 | 41.18% |
| Producers | 0.00% | 100.00% | 100.00% | 0.00% | 100.00% | 85.82% | 89.91% | 22.92% | 43.75% | 85.14% |
| Kappa | 0.79 | | | | | | | | | |
| Kappa v | 0.000336 | | | | | | | | | |

- *31 spectra selected, including 3 water, 2 glint, 6 phau, 9 spal, 5 sppa and 6 vilu
- Classification accuracy was significantly higher than EMC
- Two classes (disp and juro) were not selected because of low sample numbers
    - Reduced errors of commission

# Wetland Spectra: Vol. I

- **Water spectra included dark water, muddy water and glint**
  - **This list was not comprehensive**
- ***Phragmites* is defined by a "classic" spectrum varying primarily in brightness**
  - **Some mixed water spectra occurred**





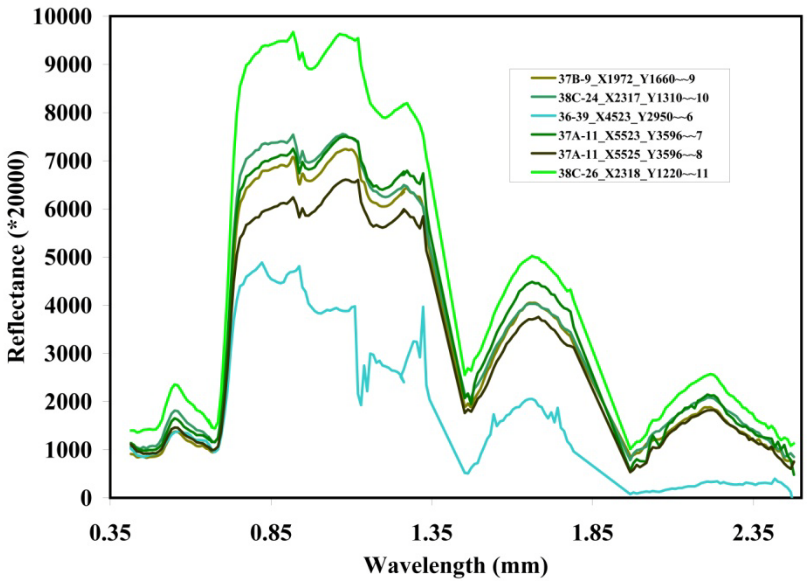
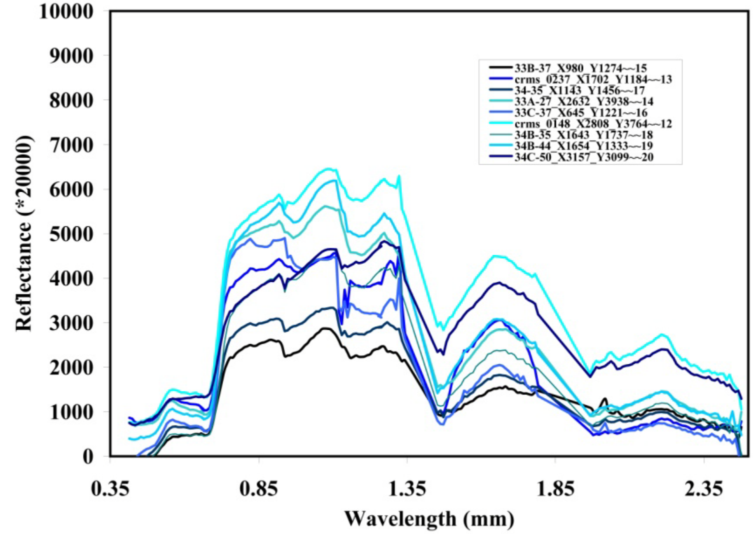



