Quantification of Health and Productivity of Salt Marshes Using Satellite Data

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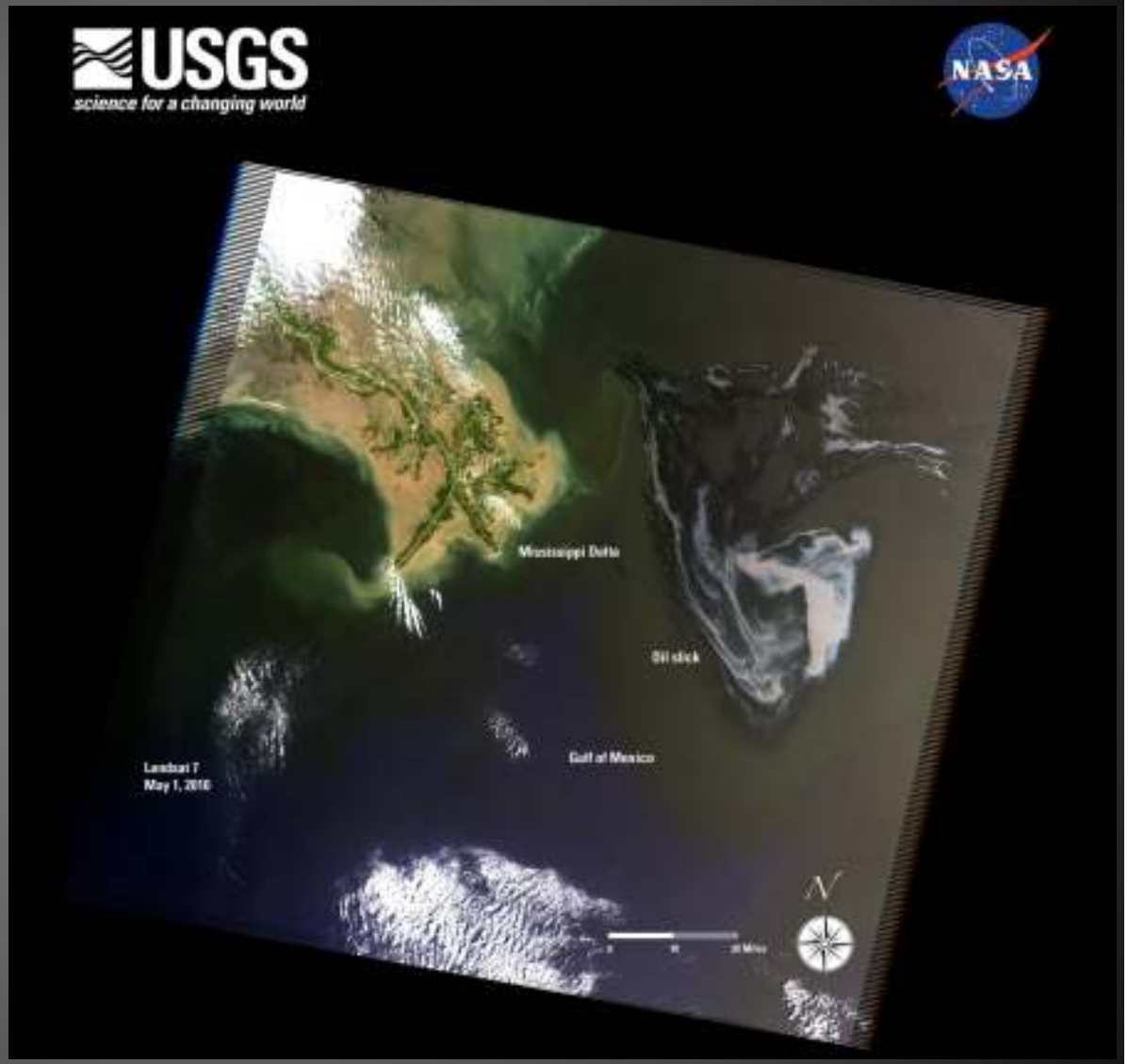
Salt Marsh

The Deepwater Horizon oil spill

- 20 April 2010
  - Continued flowing for three months
- Largest off-shore oil spill in U.S. history
  - Estimated 206 million gallons of crude oil
- First major U.S. oil spill to affect marsh/wetland habitat



http://gallery.usgs.gov/photos/05_05_2010_s84Aq10Ppk_05_05_2010_1

Impact on Salt Marsh Habitat

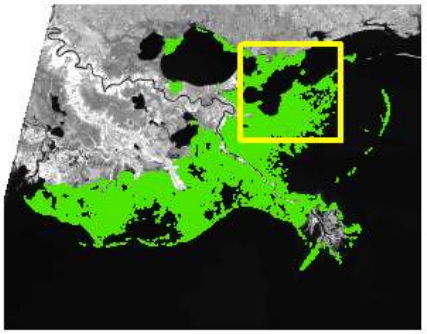
- Particularly damaging to marshland and marine habitat
  - Loss in green biomass (browning)
  - Reduction in photosynthetic activity
  - Impact from cleaning efforts
    - Burning
    - Flushing
    - Skimming

Objectives

- Estimate short term impact of the oil spill on salt marsh habitat by evaluating marsh biophysical characteristics
- Using remote sensing data, develop models and products that will facilitate monitoring restoration efforts of the coastal salt marsh habitat

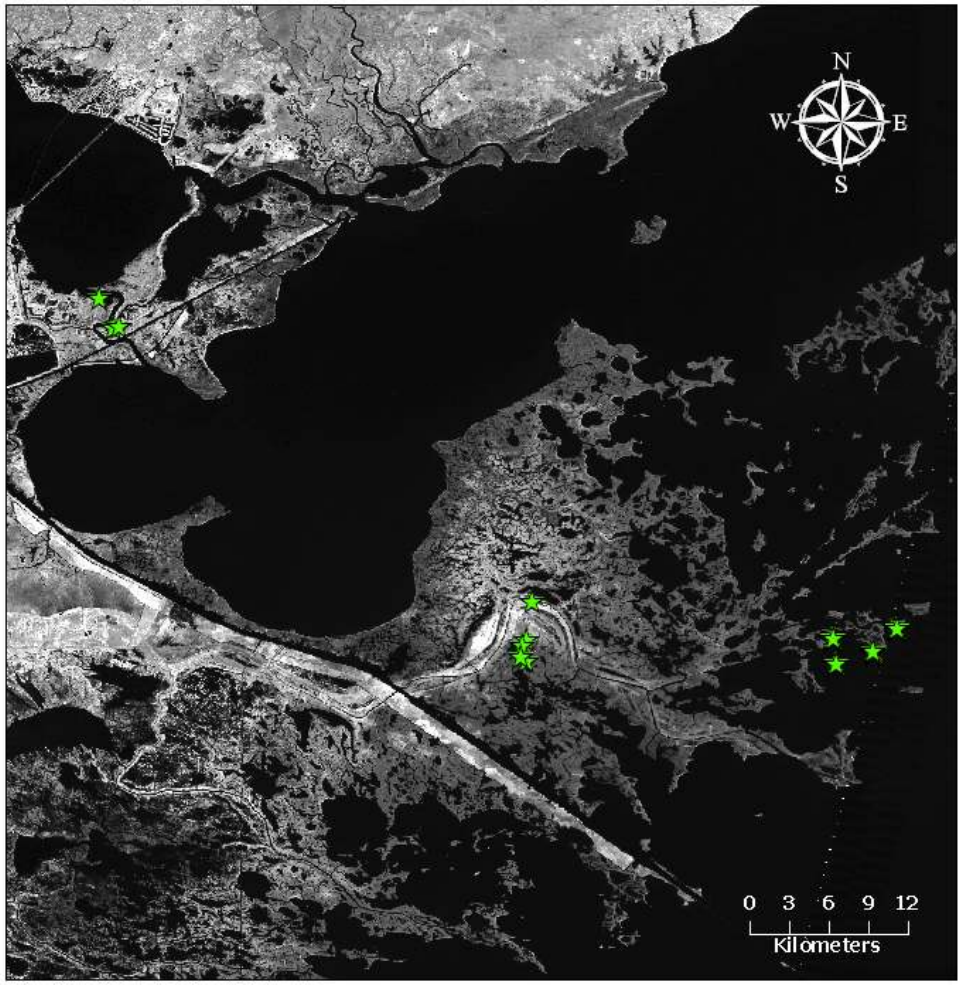
Study Area

Louisiana Estuarine and Marine Salt Marshes



Area - 4554.7 sq. km

Vegetation:
Spartina patens
Spartina alterniflora
Juncus roemerianus
Distichlis spicata
Salicornia virginica



