Diverse Uses of Hyperspectral Remote Sensing for Mapping and Monitoring of Wetlands

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Remote Sensing Workshop for Water Resources Management

San Diego, California,
September 28 & 29, 2012

Applications of Remote Sensing

- Track invasive species, monitor spread and persistence
- Map contamination after an environmental disaster
- Monitor stress and recovery in wetland plant communities

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What is needed?

Multi-temporal images

Hyperspectral bands

Good spatial resolution

Spatial

Large spatial extent (2600km^2)

High spatial resolution data (3m)

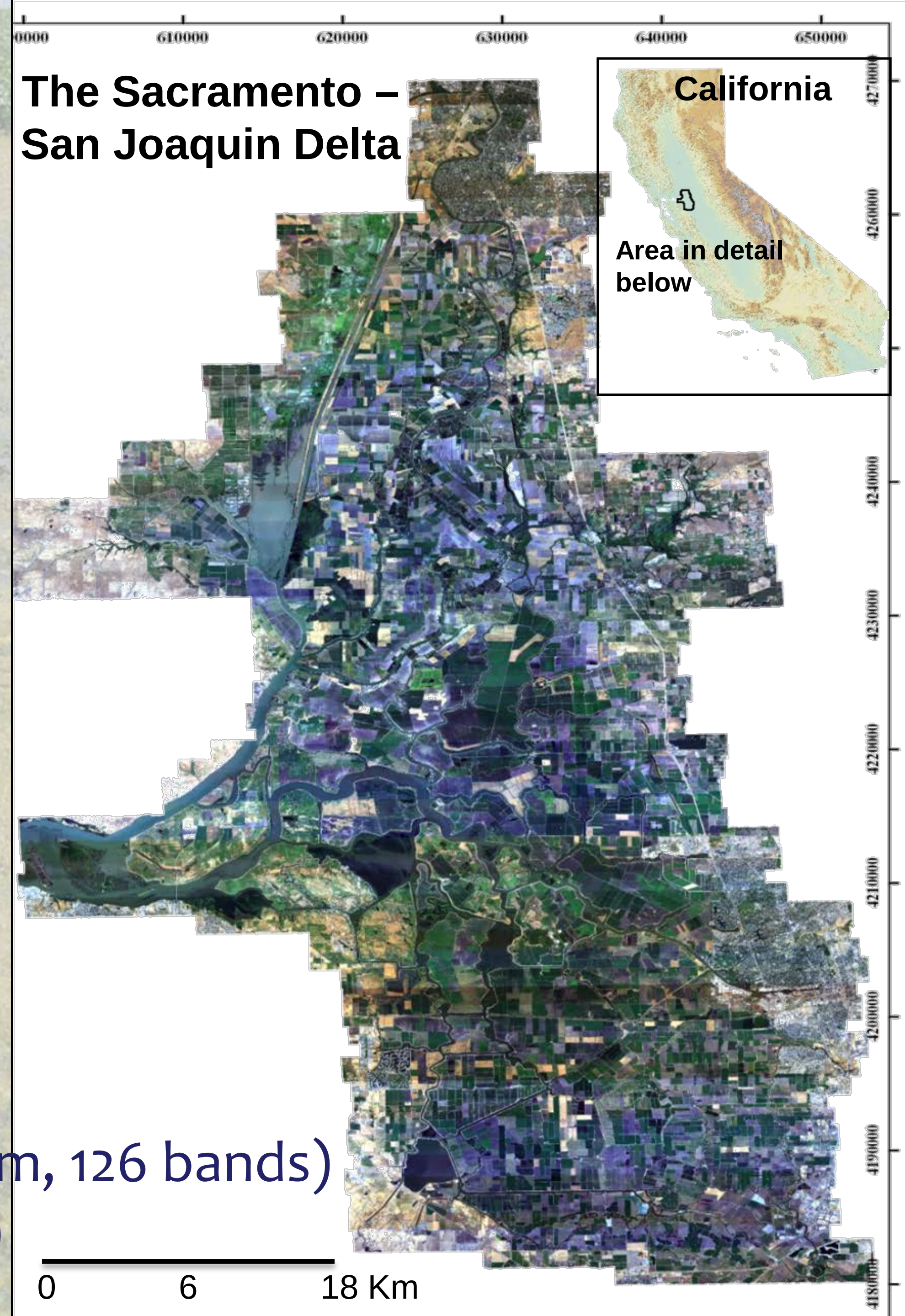
Temporal

Multiple years (June 2004 - 2008)

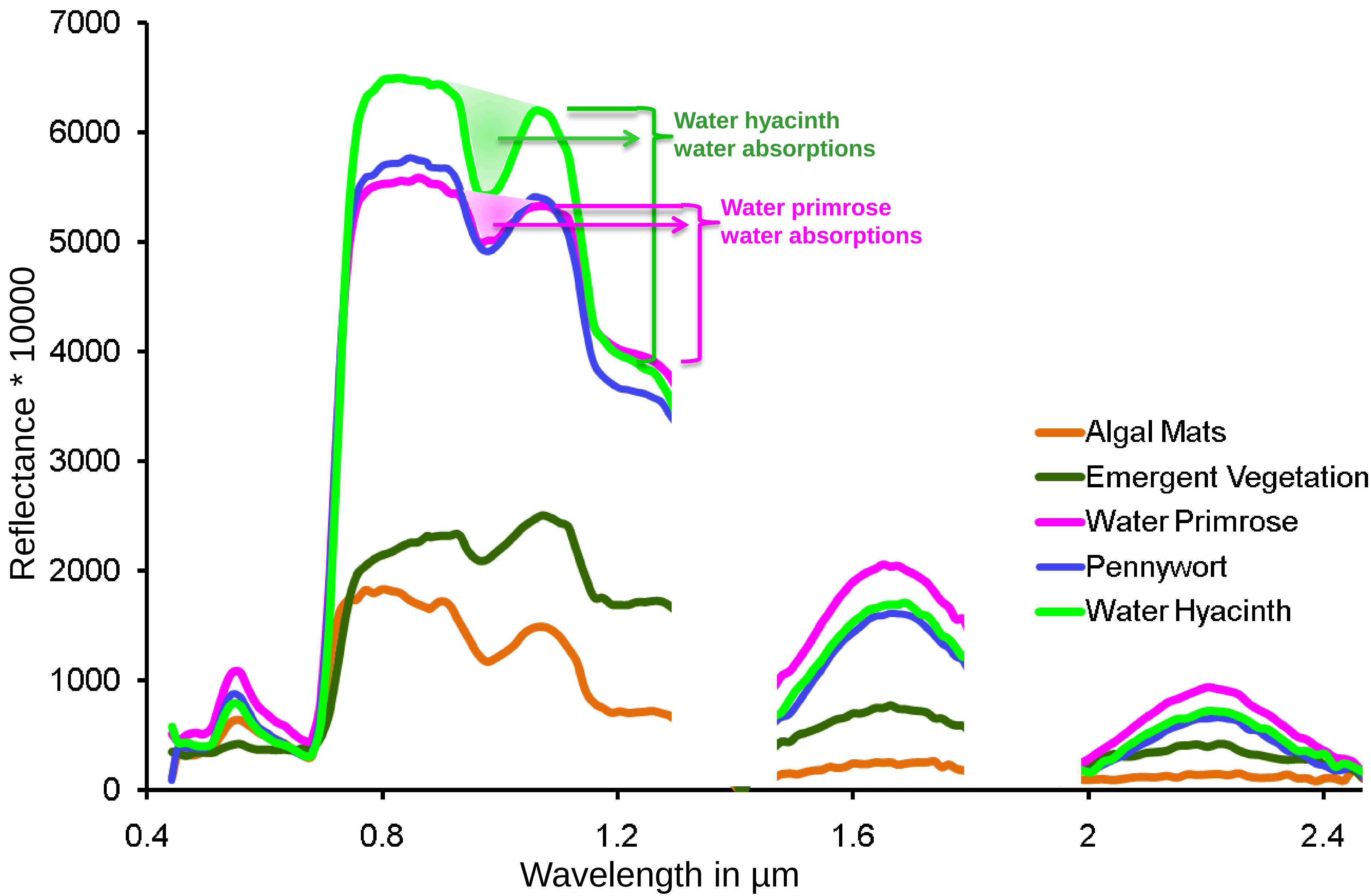
Spectral

Spectral resolution (BW: 10 – 15 nm, 126 bands)

Spectral extent (400 to 2400 nm)