**Photo source:http://plants.usda.gov/java/profile?symbol=PHAU7&photoID=phau7_002_avp.tif**

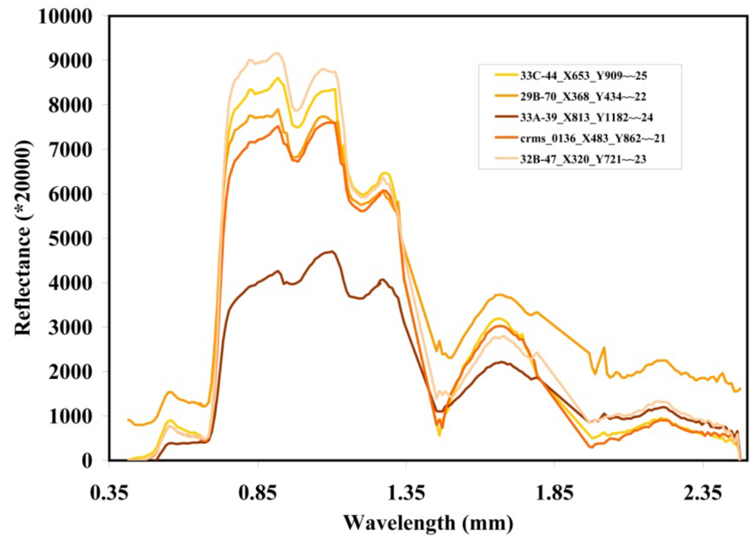
# Wetland Spectra: Vol. II

- ***Spartina alterniflora*** **is highly variable, generally dark due to structure**




**Source:http://plants.usda.gov/java/largeImage?imageID=spal_002_ahp.tif**

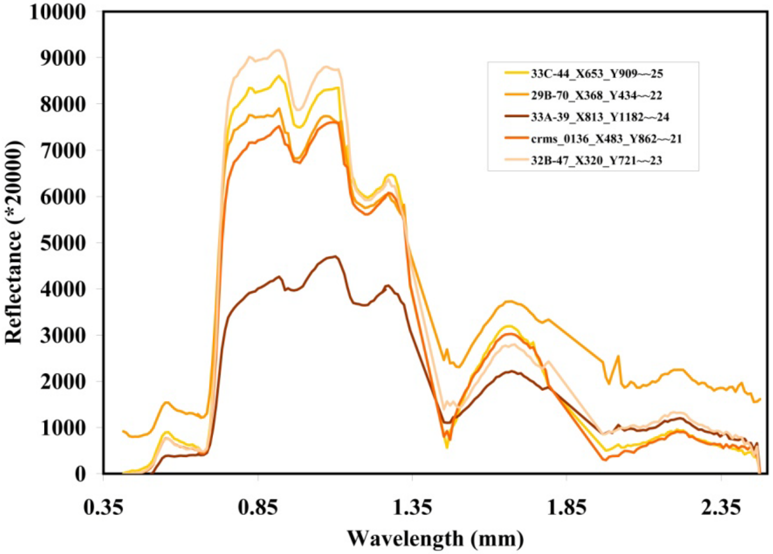
- ***Spartina patens*** **is less variable and brighter**




**Source: http://www.google.com/imgres?imgurl=http://siera104.com/images/bio/ecology/saltmeadow.jpg**

# Wetland Spectra: Vol. III

- ***Vigna luteola*** **is defined by a bimodal reflectance between bright (unflooded) and dark (flooded?) spectra**
  - **sppa is included for comparison**