Sites

Field Data

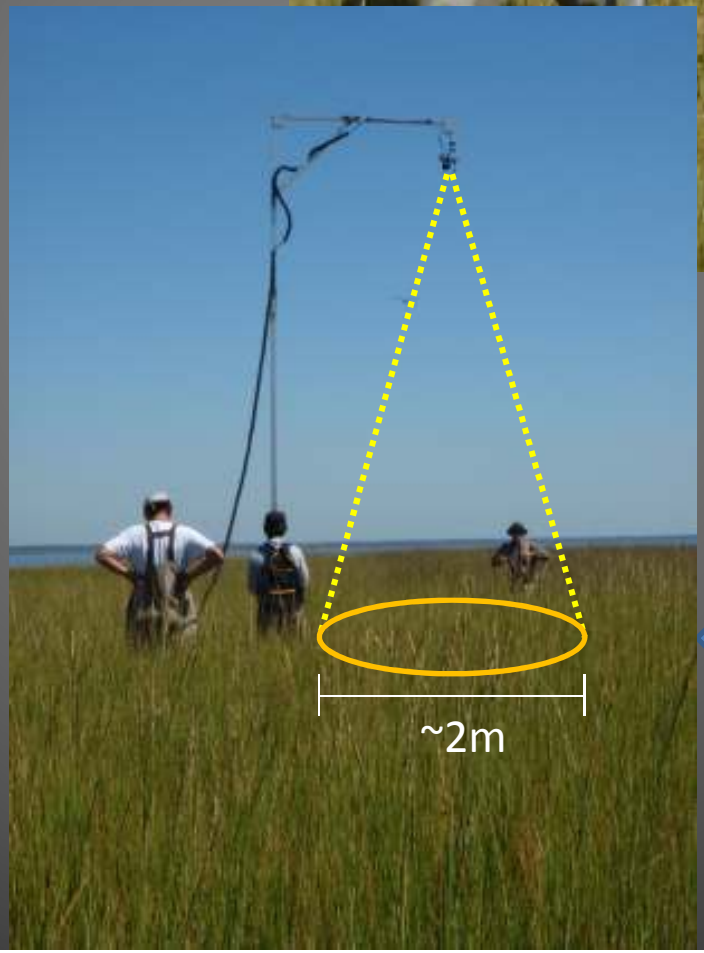
- 69 locations; Aerial and Ground Survey
- Top of Canopy (TOC) hyper-spectral reflectance data (Ocean optics USB 4000 Spectroradiometer and ASD sensor)
- Vegetation Fraction (Olympus E-502 Digital Camera)
- Leaf Area Index (LAI Plant Canopy Analyzer 2000)
- Leaf level chlorophyll content (Minolta SPAD 502)
- Canopy level chlorophyll content calculating as $Chl_{upper} \times LAI$
- Above ground green biomass (gm/ft^2)

Field Methods

Dual Sensor Approach

$$\rho = \frac{L_{\uparrow}}{E_{\downarrow}}$$

L = upwelling radiance
E = downwelling irradiance
p = remote sensing reflectance (sr^{-1})



Data acquisition

Sensor-Target : 16 ft
IFOV: 2.2 meter

Field Methods:

Canopy Chlorophyll

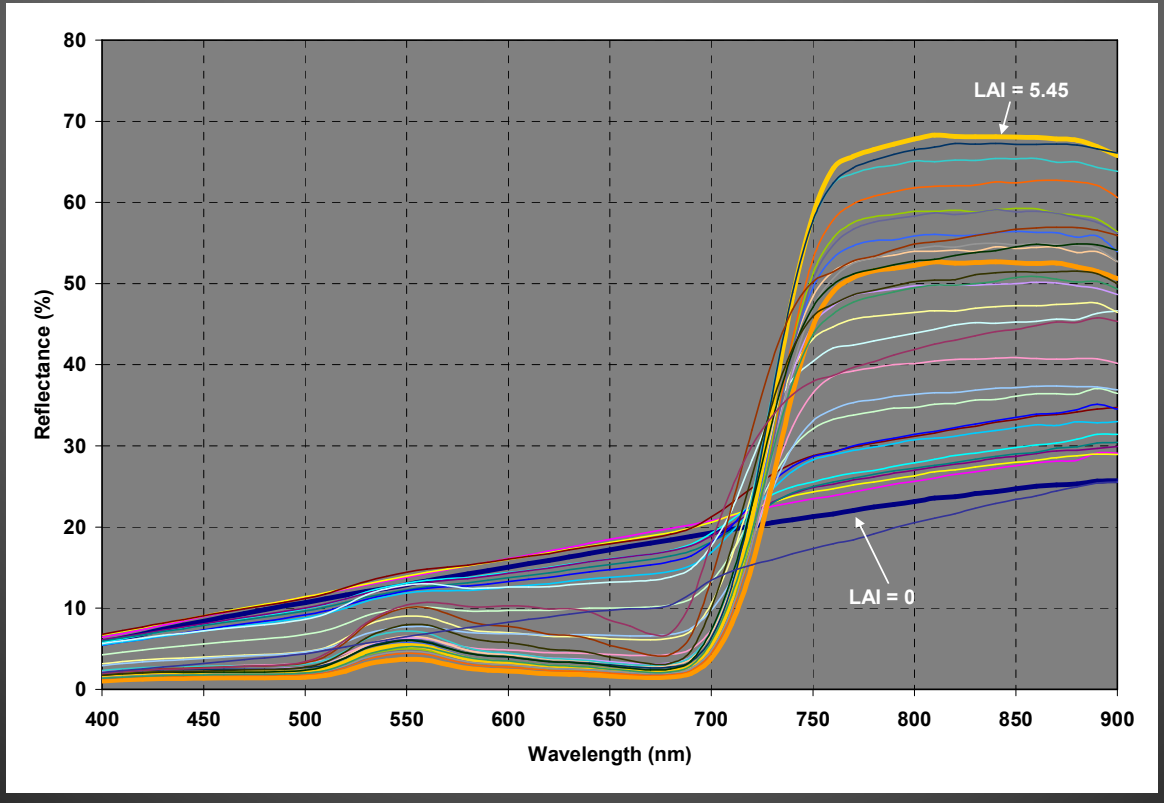
Leaf Area Index (LAI)

Leaf Level Chlorophyll

Canopy Chl = Leaf Level CHL * LAI

Leaf Area Index (Foliage area/Ground area)

The measurement of LAI is of fundamental importance in ecological research because LAI is a measure of plant growth; it directly affects the interception and absorption of light by the canopy and it influences the primary productivity of vegetation.

