Using hydrogeophysical methods to understand disturbance in peat soils due to saltwater intrusion: from soil collapse to changes in biogenic gas dynamics

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Worst-case scenario ≈1.5 m by 2100

1. Introduction:
1. Current
Sawgrass marsh builds peat soil on top of the limestone only in freshwater areas. Mangroves develop peat soil in saline and brackish conditions.

2. Saltwater Intrusion
Intrusion of saltwater causes sawgrass dieback and mangrove expansion. Freshwater peat soil begins to degrade with exposure to saltwater.

3. Peat Collapse
Freshwater peat collapses and the water is too deep for plants to become established. Mangroves established elsewhere help to re-stabilize soil.

From: Davis and Everglades Foundation
Comas and Slater, 2004

- **Pore dilation in peat soils:**
  - Ours et al, 1997; Hoag and Price, 1997
  - *Sphagnum* peat soils

- **Biogenic gas dynamics:**
  - Increased dilation may increase biogenic gas release (i.e. ebullition)
  - Increased salinity decreases gas production (i.e. methane)
2. Objectives:

- To investigate the effects of salinization on:
  
  1) the peat matrix and potential peat collapse, as induced by changes in the physical properties of peat (i.e. porosity or hydraulic conductivity)
  
  2) biogenic gas fluxes in peat soils, particularly in terms of production, accumulation and release of biogenic gases in peat soils (such as methane and carbon dioxide)
3. Methodology:

The approach is: a) multi-method; b) multi-scale: both in space and time; c) field+lab based.
4. Fieldsites

Mangroves

Transition Zone / brackish

Platform 1

Platform 2

Platform 3

Freshwater Marsh

Salinity gradient (mS/cm)

72 46 1 0.1

seawater  brackish  freshwater

fresh groundwater

mixing zone

groundwater

groundwater

saline
Fakahatchee Strand State Preserve

preliminary

Site 1
Site 2

WCAs
BCNP
ENP
FSPSP

Salinity gradient

Google Earth
Site 1

Ponds and saltwater conductivity

40.7 mS/cm
Pocking and pond formation and growth; *Andres, Savarese et al 2009*
Site 2

No well defined ponds (precursors?) and brackish conductivity

21.5 mS/cm
Site 3? freshwater

Disney Wilderness Preserve (DWP)

Blue Cypress Preserve

WCA-1

LILA – Loxahatchee National Wildlife Refuge

WCA-2

WCA-3

Big Cypress – Dwarf Cypress; Cypress Swamp
5. Results: a) laboratory scale

Preliminary results for Peat soil sample from Water Conservation Area 3A

Sirianni and Comas, in prep
Sub-tropical vs. boreal peat soils show strikingly similar **pore dilation** dynamics.
Fluid Conductivity (S m$^{-1}$)

- Freshwater
- Brackish Water
- Seawater

mgCH$_4$/m$^2$/day

Days of Experiment

- Release
- Production

Sirianni and Comas, *in prep*
Fluid Conductivity (S m\(^{-1}\))

- Freshwater
- Brackish Water

Gas Release

Gas Production

0.25-0.3 S m\(^{-1}\)

Sirianni and Comas, *in prep*
b) Landscape scale: geophysical characterization

Electrical resistivity imaging (ERI)

Site 2

Unit electrode spacing 1.50 m.
- areas of increased electrical conductivity
- 0.5 to 1 m deep; 2-3 m wide
- potential ponds?

Site 2

盐水

深度 (m)

距离沿着剖面 (m)

深度 0 2 4 6

距离 72 96

盐水

电阻率在 ohm.m

0.045 1.02 1.23 1.49 1.80 2.17 2.52 3.17

单位电极间隔1.50 m.
- areas of increased electrical conductivity
- Similar dimensions
- Better defined areas/ponds?

Site 1

Site 2
Tropical peat soils, West Kalimantan, Indonesia

Comas et al, 2015

Boreal peat soils, Caribou Bog, Maine

Comas et al, 2004
No continuity either laterally (like thicker peatland systems) or with depth (like sinkholes or dissolution features)
c) Plot scale: platform setup

- Gas released
- moisture content
- Temperature
- EC
- water table
- salinity
- surface deformation
d) Modeling

MEGA (Model of Ebullition and Gas storAge)
d) Modeling

MEGA (Model of Ebullition and Gas storAge)

- Peat core in profile
- Modeled peat

Production

Ebullition

Storage

- gas
- water
- peat

Modified from Ramirez et al, 2015
from Wright, Comas et al, 2018
6. Conclusions

- **Physical properties:**
  - Increased salinization induces progressive peat pore dilation resulting in increased hydraulic conductivity. Threshold at around 0.2-0.3 S m\(^{-1}\) with a change in dynamics
  - Strikingly similar pore dilation dynamics between boreal and subtropical soils
  - At the field scale, pond initiation is characterized by a contrast in electrical conductivity with no apparent lithological control from underlying limestone

- **Biogenic gas dynamics:**
  - Progressive decreased in production, accumulation, and release of biogenic gas with increased conductivity. Consistent threshold showing change in dynamics (sudden release)
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