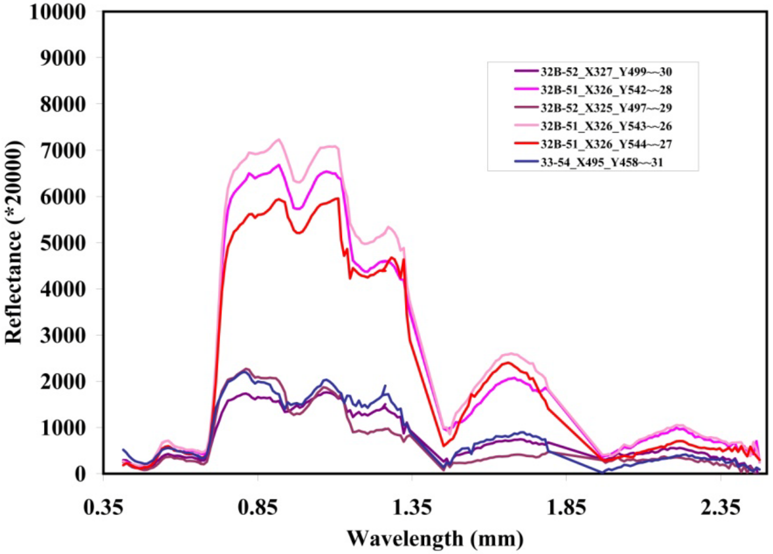
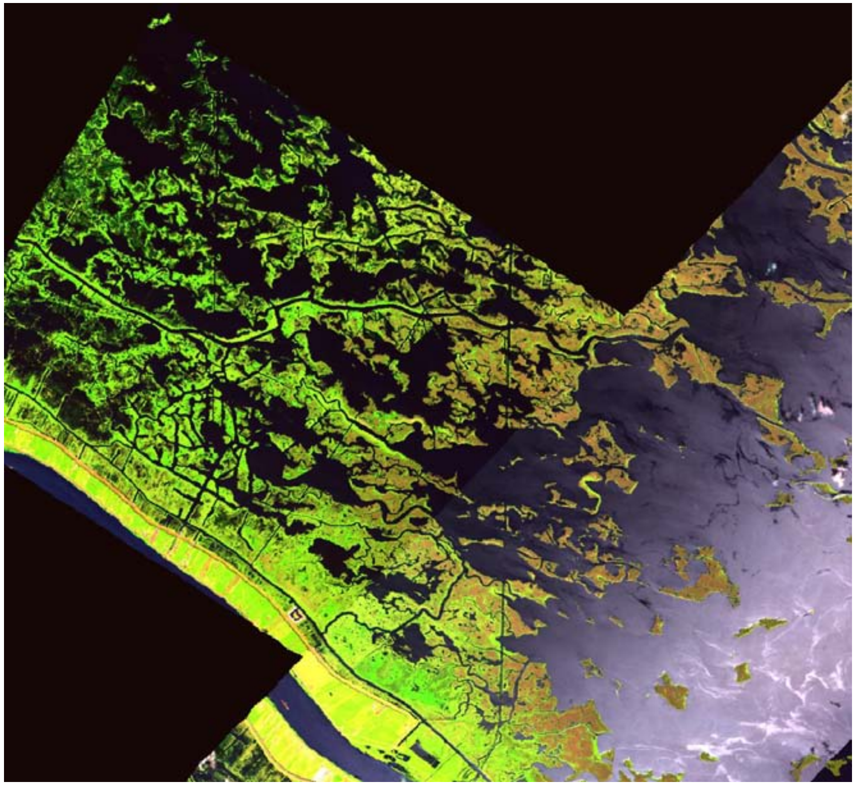
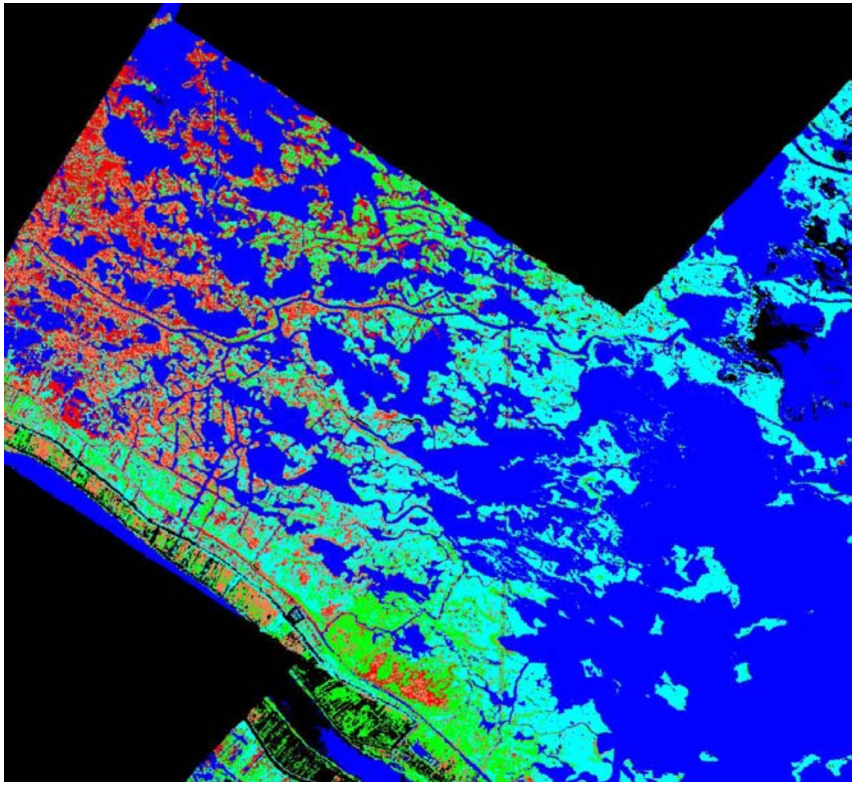