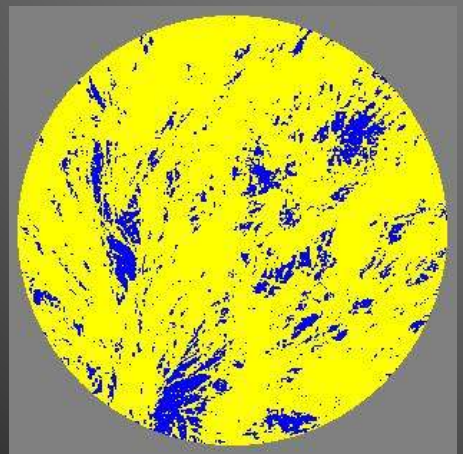


Vegetation Fraction (%)

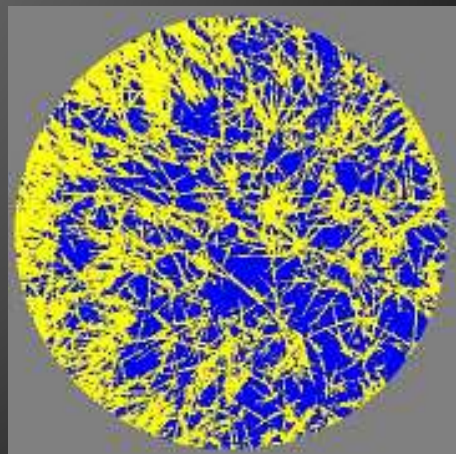
Vegetation Fraction (VF) = ratio of green vegetation area to ground area

Vegetation fraction is obtained as a ratio of the number of vegetation pixels to the total number of pixels in the image, expressed in percent

VF = 86%



VF = 42%



Field Methods

1. Canopy Height
   - Average of 5 measurements within a 1m radius of the scan center

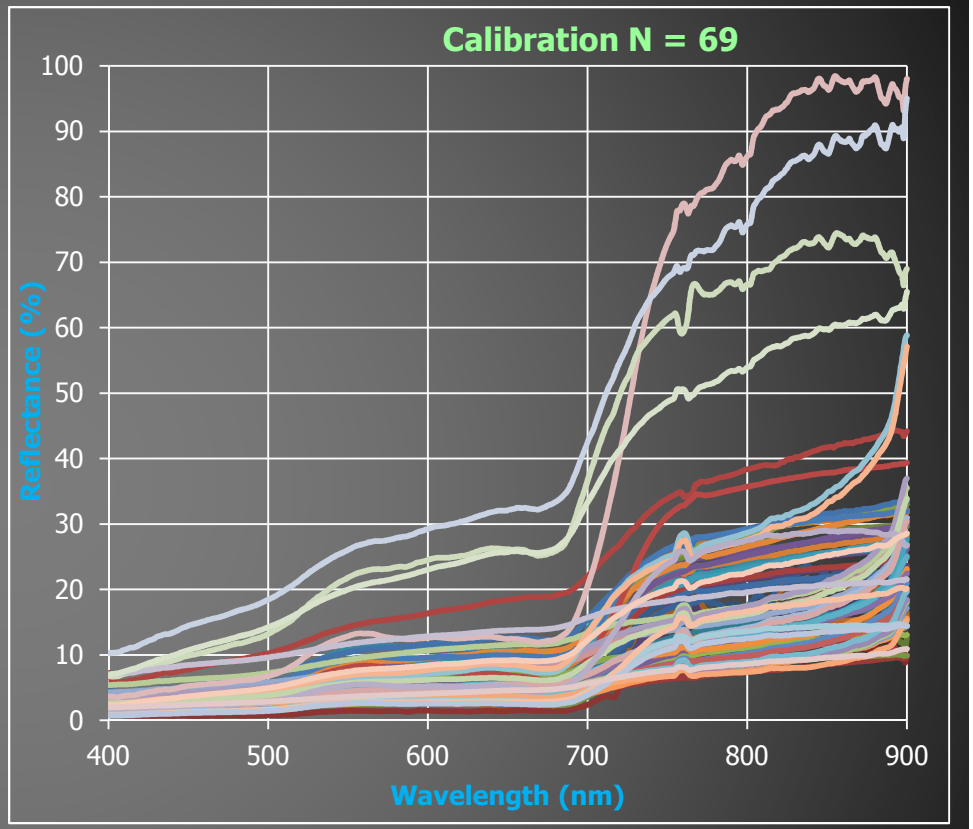
2. Green Biomass
   - Destructive sampling of vegetation after reflectance acquisition
     - Samples were sorted, oven dried, and weighed

Biomass sample collection

Sorting biomass

Field Data

N = 69	Min	Max	Mean	St. Dev
Biomass (g/ft^2)	3.9	566.2	82.6	84.04
LAI	0.01	2.57	1.02	0.7
VF (%)	0.3	99	34	25.34
Canopy Chlorophyll (mg/m^2)	0.4	1321	134.1	209.88



Objective: Measure *in-situ* canopy-level reflectance of dominant vegetation

a) Develop spectral models to characterize selected biophysical parameters of each vegetation species individually

b) Develop a single model to characterize biophysical parameters for the entire marsh regardless of speciation

Applied Vegetation Indices (VIs) for GBM estimation per species

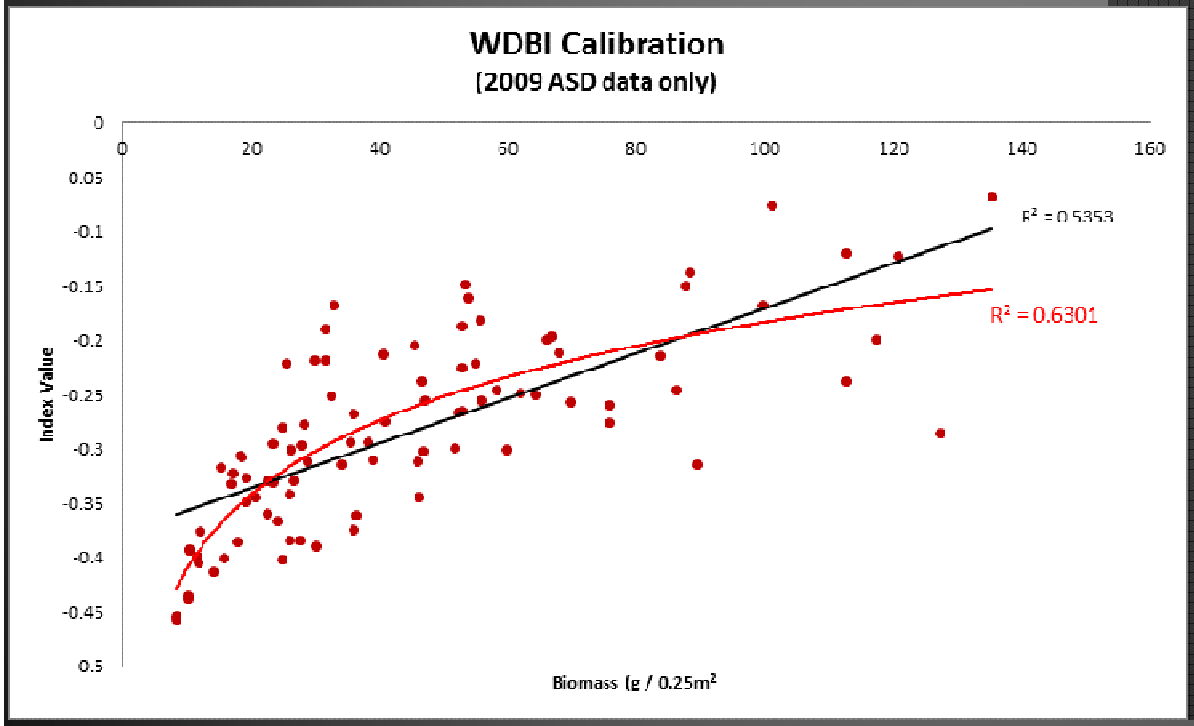
Vegetation Index	Application	Formula	Reference
Normalized Difference Vegetation Index (NDVI)	Biomass, Chl, VF	$\frac{NIR - Red}{NIR + Red}$	Rouse et al., 1974
Wide Dynamic Range Vegetation Index (WDRVI)	Chl, LAI, VF	$\frac{0.2NIR - Red}{0.2NIR + Red}$	Gitelson, 2004
Enhanced Vegetation Index (EVI)	Biomass, LAI	$\frac{2.5NIR - Red}{NIR + 6Red - 7.5Blue}$	Huete, 2002
Chlorophyll Index – Green (CI_{green})	Chl, GPP, VF	$\left(\frac{NIR}{Green}\right) - 1$	Gitelson, 2006
Chlorophyll Index – Red Edge ($CI_{red\ edge}$)	Chl, GPP, VF	$\left(\frac{NIR}{Red\ Edge}\right) - 1$	Gitelson, 2006

Applied 15 VIs

- 5 models with 3 variants of each model using 760, 800, and 1100nm for NIR

Weighted Difference Biophysical Index (WDBI): best correlated when working with all species

$$WDBI = \frac{0.2 \times \rho_{NIR} - \rho_{green}}{0.2 \times \rho_{NIR} + \rho_{red}}$$