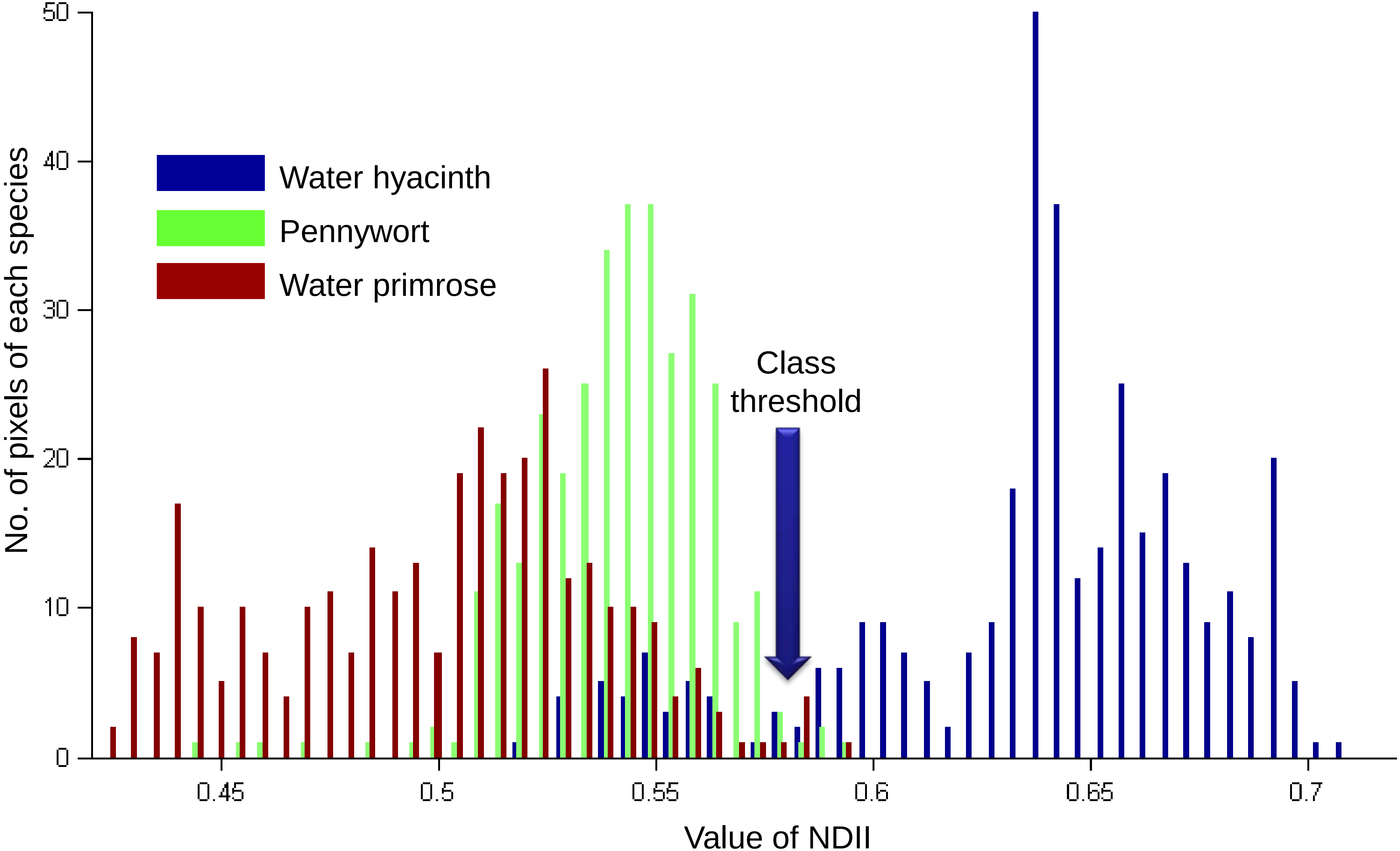


Water Hyacinth vs. Pennywort/Primrose



2007 – NDII

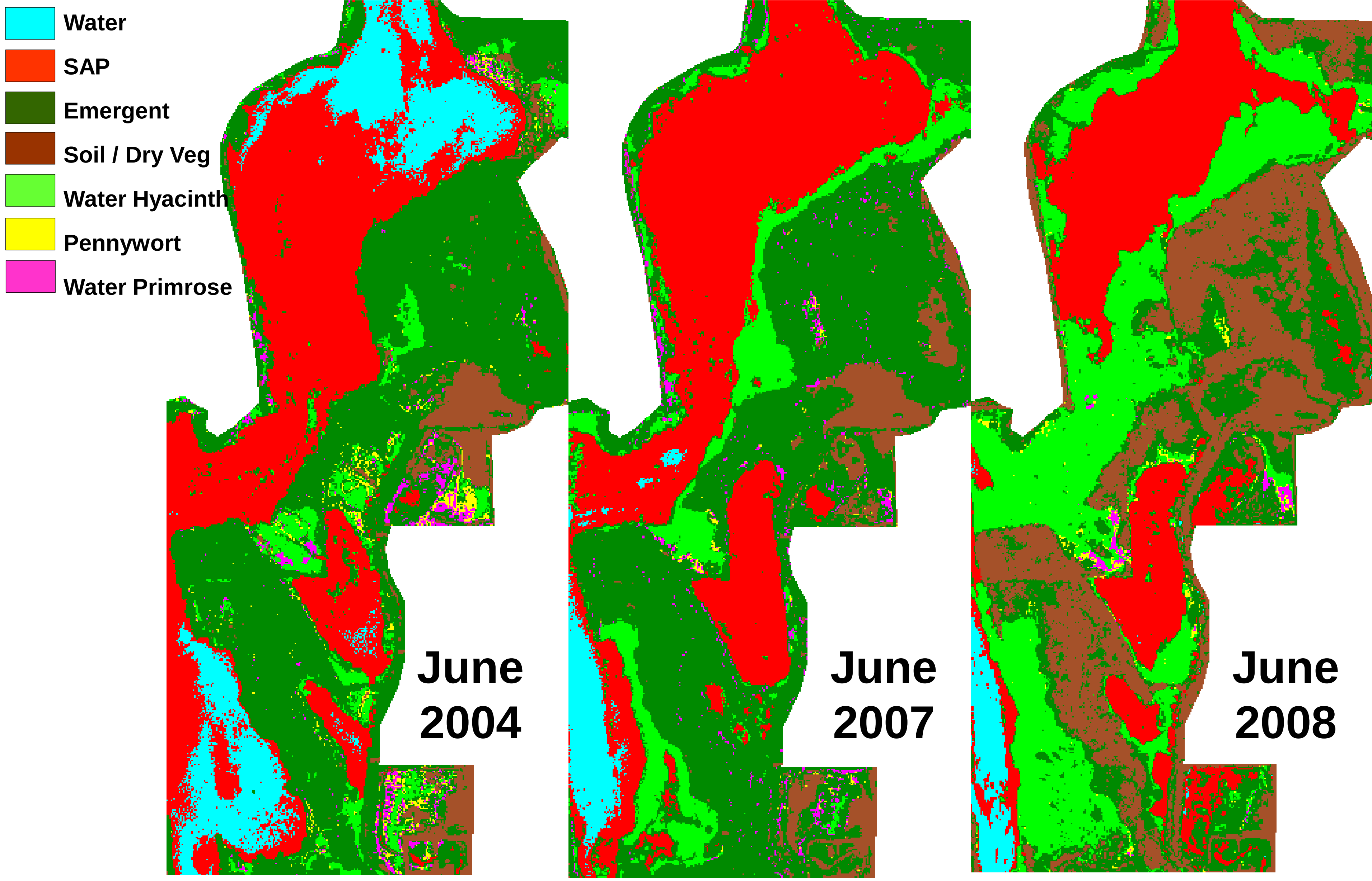
Water hyacinth vs. Pennywort/primrose



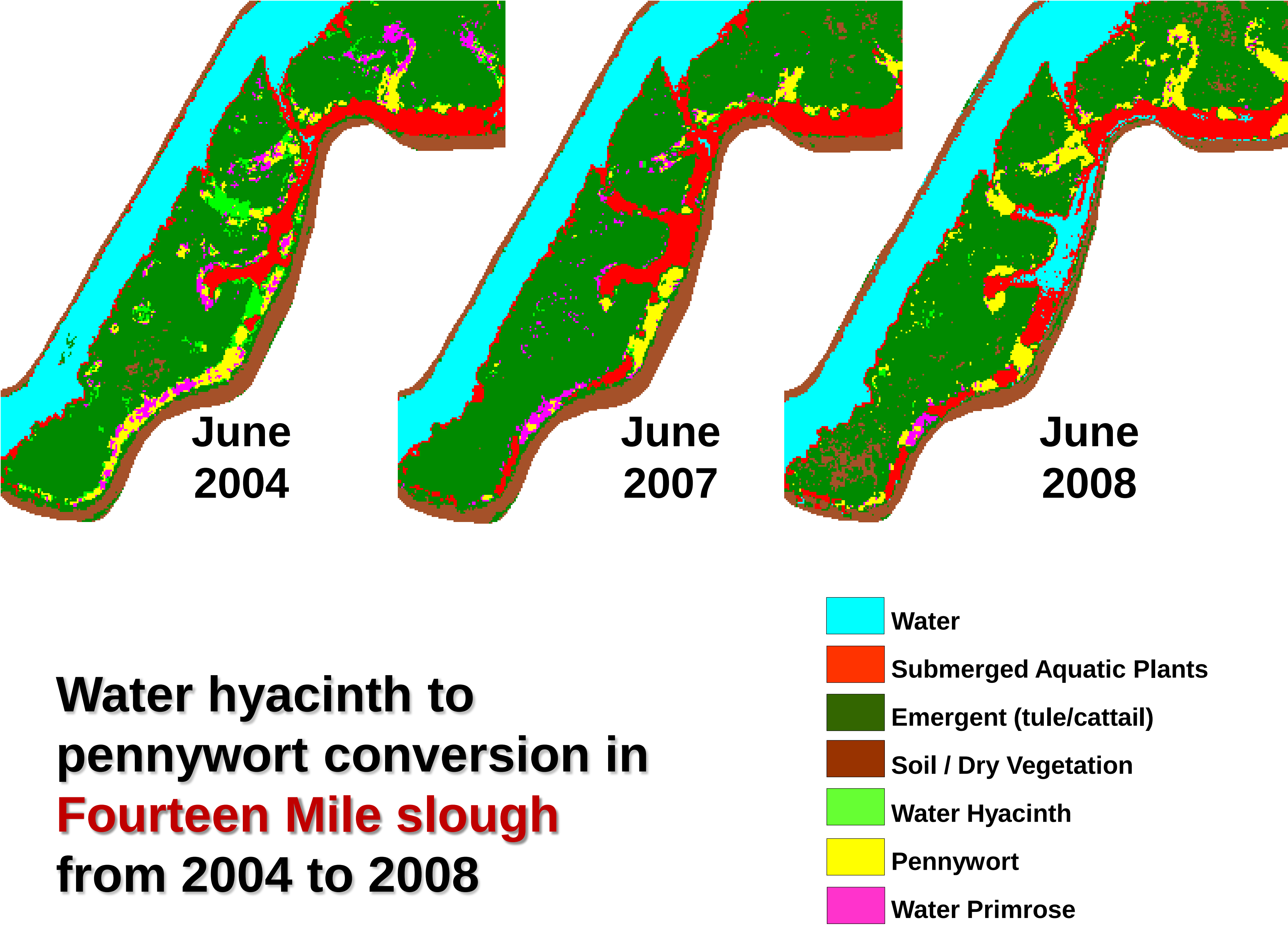
Track

spread
persistence
change in distribution

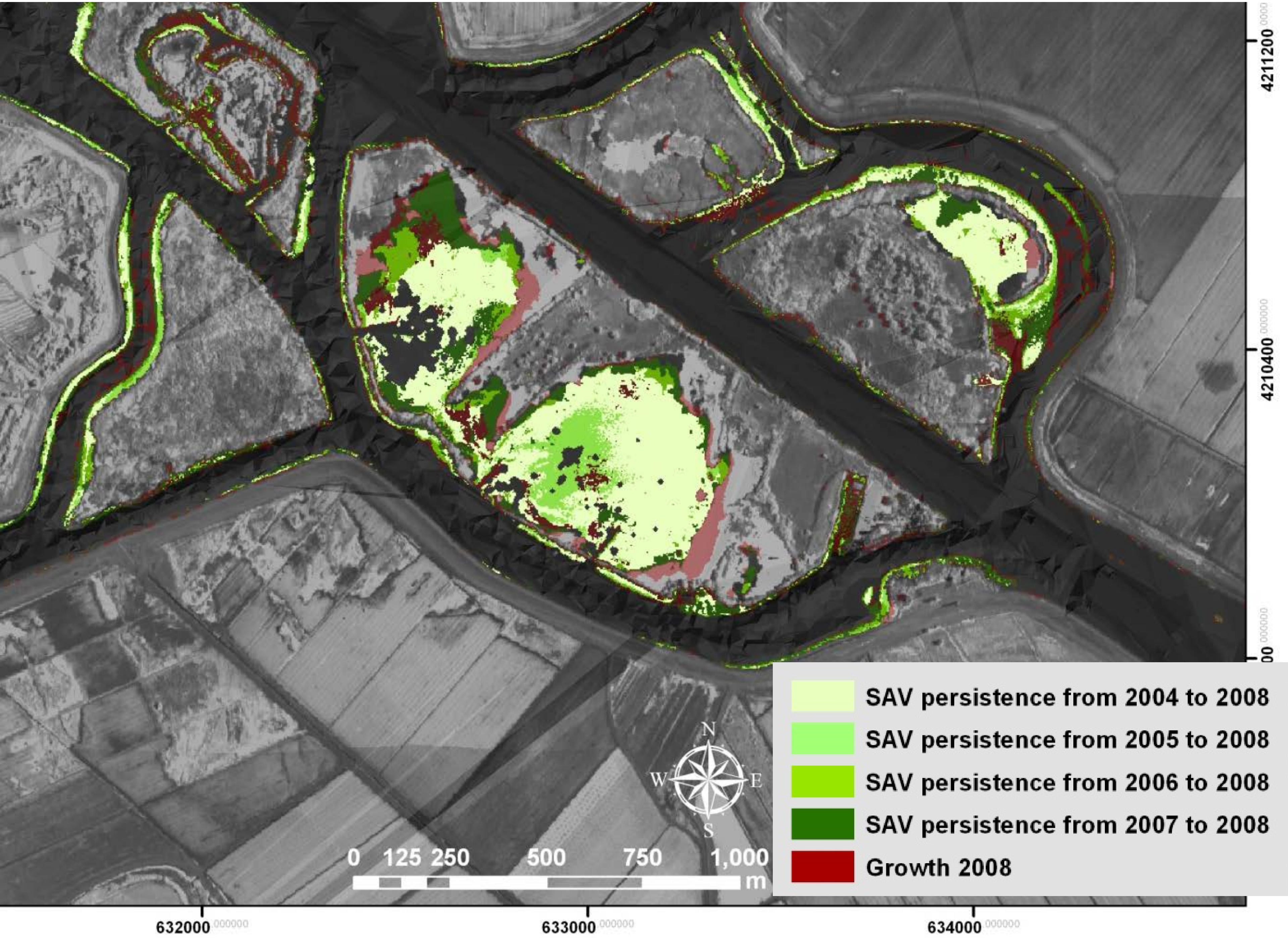
of invasive species



Increase in water hyacinth cover in Stone Lake from 2004 to 2008



Water hyacinth to pennywort conversion in Fourteen Mile slough from 2004 to 2008