**Photo source:http://plants.usda.gov/java/largeImage?imageID=vilu3_001_avp.tif**

# Mapping Wetland Dominants

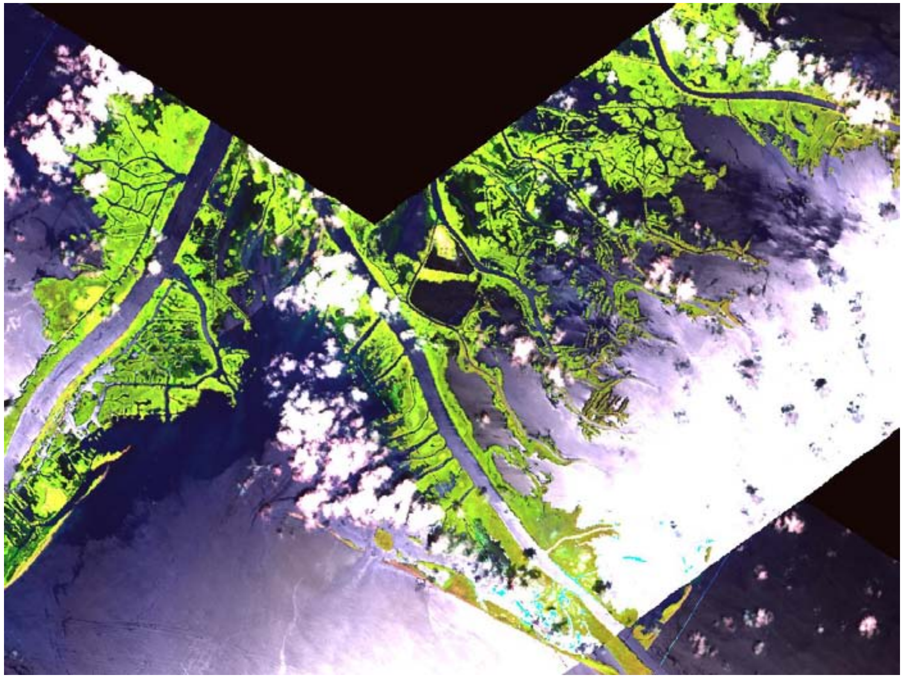


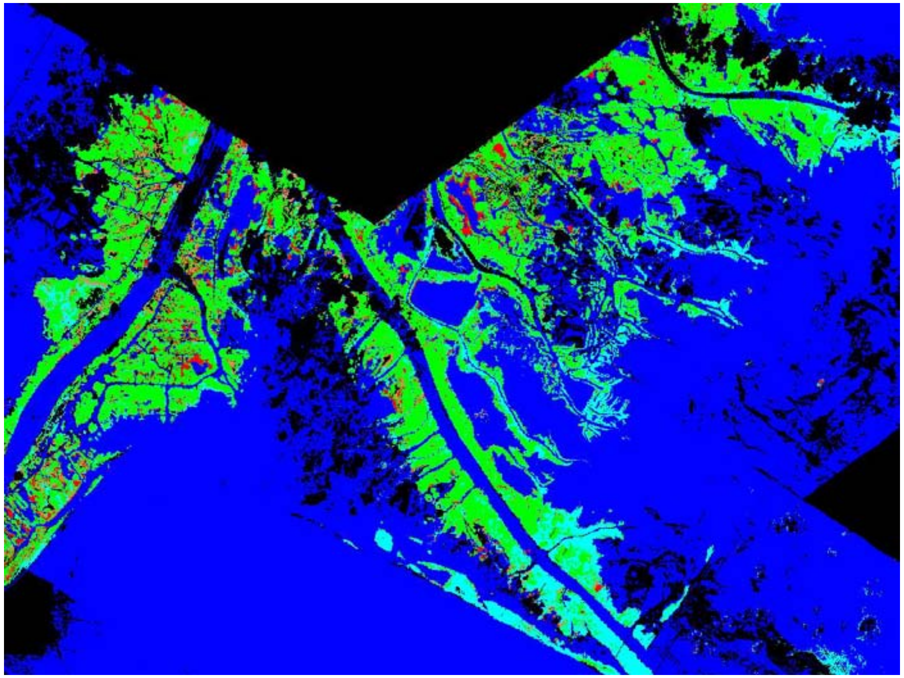


Water/glint | phau | spal | sppa | vilu | Unclass

- Vegetation mapped cleanly across scene boundaries
- Accuracy appears higher than reported using the test library due to mixed species in the NWRC sites