Uses three characteristics of vegetation reflectance:

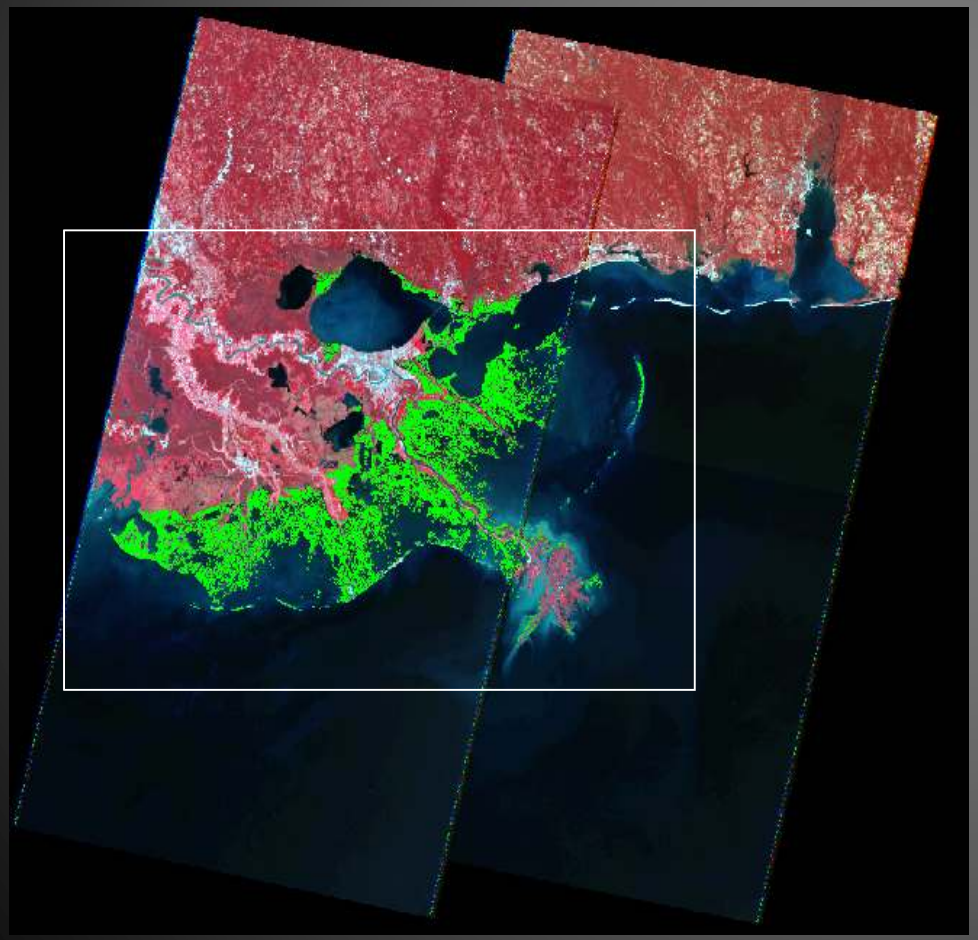
1) Visible wavelength with least absorption and most reflectance (r_{green})
   - Does not saturate at high biophysical values

2) Visible wavelength with the highest absorption (r_{red})
   - Representative of non-pigment scattering

3) Spectral region most sensitive to vegetation canopy structure (r_{NIR})

Satellite Data

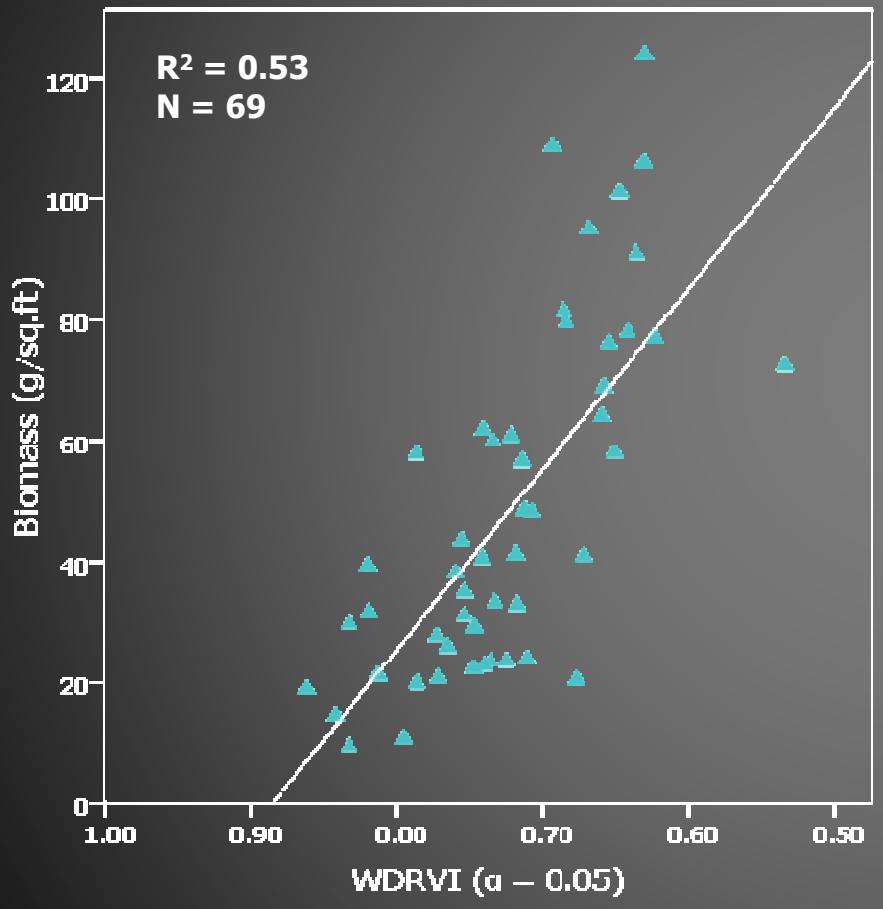
Multi-temporal LANDSAT TM 2009 - 2010

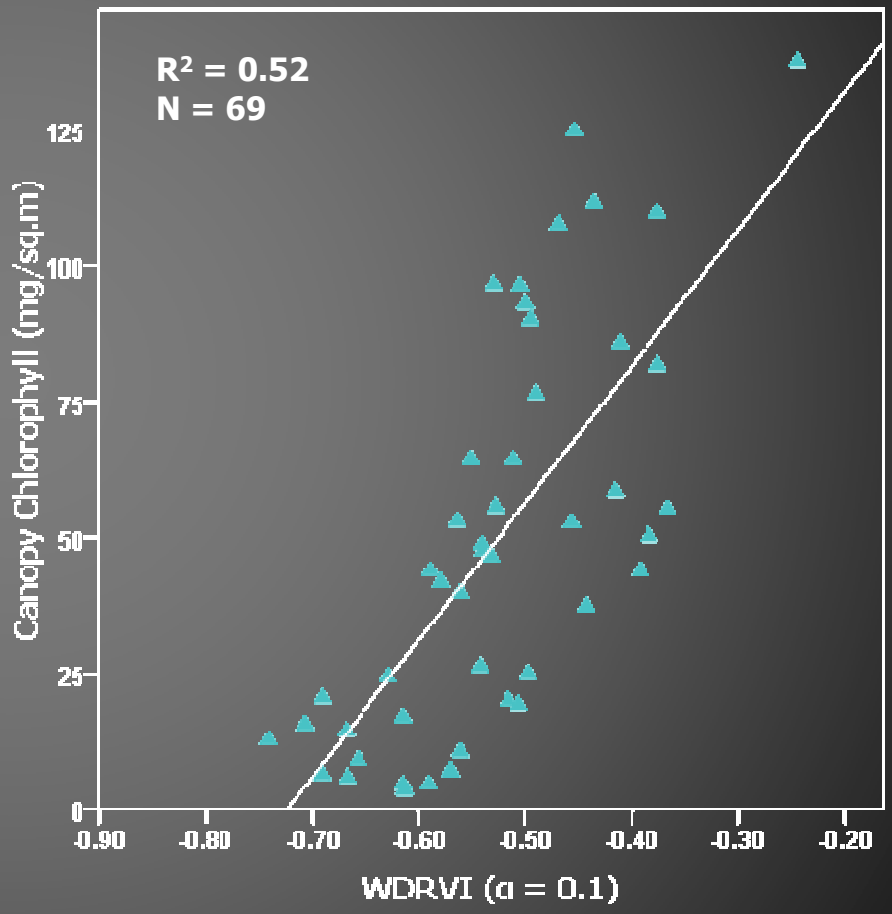


Dates	2009	2010
April	4	7
May	6	9
June	7	3
July	9	5
August	3	6
September	4	7
October	13	9