SAV persistence from 2004 to 2008
SAV persistence from 2005 to 2008
SAV persistence from 2006 to 2008
SAV persistence from 2007 to 2008
Growth 2008
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633000.000000
634000.000000
4211200.000000
4210400.000000

Applications of Remote Sensing

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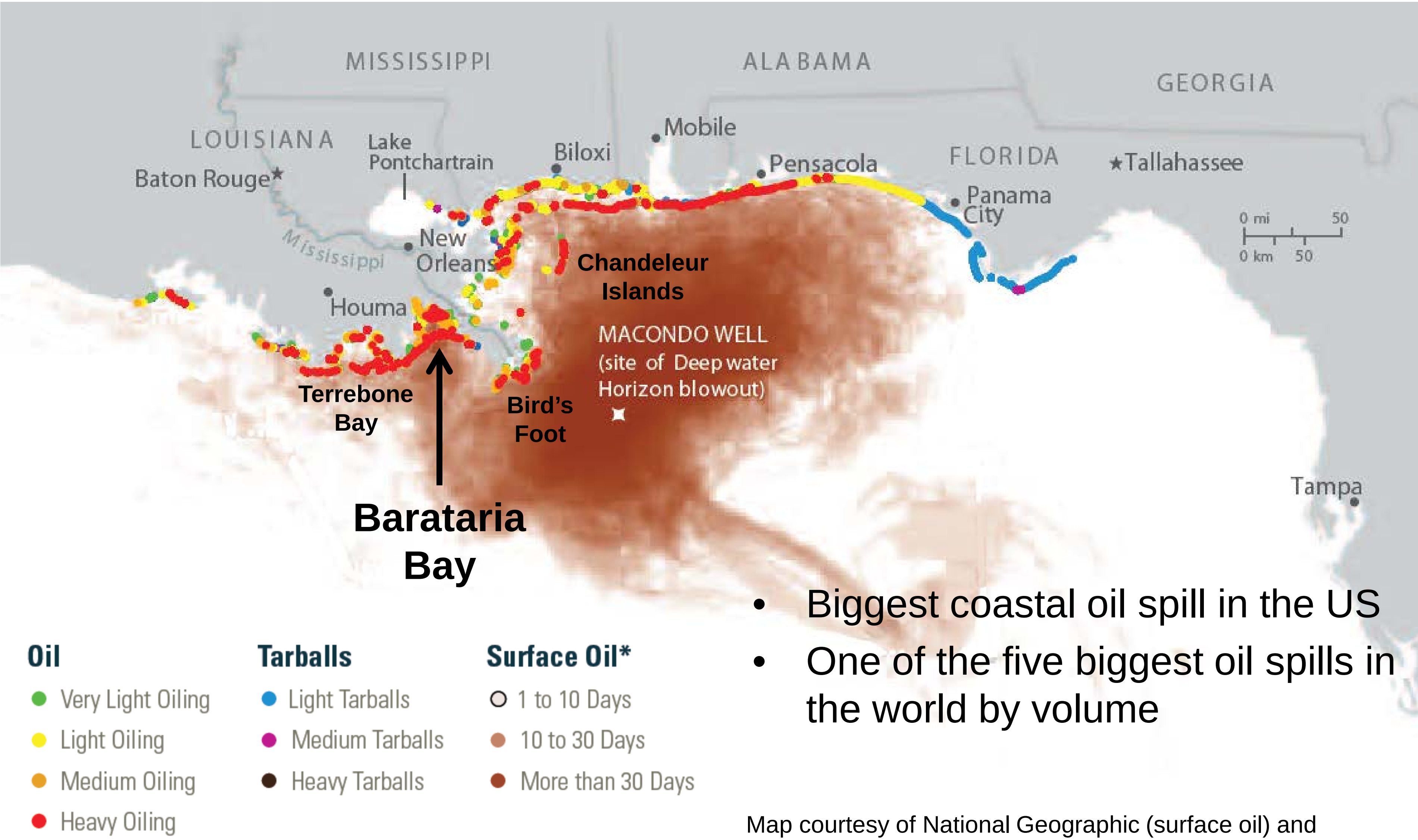
The Macondo Oil Spill