# Mapping Wetland Dominants



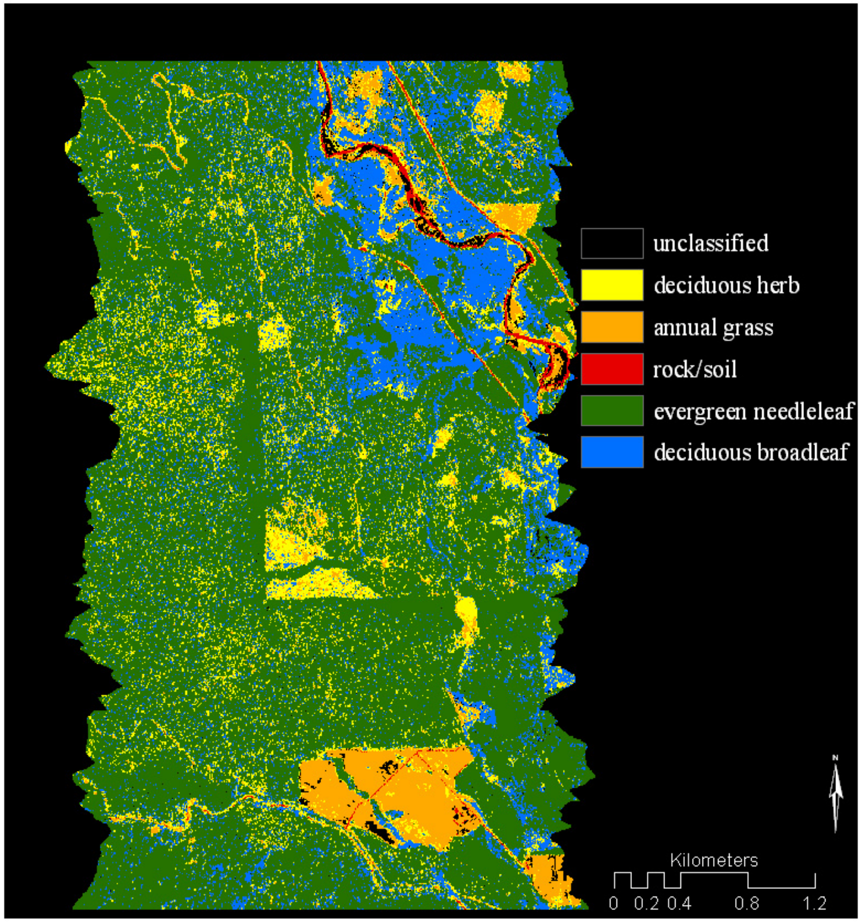


Water/ glint   phau   spal   sppa   vilu   Unclass

- Vegetation mapped cleanly across scene boundaries
- Phragmites dominates farther south along the delta

# Wind River

- **Species-level accuracy of 72.7% for 10 species and 63 endmembers**
- **PFT accuracy of 96.8% for 4 PFTs**
  - **Vertical height information would remove ambiguity between herbs and broadleaf plants**




| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | broadleaf | grass | herb | needleleaf | soil | unmodeled | users_acc |
| broadleaf | 2286 | 0 | 18 | 416 | 0 | 0 | 84.0441 |
| grass | 0 | 3475 | 1 | 5 | 1 | 0 | 99.799 |
| herb | 17 | 38 | 22 | 51 | 0 | 0 | 17.1875 |
| needleleaf | 86 | 60 | 4 | 16816 | 0 | 0 | 99.1159 |
| soil | 0 | 9 | 0 | 0 | 39 | 0 | 81.25 |
| unmodeled | 0 | 28 | 0 | 7 | 0 | 0 | |
| prod_acc | 95.68857 | 96.26039 | 48.88889 | 97.23041 | 97.5 | 0 | |
| | | | | | | | |
| kappa | | 0.92599 | | | | | |
| overall accuracy | | 96.8305 | | | | | |