Model Calibration

$$WDRVI = (\alpha * \lambda_{NIR} - \lambda_{Red}) / (\alpha * \lambda_{NIR} - \lambda_{Red})$$

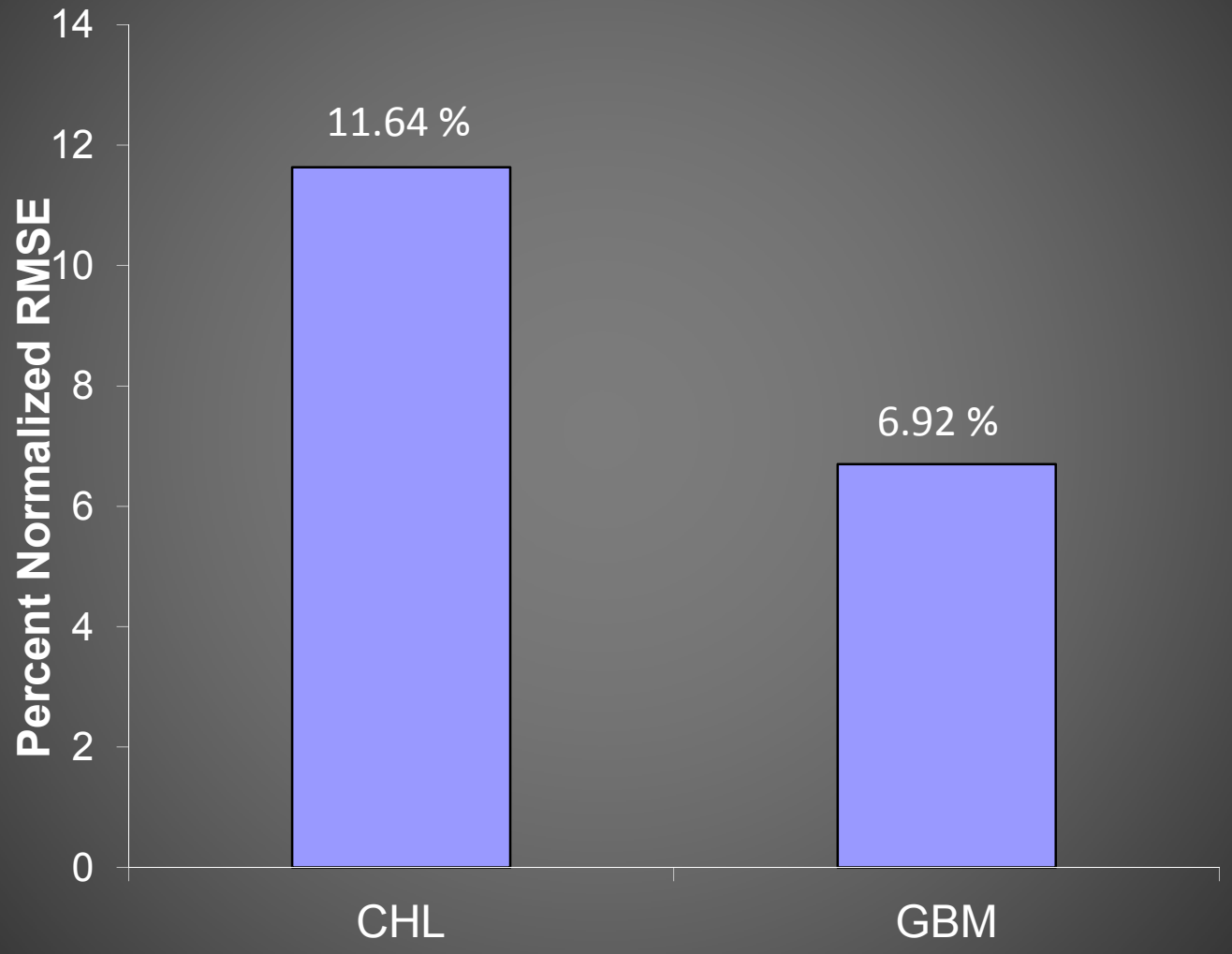




GBM = 298.943 × WDRVI (α = 0.05) + 264.494

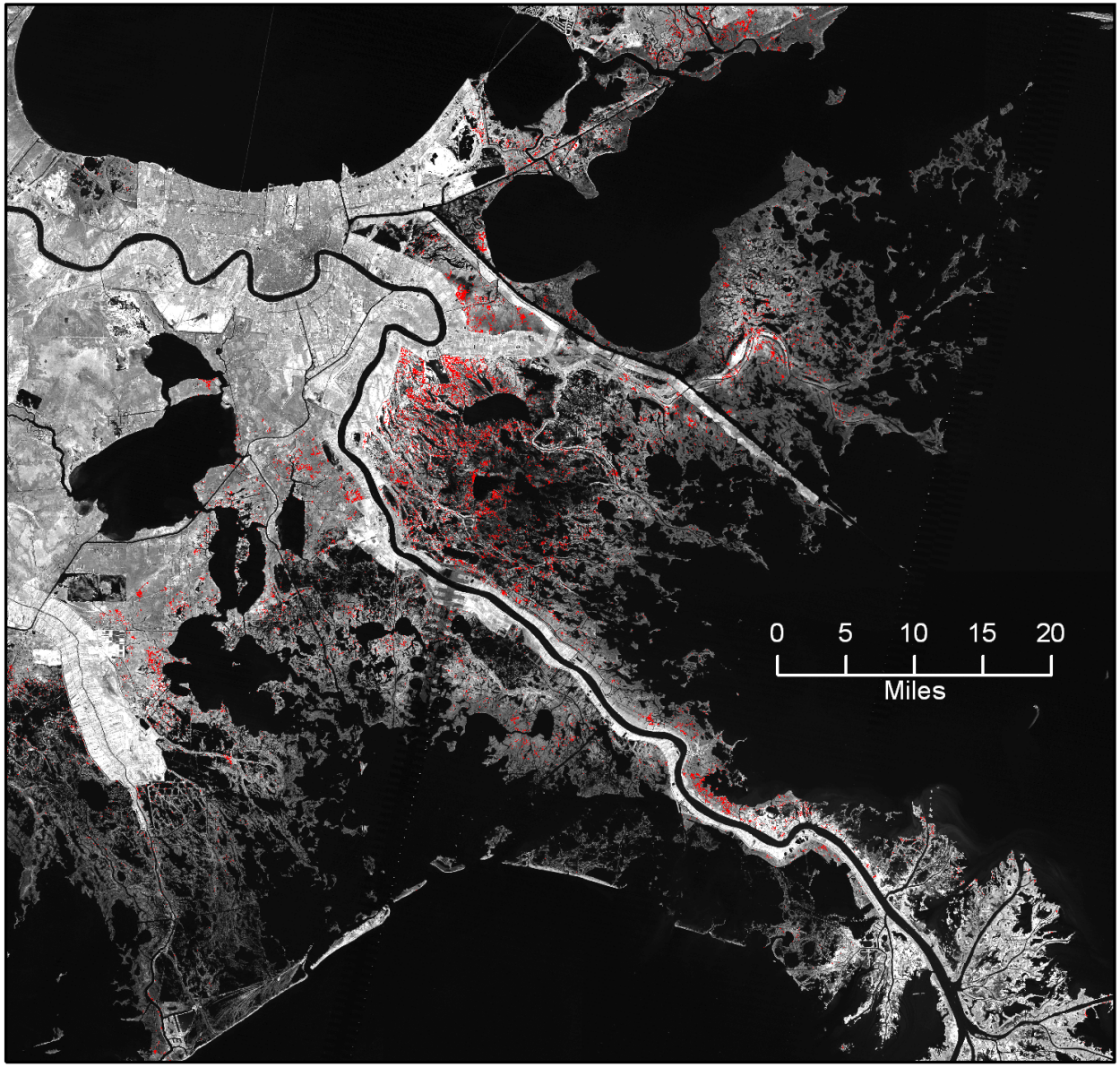
CHL = 251.955 × WDRVI (α = 0.1) + 182.327