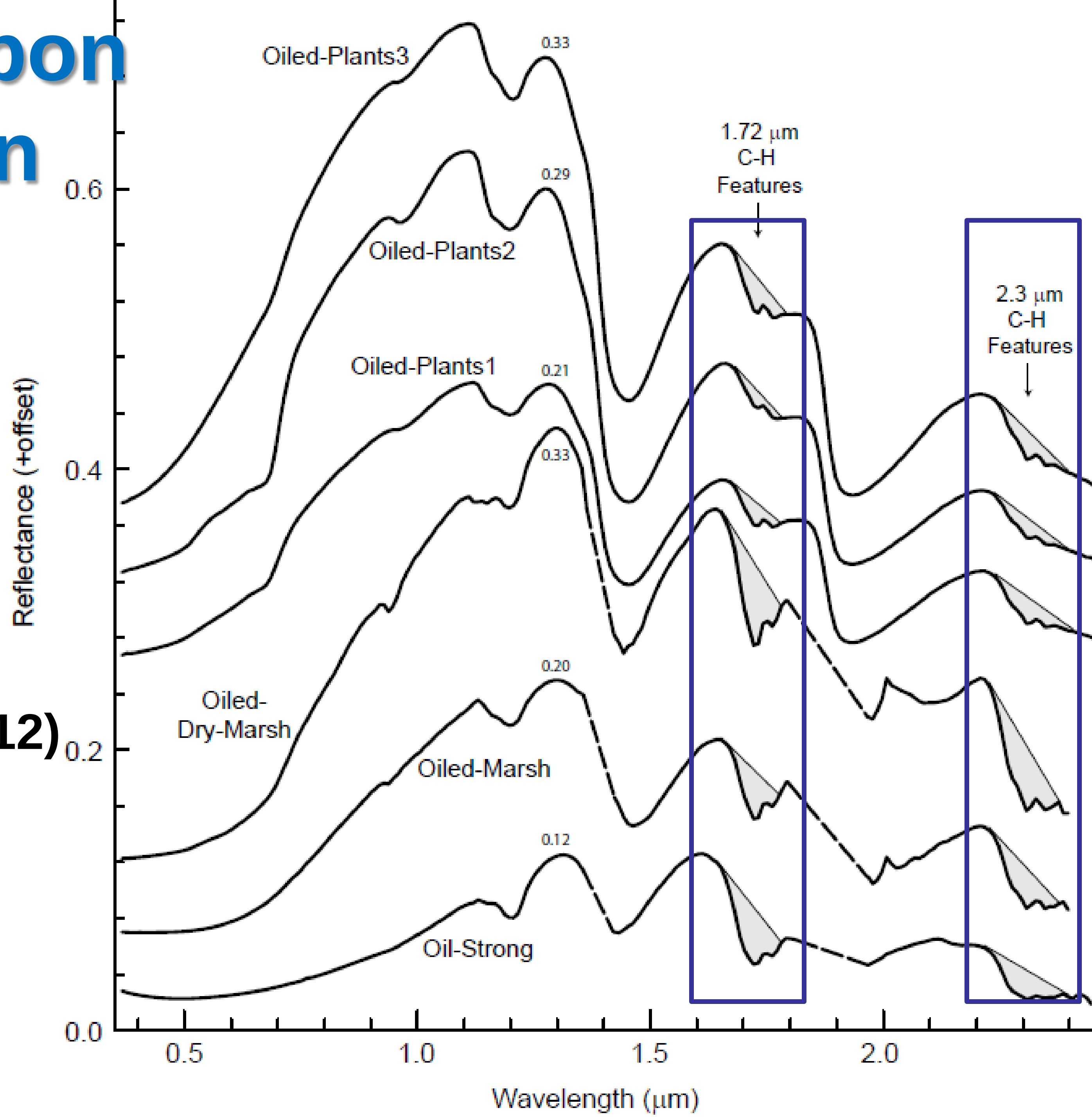
- Biggest coastal oil spill in the US
- One of the five biggest oil spills in the world by volume

Surface Oiling Surveys: May 17 - July 25
Shoreline Oiling: Most severe oiling observed through November

Map courtesy of National Geographic (surface oil) and modified by Commission staff, NOAA/Coast Guard SCAT map (shoreline oiling)

Graham et al. 2011

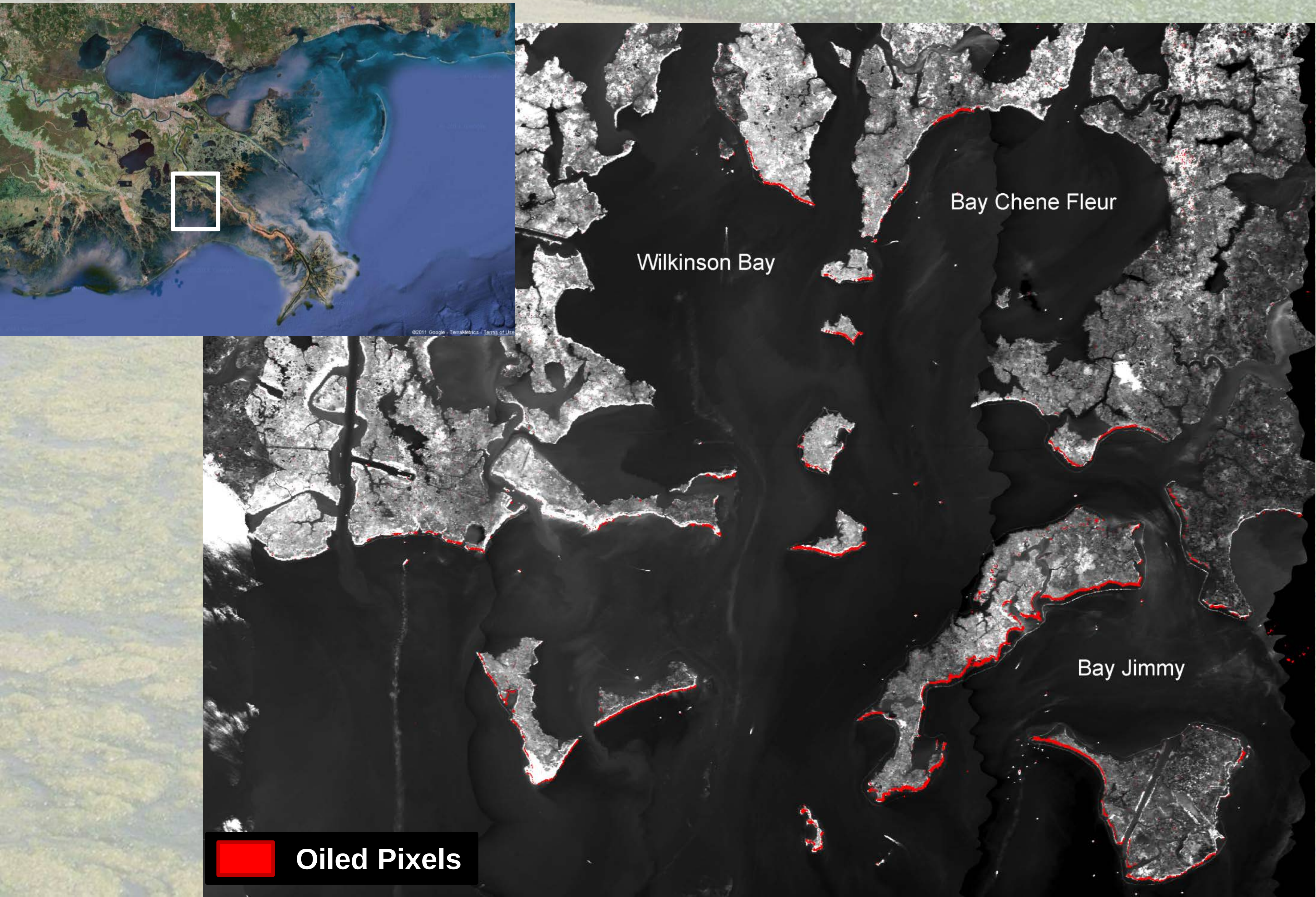
Hydrocarbon absorption features used to detect oil



(Kokaly et al. 2012)

- 1720 nm
- 2300 nm

Oiled Shoreline in Barataria Bay (Kokaly et al. 2012)



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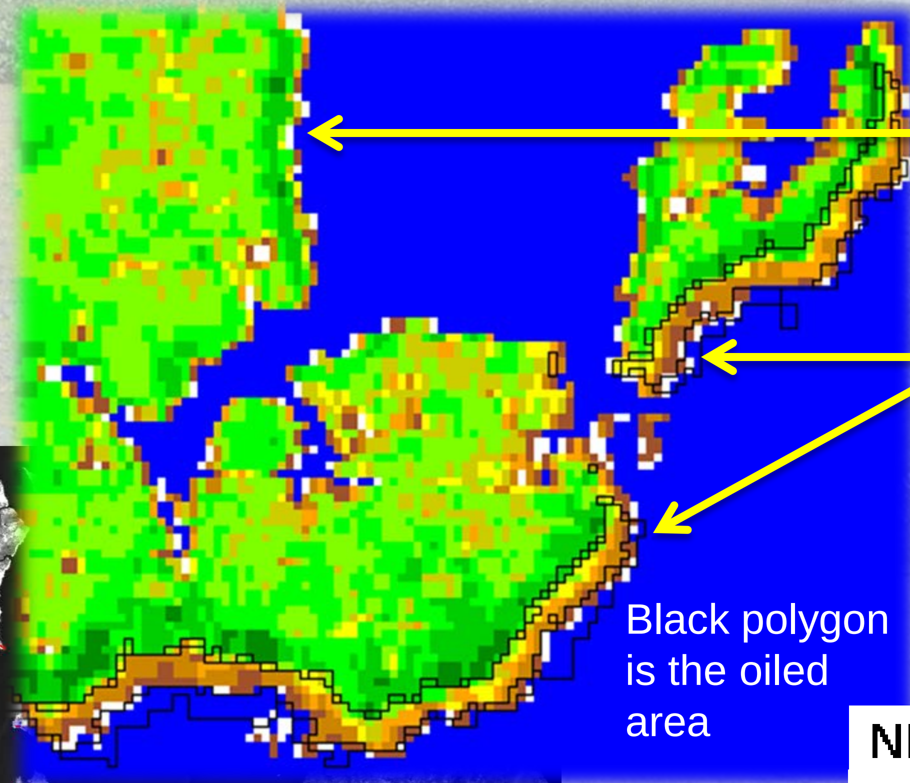
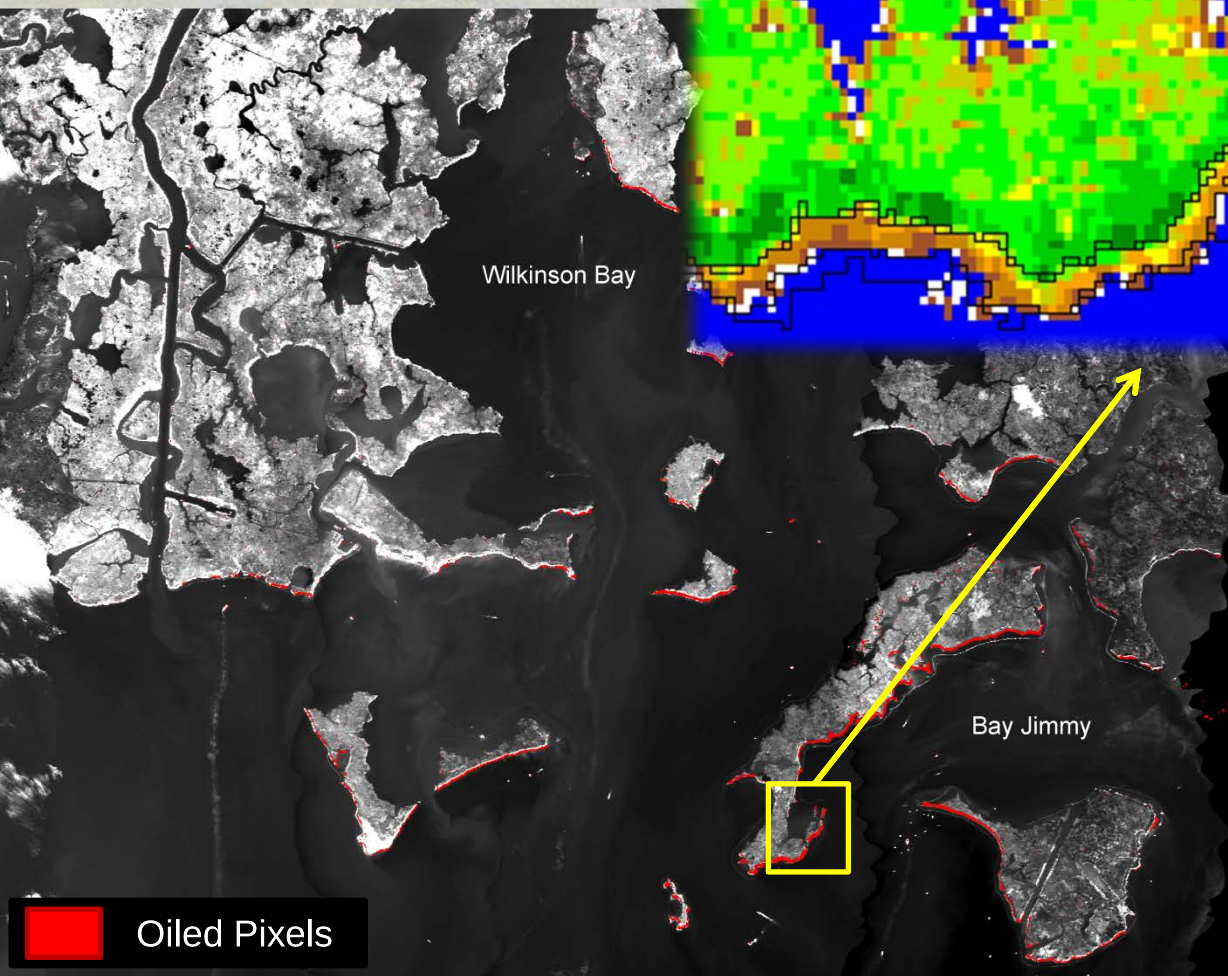
Sharp transition from green to dead vegetation