# Santa Barbara Front Range

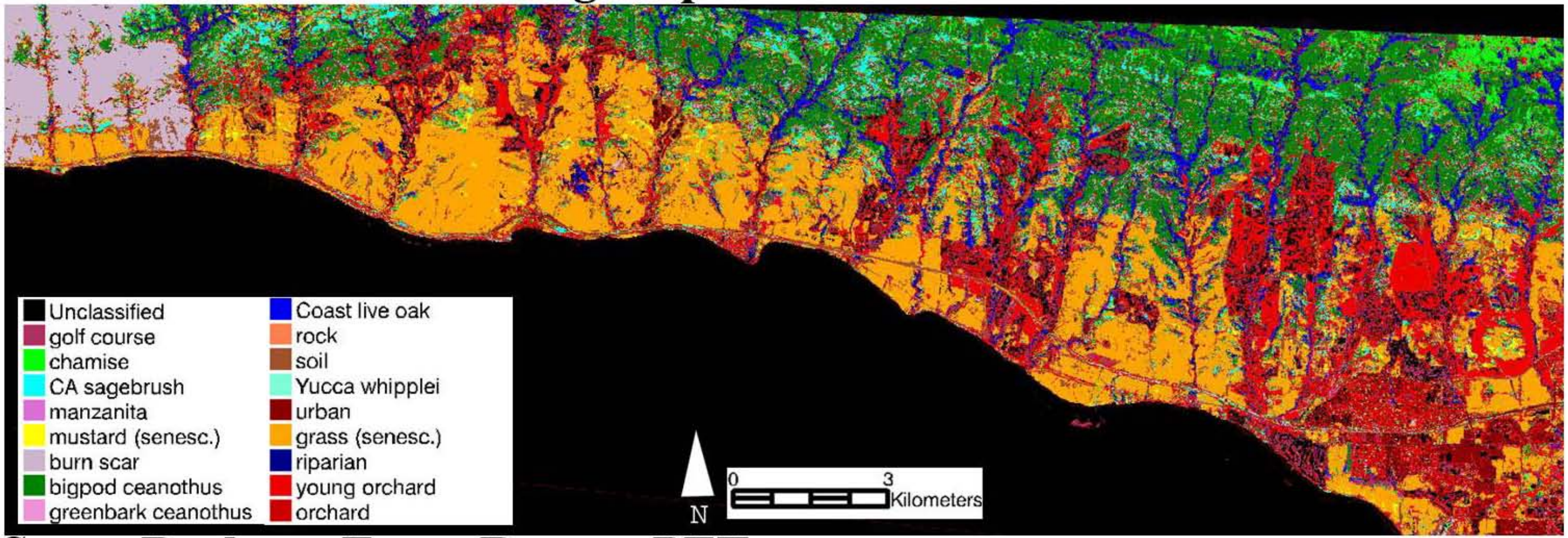
- 13 species, 9 other categories (i.e., soil, rock, orchards) totaling 115 ems
- Species accuracy of 68.6%
- PFT level (8 PFT + 6 other), 103 ems, 81% accuracy