Model Validation



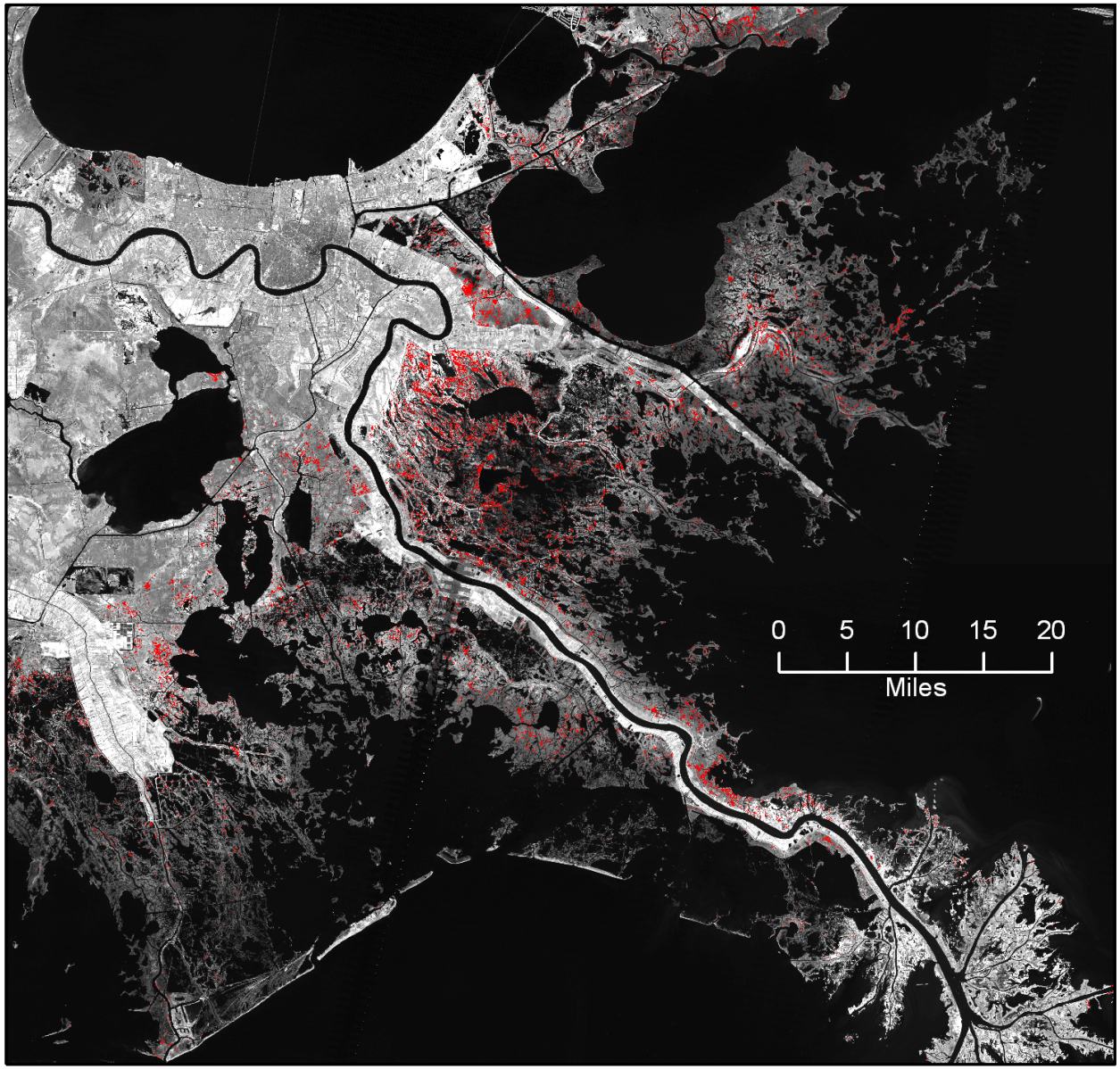
CHL Change 2009-10 (mg/sq.m)

> 20

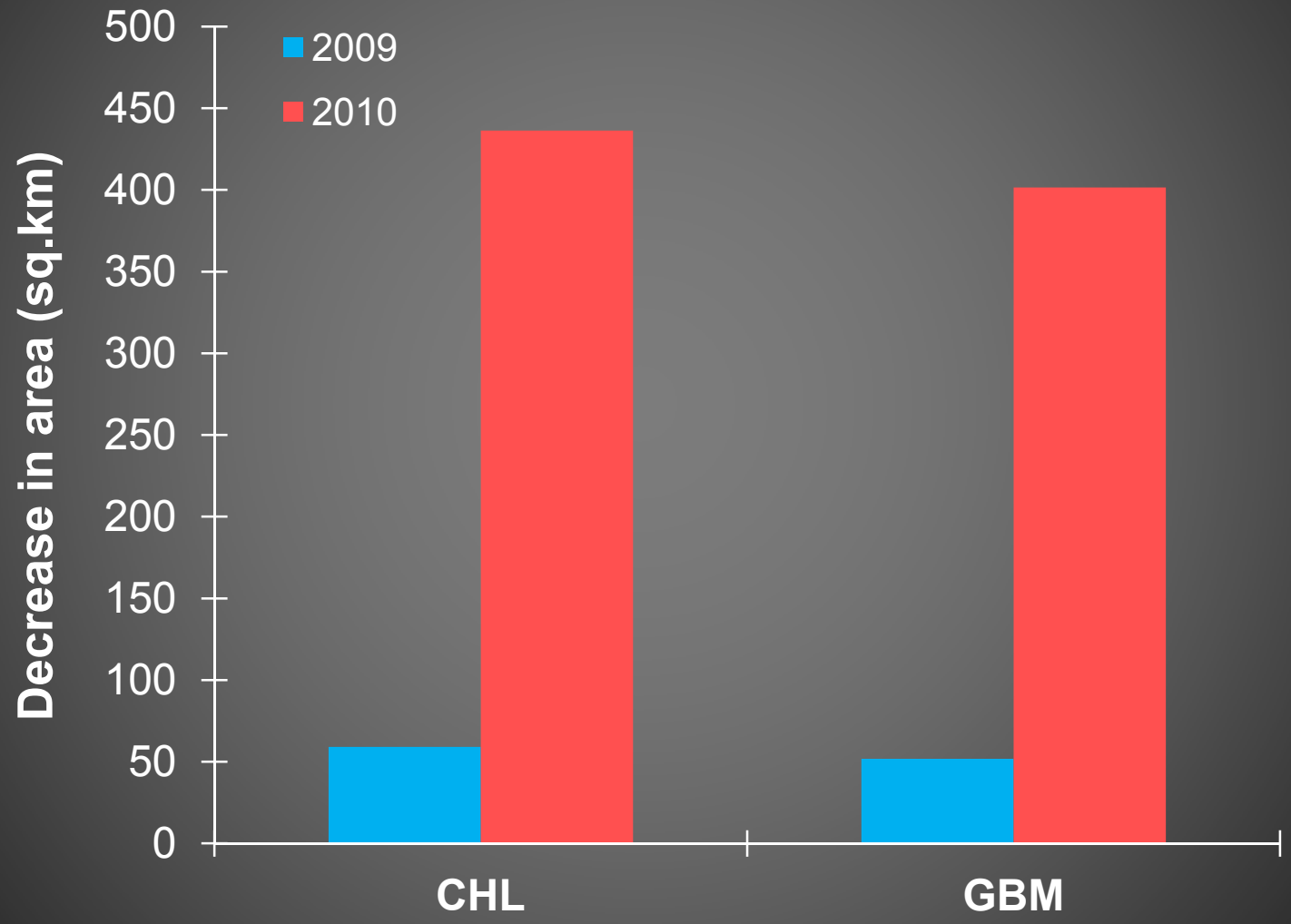


GBM Change 2009-10 (g/sq.m)