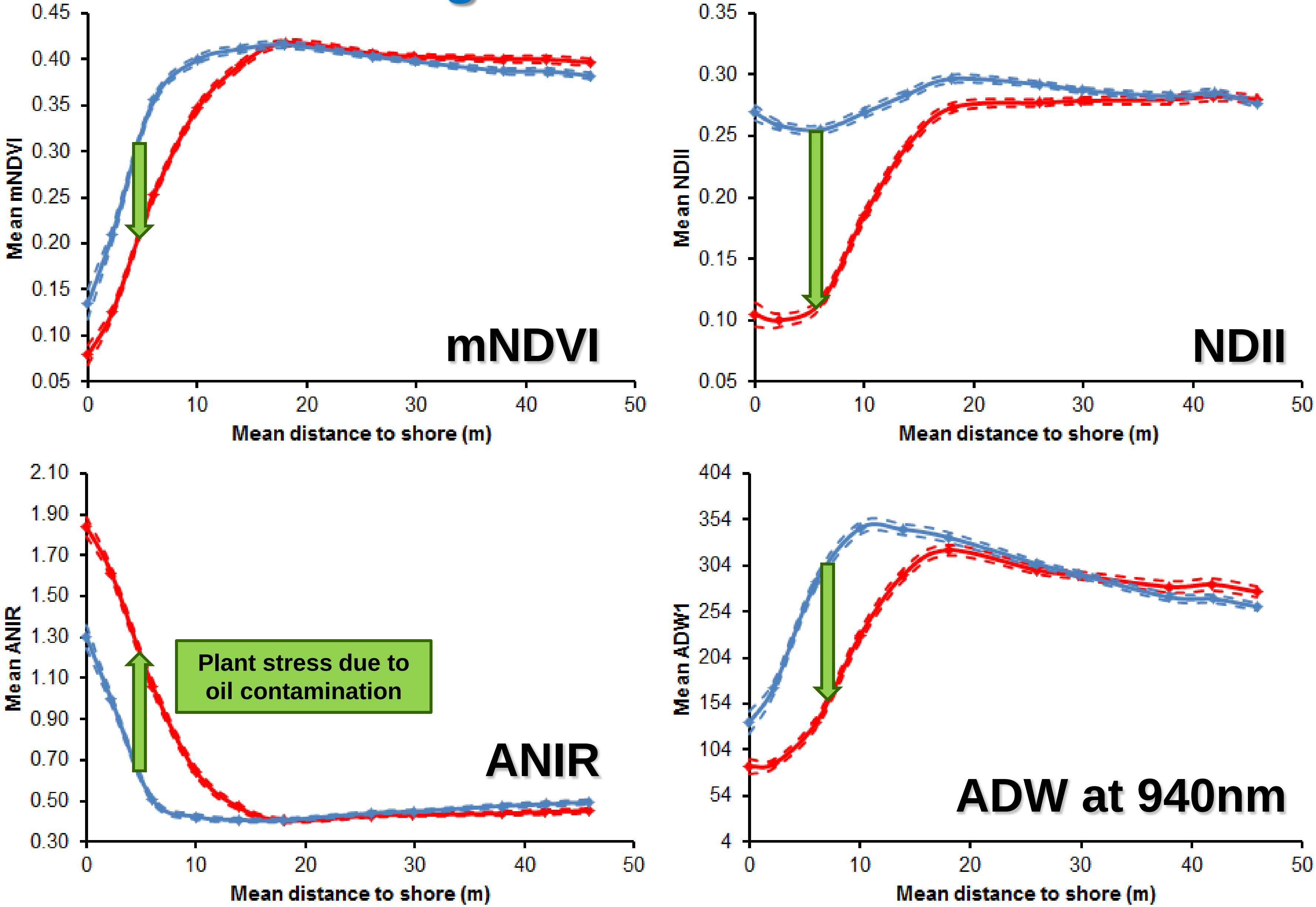
Erosion risk along retreating vegetation edge

NDVI Response in Oiled Areas

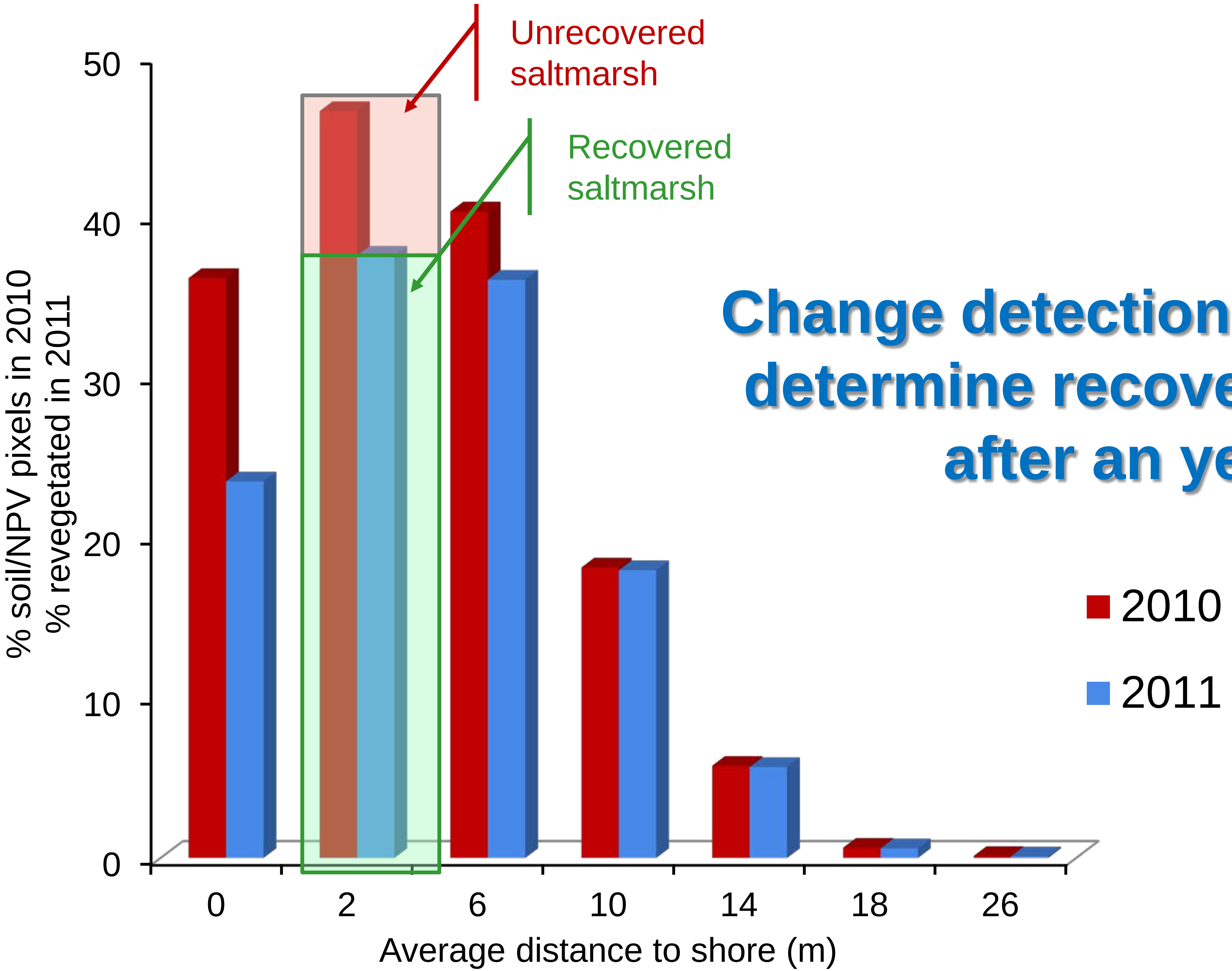




Index trajectories w.r.t to distance to the shore along oiled and oil-free shores