| | ag | gc | adfa | arca | argl | dbrni | burn | cecu | ceme | cesp | quag | qudu | rock | soil | umca | yuwh | urban | dgrass | riparian | sycamore | orchard_sc | orchard_lo | unmodeled | User's Accu |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ag | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| gc | 13 | 2442 | 43 | 2 | 240 | 0 | 0 | 2 | 53 | 3 | 20 | 49 | 0 | 0 | 1 | 0 | 1 | 0 | 31 | 1 | 167 | 216 | 0 | 74.36 |
| adfa | 0 | 0 | 565 | 2 | 209 | 0 | 0 | 10 | 151 | 5 | 4 | 1 | 0 | 0 | 1 | 6 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 59.1 |
| arca | 0 | 0 | 1 | 16 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 88.89 |
| argl | 0 | 0 | 17 | 0 | 6 | 0 | 0 | 0 | 6 | 0 | 5 | 0 | 0 | 0 | 1 | 0 | 6 | 0 | 0 | 0 | 0 | 0 | 0 | 14.63 |
| dbrni | 0 | 0 | 0 | 1 | 0 | 6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 13 | 0 | 0 | 0 | 0 | 0 | 30 |
| burn | 0 | 0 | 0 | 0 | 0 | 0 | 2353 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 100 |
| cecu | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| ceme | 0 | 1 | 90 | 0 | 64 | 0 | 0 | 0 | 675 | 107 | 119 | 7 | 0 | 0 | 3 | 1 | 0 | 0 | 1 | 0 | 4 | 0 | 0 | 62.97 |
| cesp | 0 | 2 | 3 | 0 | 1 | 0 | 0 | 0 | 15 | 16 | 3 | 0 | 0 | 1 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 37.21 |
| quag | 0 | 24 | 6 | 0 | 5 | 0 | 0 | 0 | 58 | 41 | 487 | 7 | 0 | 0 | 42 | 3 | 0 | 0 | 18 | 3 | 6 | 0 | 0 | 69.57 |
| qudu | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| rock | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 35 | 11 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 74.47 |
| soil | 0 | 11 | 0 | 0 | 3 | 0 | 18 | 0 | 1 | 0 | 0 | 0 | 0 | 256 | 0 | 1 | 24 | 14 | 0 | 0 | 3 | 0 | 0 | 77.34 |
| umca | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| yuwh | 0 | 1 | 6 | 0 | 3 | 0 | 0 | 0 | 3 | 3 | 1 | 0 | 0 | 0 | 0 | 7 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 26.92 |
| urban | 0 | 5 | 0 | 0 | 0 | 0 | 4 | 0 | 0 | 0 | 0 | 0 | 0 | 9 | 0 | 0 | 405 | 0 | 0 | 0 | 0 | 0 | 0 | 95.74 |
| dgrass | 0 | 9 | 1 | 4 | 0 | 2 | 4 | 0 | 1 | 2 | 0 | 0 | 0 | 10 | 0 | 0 | 0 | 625 | 0 | 0 | 0 | 0 | 0 | 94.98 |
| riparian | 0 | 2 | 1 | 0 | 2 | 0 | 0 | 0 | 0 | 2 | 13 | 40 | 0 | 0 | 10 | 0 | 0 | 0 | 185 | 4 | 6 | 6 | 0 | 68.27 |
| sycamore | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| orchard_sc | 0 | 290 | 35 | 2 | 67 | 0 | 0 | 4 | 13 | 3 | 0 | 4 | 0 | 0 | 0 | 5 | 6 | 0 | 0 | 0 | 2341 | 18 | 0 | 83.97 |
| orchard_lo | 0 | 53 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 6 | 6 | 0 | 0 | 1 | 0 | 0 | 0 | 64 | 0 | 118 | 507 | 0 | 66.97 |
| unmodeled | 51 | 1529 | 20 | 0 | 36 | 0 | 12 | 0 | 28 | 1 | 16 | 6 | 0 | 11 | 1 | 0 | 10 | 1 | 2 | 0 | 252 | 160 | 0 | |
| Producer's | 0 | 55.89 | 71.7 | 59.26 | 0.94 | 75 | 98.41 | 0 | 67.16 | 8.74 | 72.26 | 0 | 100 | 85.91 | 0 | 30.43 | 88.62 | 95.42 | 61.46 | 0 | 80.81 | 55.9 | | |
| | | | | | | | | | | | | | | | | | | | | | | | | |
| kappa | 0.64107 | | | | | | | | | | | | | | | | | | | | | | | |
| kappa | 1.67E-05 | | | | | | | | | | | | | | | | | | | | | | | |
| overall acc | 68.6197 | | | | | | | | | | | | | | | | | | | | | | | |
| #EMs | 115 | | | | | | | | | | | | | | | | | | | | | | | |