> 200

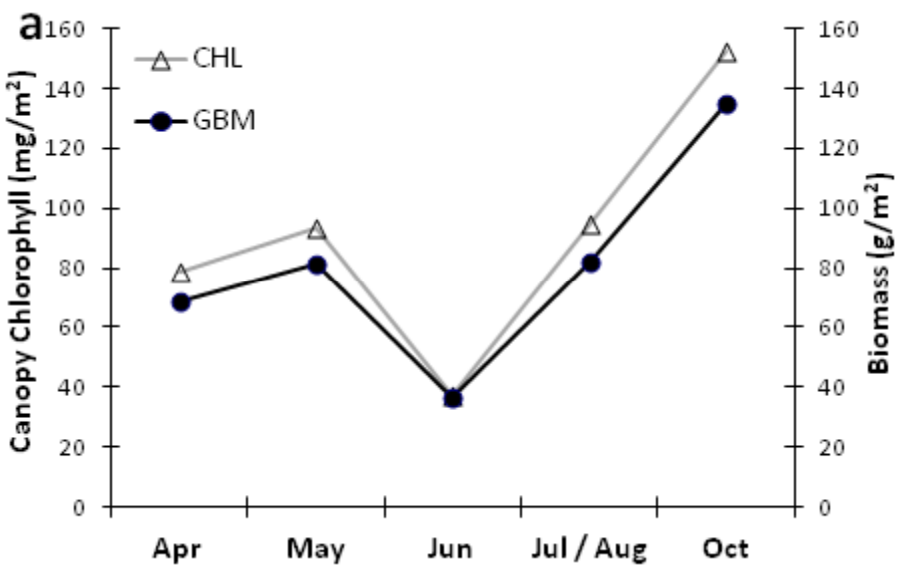


Results

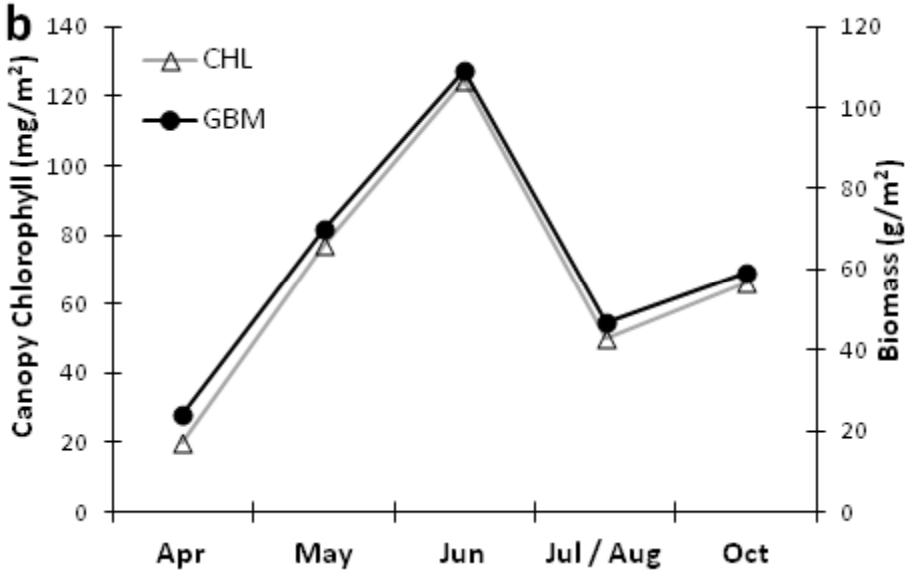

2009
2010
Decrease in area (sq.km)
500
450
400
350
300
250
200
150
100
50
0
CHL
GBM