Change detection to determine recovery after an year



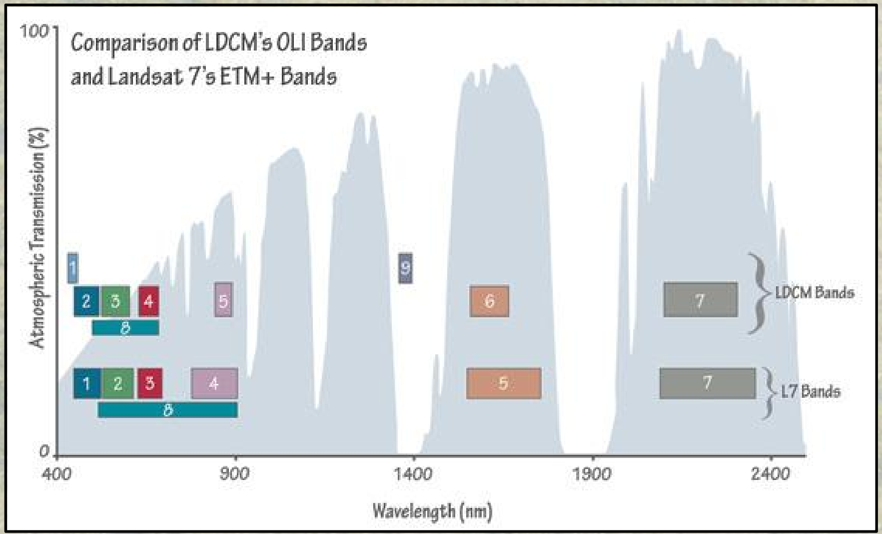
Why remote sensing?

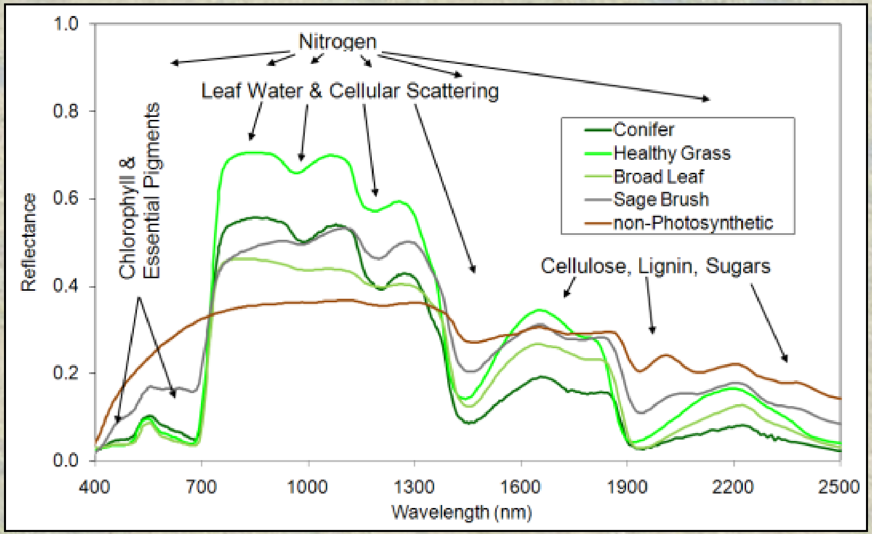
- Measures direct biophysical processes
  - e.g. loss of chlorophyll and other pigments, water stress
- Provides Geospatial Information
- Provides wall-to-wall coverage
- Samples difficult to reach locations
- Multi-temporal data allows
  - Monitoring change in distribution, spread and persistence
  - Monitoring stress and recovery
  - Assessment of management goals (e.g. herbicide control)

LDCM (Landsat Data Continuity Mission and HyspIRI (Hyperspectral InfraRed Imager): Future of Satellite Remote Sensing

Specifications:

	LDCM	HyspIRI	EnMAP
Spectral extent	UV to Thermal	380 to 2500 nm	420 to 2450 nm
Bandwidth	broadband (variable)	10 nm	6.5 to 10 nm
Number of bands	11 bands	210 bands	244 bands
Spatial resolution	15m (pan), 30m	60m	30m
Temporal resolution	16 days revisit	19 days revisit	on demand





Applications

LDCM, Feb 2013

- Map current and historical extent of invasive species (depends on patch size, e.g. tamarisk, ice plant)
- Detect links between climate, weather and invasive species distributions
- Detect land cover change over time (Four decades of data)
- Help in climate change forecasting

HyspIRI, 2020

- Detect pigment loss and water stress
- Map communities and functional types
- Reduce uncertainties in ecosystem composition feedbacks
- Improve inputs to climate models

EnMAP, 2013

Acknowledgements

- Field crews of CSTARS, CDBW, CDFA and USGS, Baton Rouge, LA for collection of field data
- Mui Lay, Jaylee Tuil, Sinzee Tran & Shawn Kefauver for data preparation
- George Scheer for IT support
- Marcia Carlock at CDBW for funding image acquisition over the Delta
- Dr. Diane Wickland at NASA for providing access to the AVIRIS database
- Dr. Elizabeth Blood at NSF for funding the Gulf Oil Spill project
- Dr. Mike Whiting and Dr. Jose Zarate for collecting calibration data in the field

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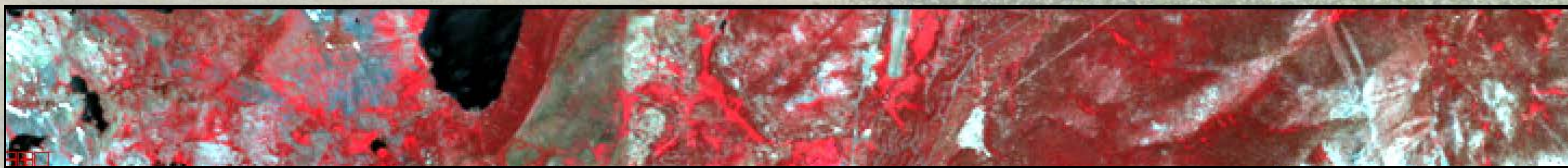
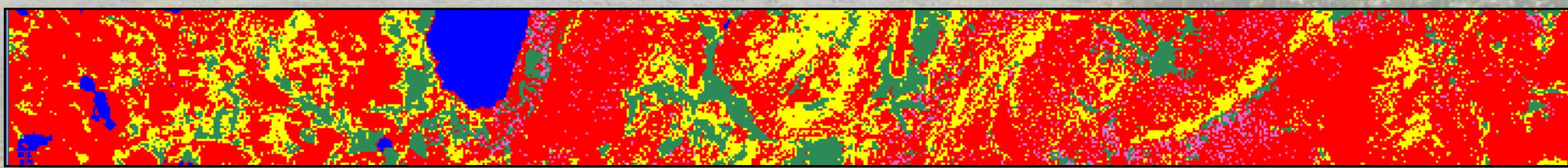
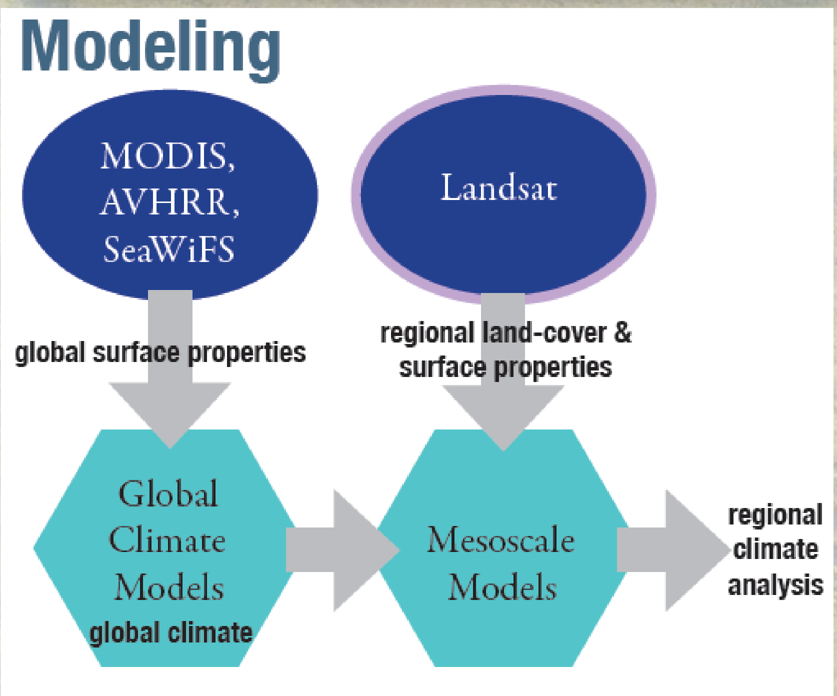
Landsat land cover classification