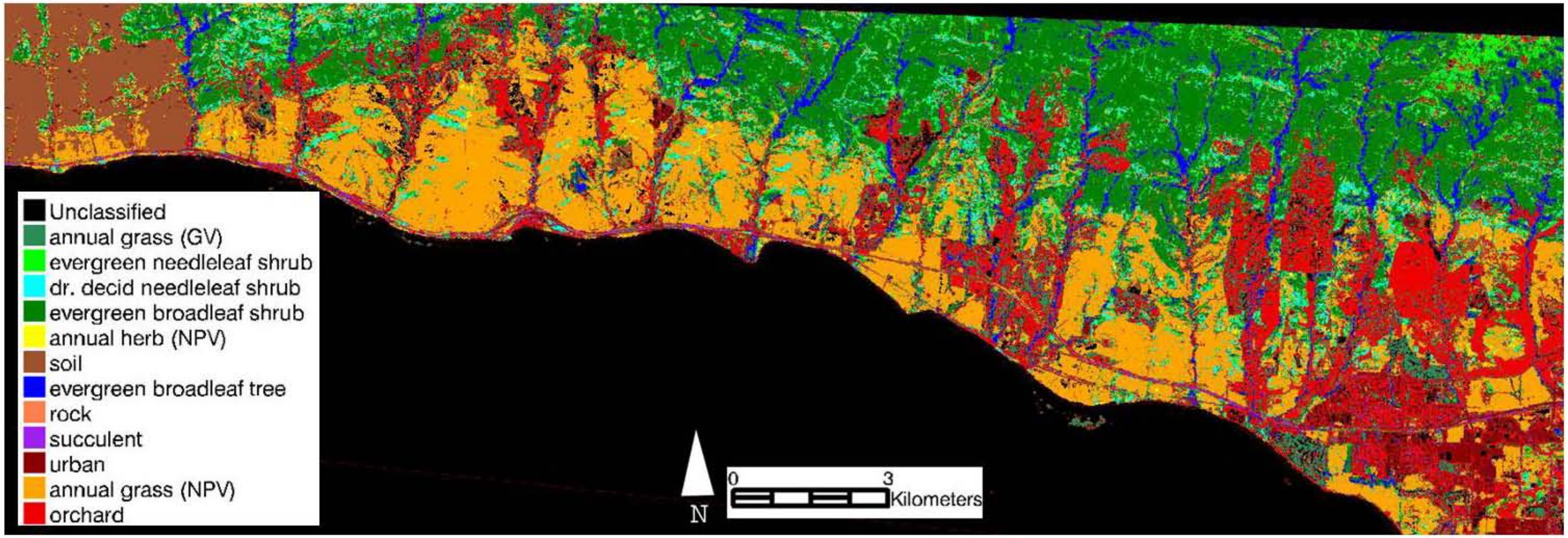
- Highly accurate (>70%) classes include adfa, dbrni, burn, quag, rock, soil, urban, dead grass, orchard+soil)
- Intermediate (50-70%) include golf courses, arca, ceme, riparian, except argl &cesp)

# Santa Barbara Front Range

Santa Barbara Front Range: Species **68.6%**




Santa Barbara Front Range: PFT **81%**




*** High Accuracy extends to the northern line with opposite viewing geometry**

# Other Experiments with Iterative Endmember Selection

- **Impact of degraded spatial resolution (4-60 m)**
  - **On-going, all sites: See Dennison**
- **Impact of degraded spectral resolution (native resolution)**
  - **On-going,**

**Kappa Statistic**

| | AVIRIS | IKONOS | MODIS | SPOT5 | TM5 |
|---|---|---|---|---|---|
| SERC | 0.37 | 0.088 | 0.23 | -0.092 | -0.067 |
| SBFR species | 0.60 | 0.31 | 0.49 | 0.34 | 0.39 |
| SBFR PFTs | 0.63 | 0.52 | 0.56 | 0.45 | 0.51 |
| WR species | 0.62 | 0.28 | 0.39 | 0.31 | 0.36 |
| WR PFTs | 0.93 | 0.45 | 0.84 | 0.82 | 0.77 |

**Keely Roth**

- **Impact of random sampling**
  - **100 runs:**
    - **Accuracy varies substantially between models**
    - **Do you choose the best of 100 or build an ensemble of models?**

# On-going Research in the Gulf

- **Improve spectral library to include missing species**
  - ***Juncus roemerianus, Distichlis spicata*, Mangroves**
- **Export analysis to July Twin Otter data sets**
  - **Understory glint appears to have drastically changed the spectral shape of some wetlands**
  - **Differences in tidal heights may have modified NIR reflectance**
- **Expand to three+ endmember models to map senescence and oil coated vegetation**
- **Calculate additional stress measures**
- **Image oil impacted vegetation**

# Questions?