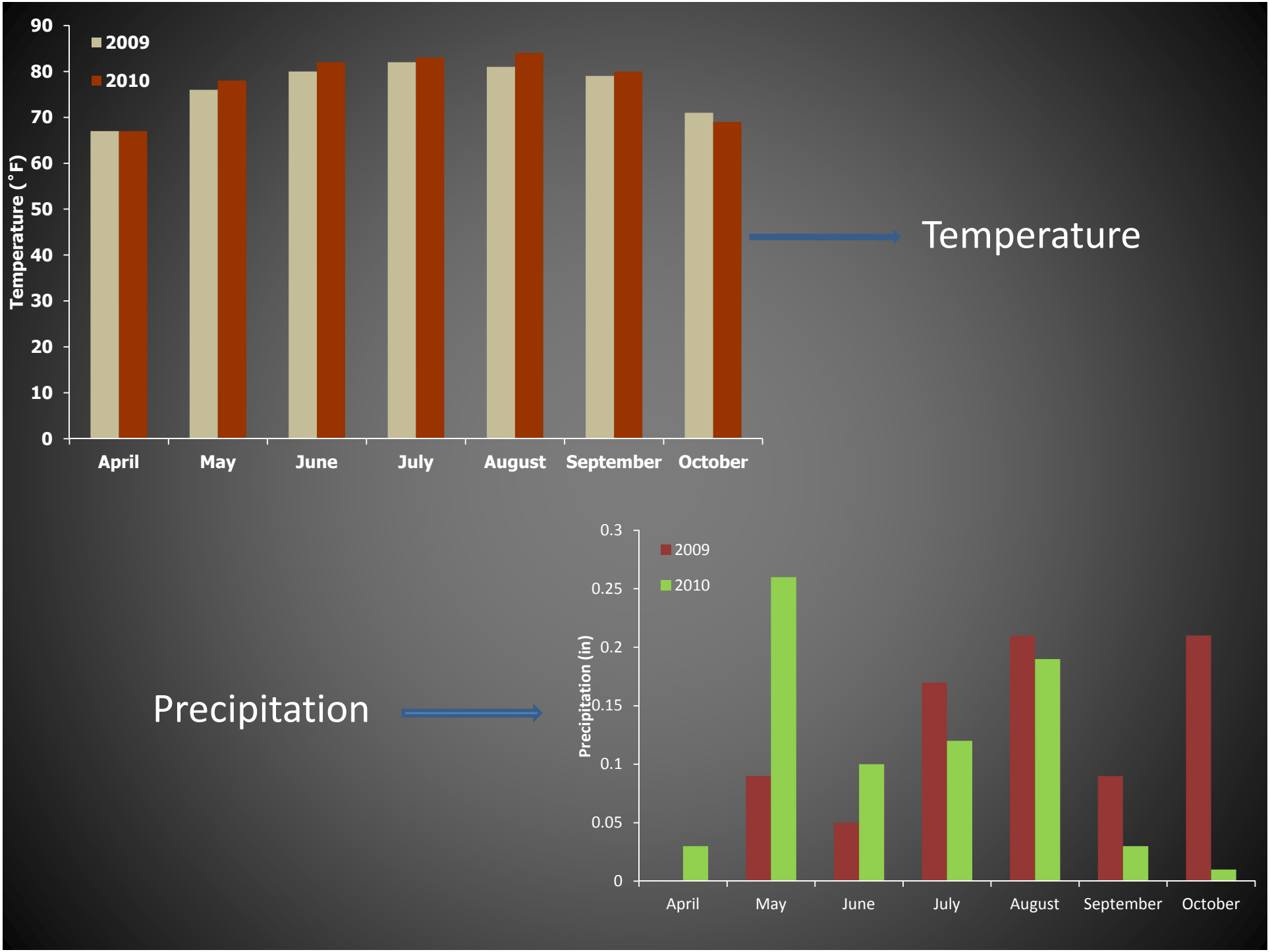
Results: Phenology

Fringing Marshes

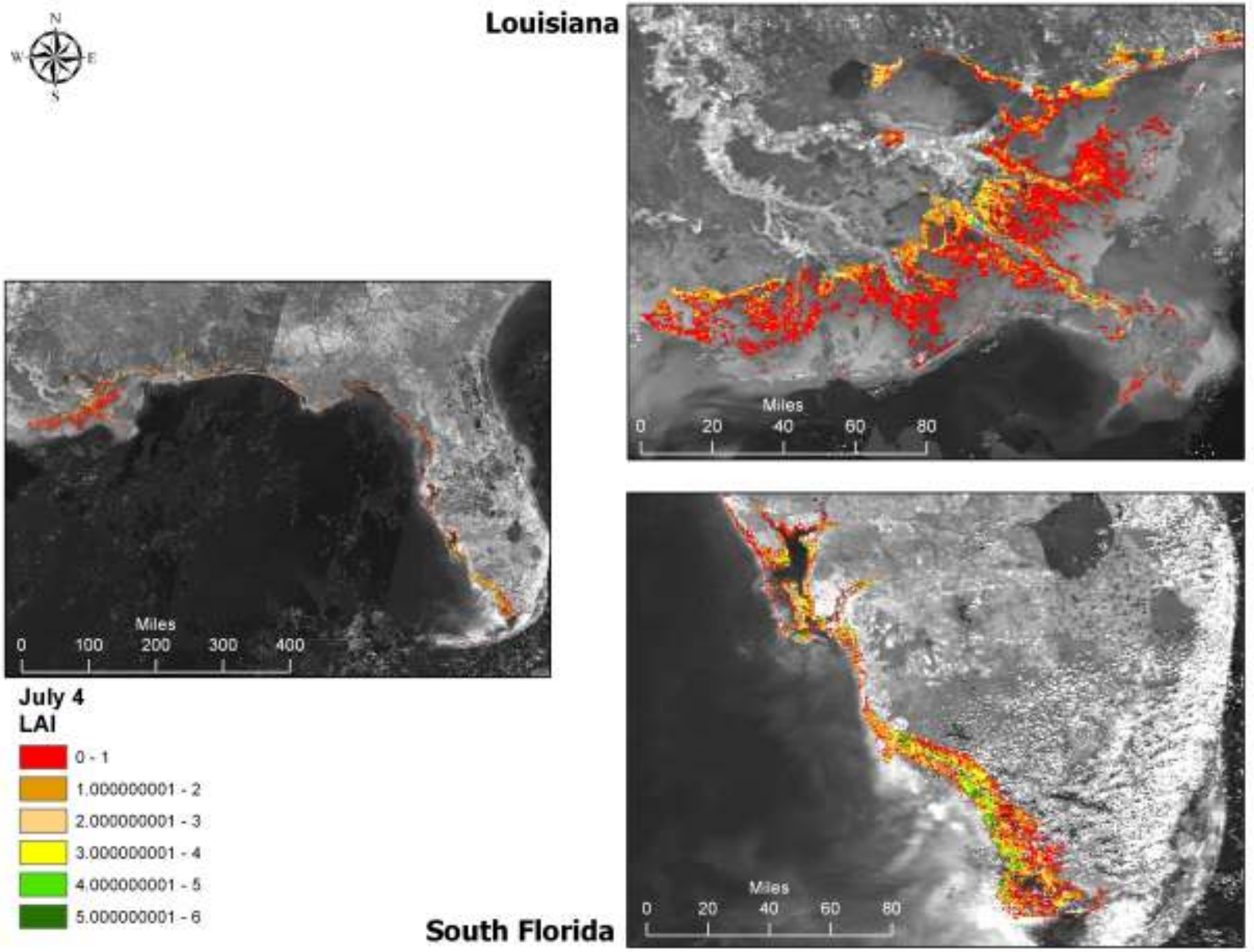


Interior Marshes

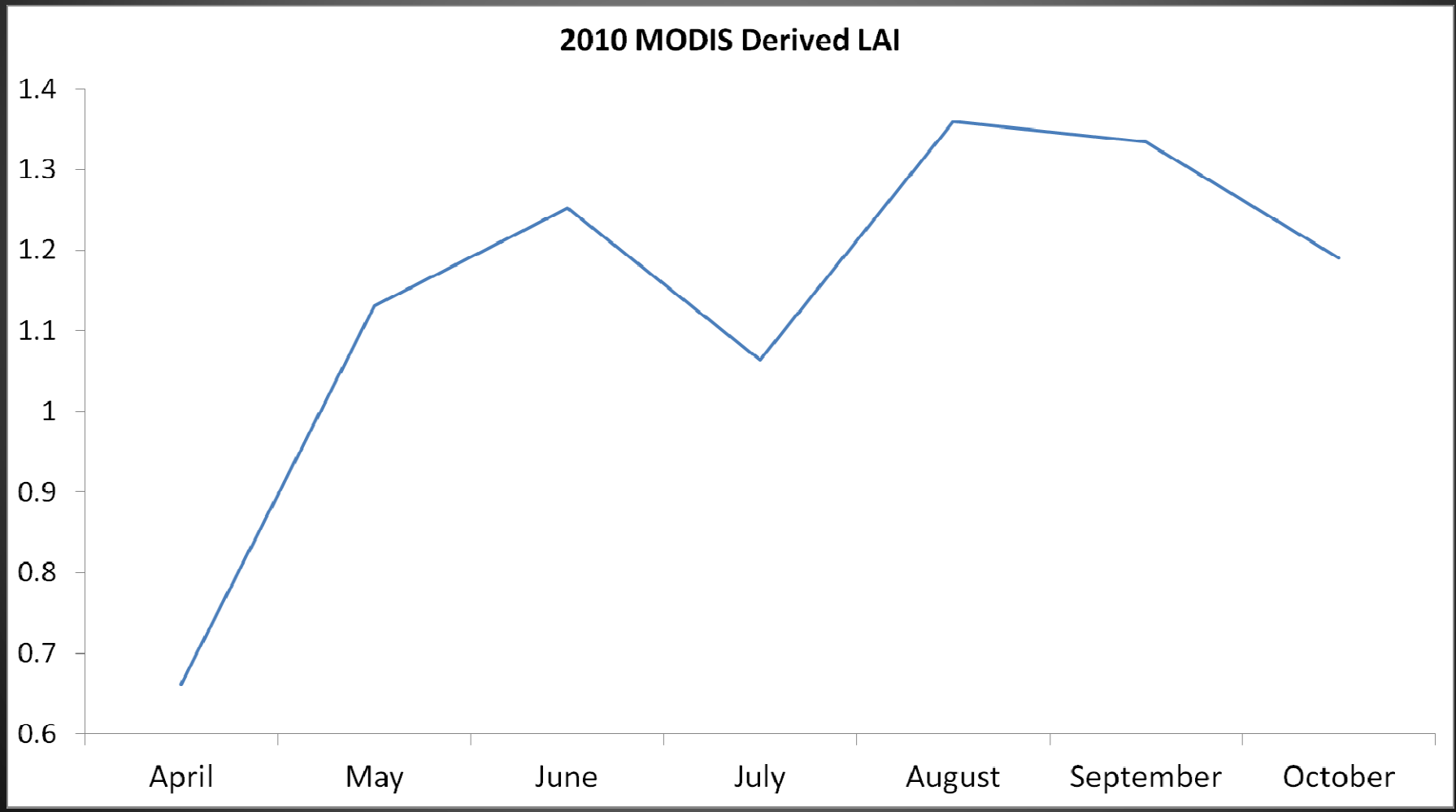



90
80
70
60
50
40
30
20
10
0
Temperature (°F)
2009
2010
April
May
June
July
August
September
October
Temperature
Precipitation
0.3
0.25
0.2
0.15
0.1
0.05
0
Precipitation (in)
2009
2010
April
May
June
July
August
September
October

Preliminary Results: MODIS



Preliminary Results: MODIS



Conclusion and Future Research

- This study successfully delineate the critical hotspots and the pattern of marsh stress and so that prioritization of restoration areas can be performed
- Tune models with more local data
- Apply the approach on the marsh degradation caused by other factors

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