Color Infrared Landsat data over South Lake Tahoe Basin



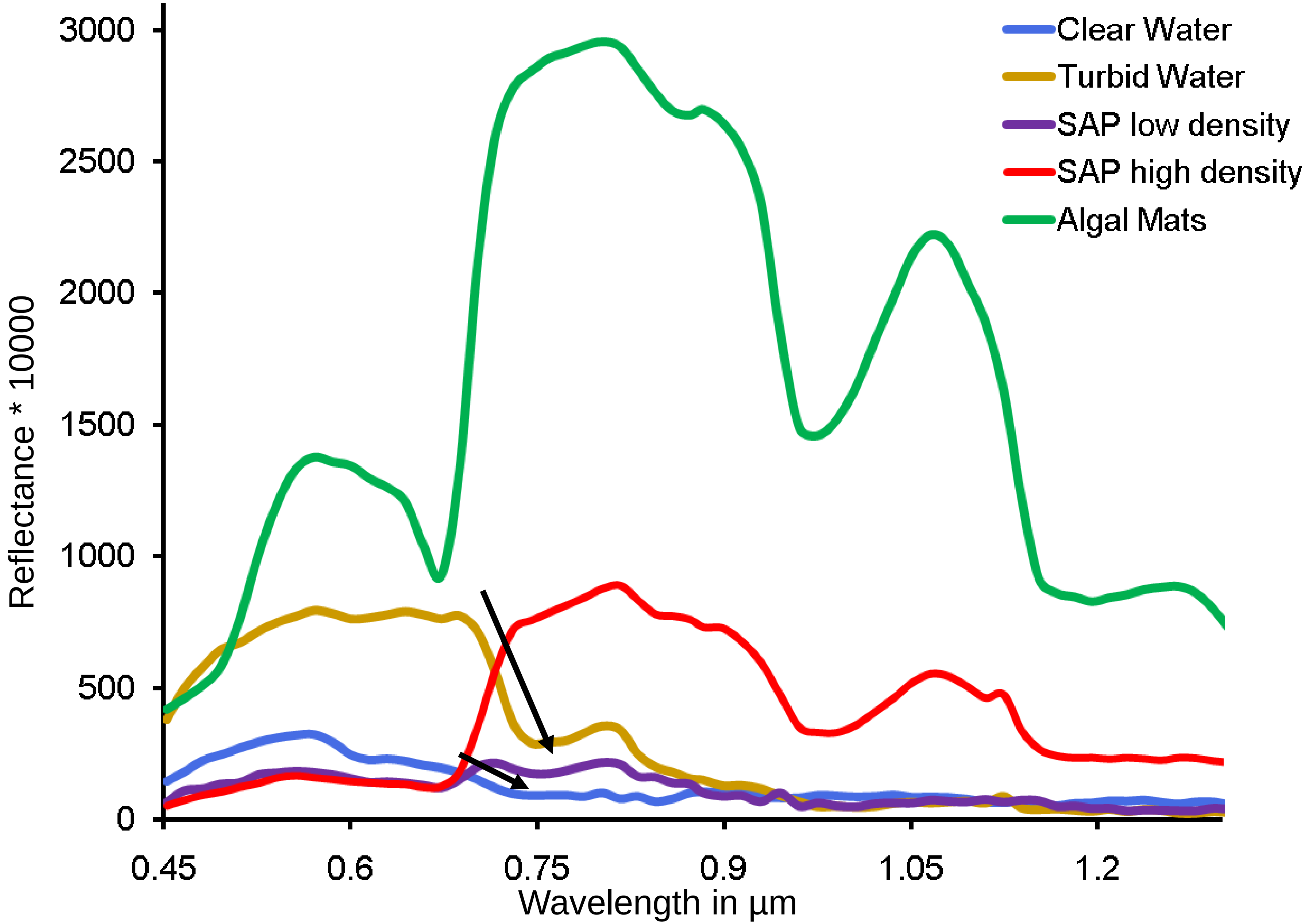
Support Vector Machines Classification



Climate Change fore-casting at regional level requires land-cover and surface properties derived from Landsat Data

- **Water**
- **Trees**
- **Grasslands**
- **Shrubs**
- **Soil/Rock**

Water vs. Submerged Aquatic Plants



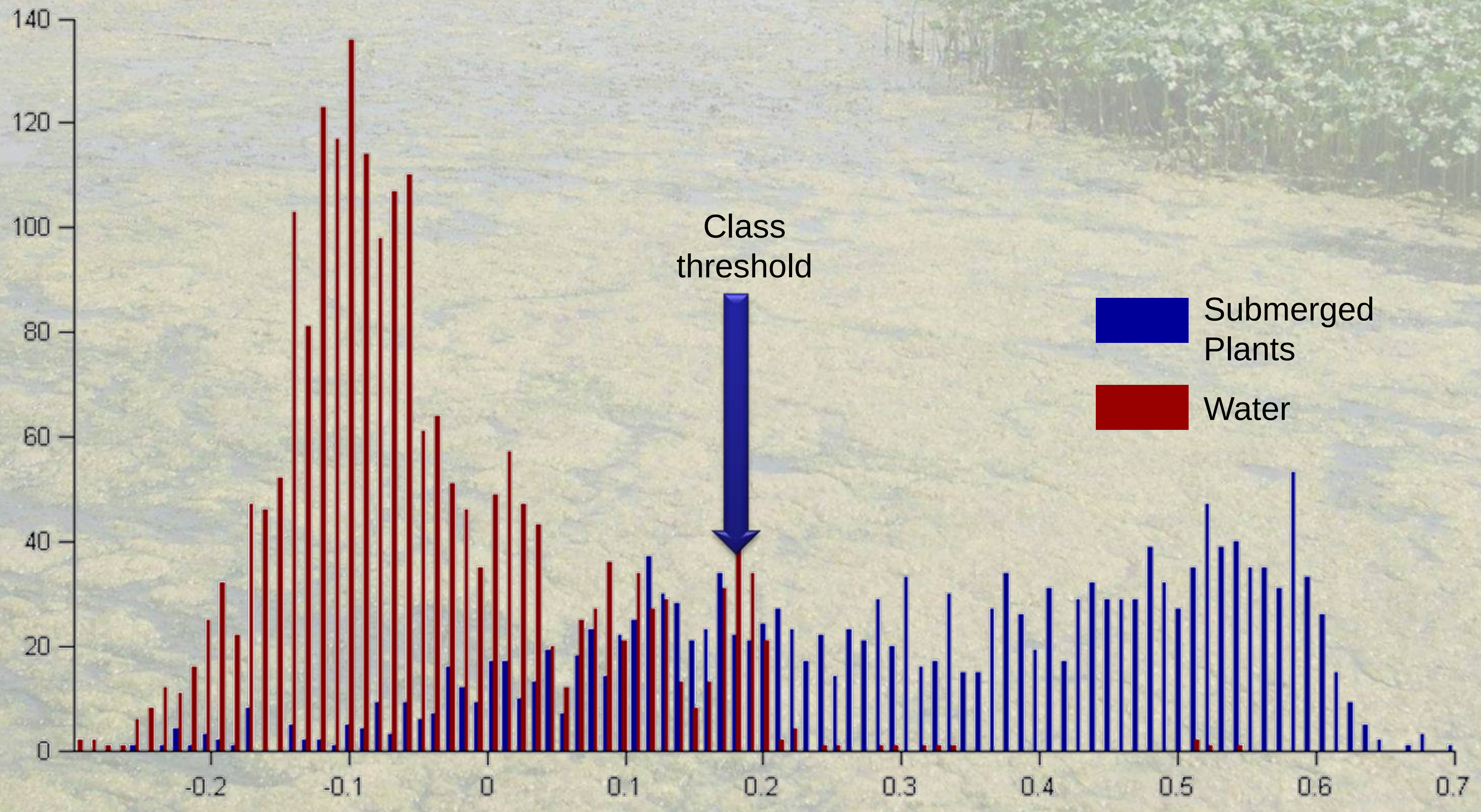
Summary of Results

Water hyacinth

- **Accuracies: 62% - 100%**
- **Kappas: 0.6 - 0.9**
- **Useful inputs**
  - VIS, NIR & SWIR reflectance
  - *Narrow band* indices
  - Water indices & continuum removals
- **Water hyacinth classification method**
  - Hybrid decision trees
  - Biophysiologically based, with statistical support and expert knowledge

2007 – mNDVI

Submerged Aquatic Plants vs. Water




2008

Simulating Submerged Aquatic Plants Classification at Landsat Spectral and Spatial Scales

Spatial Resolution	Spectral Bands	SAP Users Accuracy	SAP Producers Accuracy	Overall Accuracy	Overall Kappa
3m	6 bands	**73.6**	**53.1**	**81.1**	**0.67**
	125 bands	**81.7**	**51.7**	**82.2**	**0.69**
15m	6 bands	**79.6**	**53.1**	**82.4**	**0.69**
	125 bands	**81.7**	**51.7**	**82.2**	**0.69**
30m	6 bands	**59.8**	**36.4**	**72.8**	**0.51**
	125 bands	**40.3**	**20.5**	**62.7**	**0.31**

Classification using C5.0

- **Ensemble boolean decision trees**
- **C5.0 maximizes *Information Gain Ratio* to split the training set into two homogeneous groups**
- **It uses the ratio to choose a split that minimizes branches**
  - This curbs overfitting the data – a common problem with automated decision trees
- **Winnows attributes using only important predictors**
- **Ensemble trees boost accuracy by learning from the mistakes of previous trees**

