Seasonal Water Chemistry and Spectral Reflectance in Coastal Mangroves

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FCE III LTER Goals:

1. **Water**: How do water management decisions interact with climate change to determine freshwater distribution?

2. **Carbon**: How does the balance of fresh and marine water supplies regulate C uptake, storage, and fluxes by influencing water residence time, nutrient availability, and salinity?

3. **Legacies**: How does historic variability in the relative supply of fresh and marine water modify ecosystem sensitivity to further change?

4. **Scenarios**: What are alternative socio-ecological futures for South Florida under contrasting climate change and water management scenarios?
Research Question

- Can water quality be estimated and monitored using remote sensing?
  - Provide spatial estimates of water quality across various mangrove communities and identify seasonal trends using electro-magnetic spectral signatures

*Spoiler Alert*

- Water chemistry estimated from leaf spectra
- Leaf-level and satellite-level data show comparable results
Everglades Overview

- Restoration
- Sea-level Rise
- Salt water Intrusion
- Rain ≈ ET
  - \(~60-80\%\) during wet season (May-Oct)

(Price et al., 2008)
Red, black and white mangroves (tall)

Bedrock groundwater

Pore water at 85 cm and 20 cm depth

Eddy-covariance tower (SRS6)

SW/GW level
**SITE LAYOUT**

- Red mangroves (dwarf)
- Top of bedrock GW wells
- Pore water at 20cm depth

**HYDROLOGY/METEOROLOGY**

- Weather station (TsPh7)
- SW/GW level

Courtesy of Xavier Zapata
Vegetation Reflectance

- Based on vegetation structure
- $\Delta$ environment $\approx \Delta$ structure $\approx \Delta$ spectra
- Used to calculate spectral vegetation indices

www.missionscience.nasa.gov
Spectral Vegetation Indices (SVI)

- Band combinations based on various wavelengths of the measured EM spectra
- Related to changes in the chemical and structural features
- Maximize sensitivity & minimize noise

**SVI used in study**

- EVI
  - [Total Nitrogen]
- REIP slope
  - [Ca^{2+}]
- RFf_r
  - [Cl^{-}]
- RE3
  - [SO_{4}^{2-}]
- D705/722
  - [Total Phosphorus]
Field to regional upscaling

- Leaf-scale

- Canopy-scale

- Regional-scale

Site/local hydrology
- Water quality
- Water availability
- Field spectra

upscaling

goingroundtruthing

Regional hydrology
- Water quality
- Water availability
- Satellite spectra
Results

- Δ spectra attributed to seasonal variability in water chemistry
- > variability at SRS4
Significant correlations between SVIs and ion and nutrient concentrations

- Cl$^-$ @ GW (mg L$^{-1}$)
  - $y = 3985x + 1733$
  - $R^2 = 0.27; p = 0.002$

- $SO_4^{2-}$ @ 20cm (mg L$^{-1}$)
  - $y = -202.3x + 1749$
  - $R^2 = 0.44; p = 0.001$

- $Ca^{2+}$ @ 20cm (mg L$^{-1}$)
  - $y = -401x + 947$
  - $R^2 = 0.41; p = 0.008$

- All Mangroves (SRS)
  - $y = 71.5x - 96$
  - $R^2 = 0.4; p = 0.000$

- Red Mangrove
  - $y = 57.1x - 66$
  - $R^2 = 0.47; p = 0.014$

- Red Mangroves
  - $y = 7.06x - 2.7$
  - $R^2 = 0.60; p = 0.000$
Satellite acquisitions

- **Landsat 5TM**
  - 30m x30m grid
  - 6 bands + 1 thermal
  - 14 day repeat

- 15 images from 1993-2009
- Decrease in NIR (band 4) with increase in [Cl\(^-\)]
- Strong correlations (p < 0.05) with SRS 5&6 sites
Seasonal [Cl\(^-\)] variations
- Low [Cl\(^-\)] in wet season
- High [Cl\(^-\)] in dry season

Downstream gradient

Model Results
Landsat 5TM Reflectance and [Cl⁻]

- **Reflectance (%):**
  - Y-axis ranging from 0 to 60%

- **Surface water Cl⁻ (mg/L):**
  - X-axis ranging from 0 to 364 DOY
  - Y-axis ranging from 0 to 25,000 mg/L

- **Data Points:**
  - Black circles: [Cl⁻]
  - Yellow circles: model [Cl⁻]
  - Red squares: Band 2
  - Green triangles: Band 3
  - Purple squares: Band 4

- **Curves:**
  - Trend lines for different bands

- **Question Mark:**
  - Located near a cluster of data points

The graph illustrates the relationship between reflectance and surface water chloride concentration over time, as measured by different bands of the Landsat 5TM satellite.
Summary

- Leaf-level and satellite-level data show comparable results
- Seasonal spectral trends associated with changes in water chemistry

Future Directions

- Additional data to improve model
- Decadal changes through times
  - Landsat legacy (1970s-2000s)
- Use stressed conditions to better constrain satellite ET estimates
- Extrapolate to the Caribbean and elsewhere
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Questions