Hybrid Strategy

Classification using decision trees

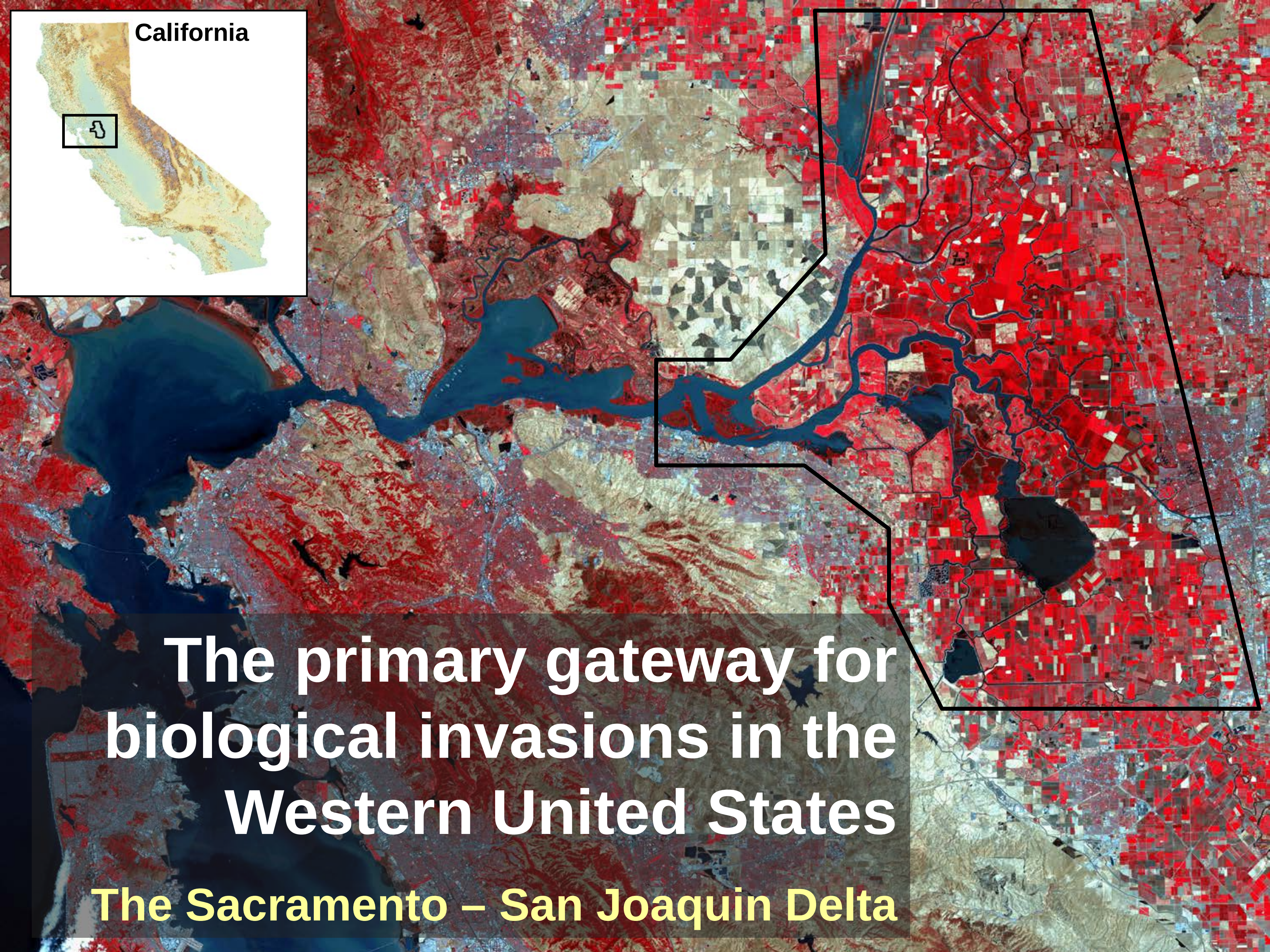
Hybrid approach

Biophysiological basis of classification

- ANOVA to decide useful variables
- Histograms to decide thresholds
- Expert knowledge used in building tree

Essentials for successful classification

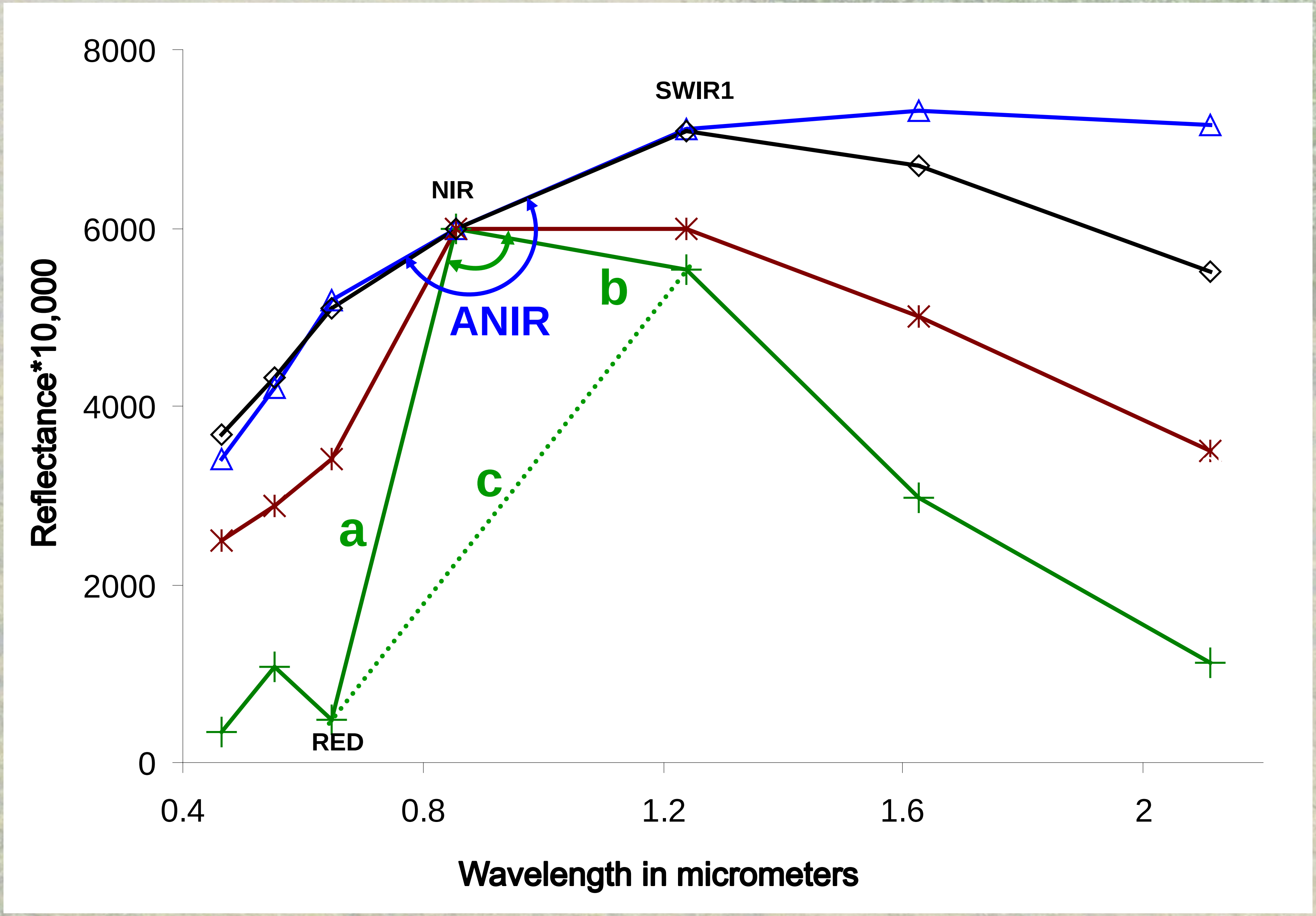
- Using multiple inputs in addition to image bands
  - Different techniques can gather distinct information about target classes
- Using methods that can accommodate
  - Multi-modal distributions of target classes
  - Multiple data types with different ranges and magnitudes
  - Be robust and automated when dealing with huge datasets over vast spatial extent
- Collecting enough training and validation data
- Matching target class complexity with required data
  - Study system complexity
  - Separability of target classes in spectral space


California
The primary gateway for biological invasions in the Western United States
The Sacramento – San Joaquin Delta

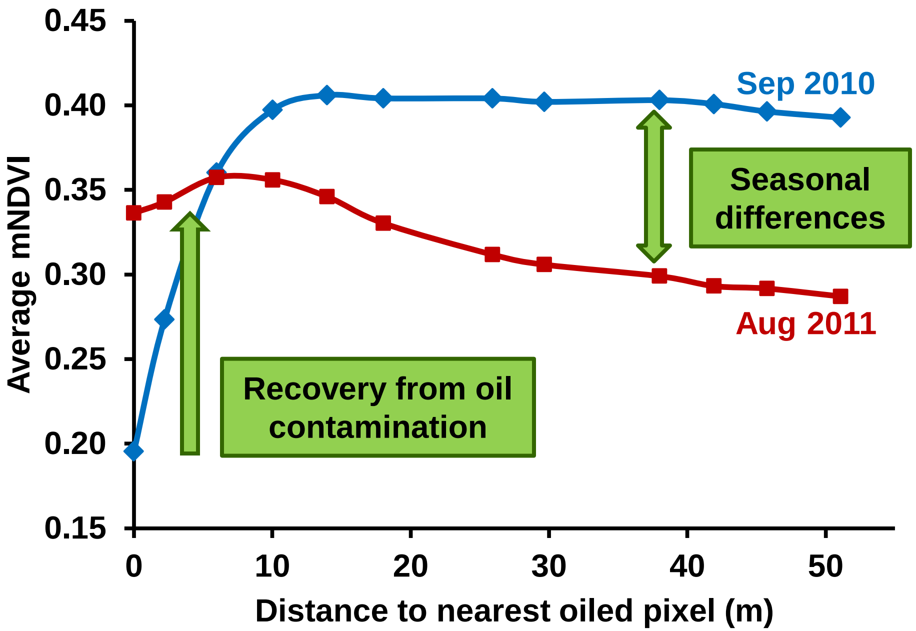
The classification problem

- **Multiple Inputs**
  - Reflectance bands from the imagery
  - LiDAR derived tree height
  - Spectral Indices
    - Broad band e.g. NDVI & narrow band indices e.g. CAI
    - Indices measuring specific properties: water, chlorophyll, cellulose
- **Multiple Techniques**
  - Continuum removals over water absorption features
  - Linear Spectral Unmixing (LSU)
  - Spectral angle mapper (SAM)

ANIR – example of an angle index



Index trajectories w.r.t to distance from the nearest oiled pixel



Index trajectory in Sep 2010

Index trajectory in Aug 2011