Autonomous ground penetrating radar (GPR) measurements for exploring temporal dynamics in biogenic gas releases from peat soils in the Florida Everglades

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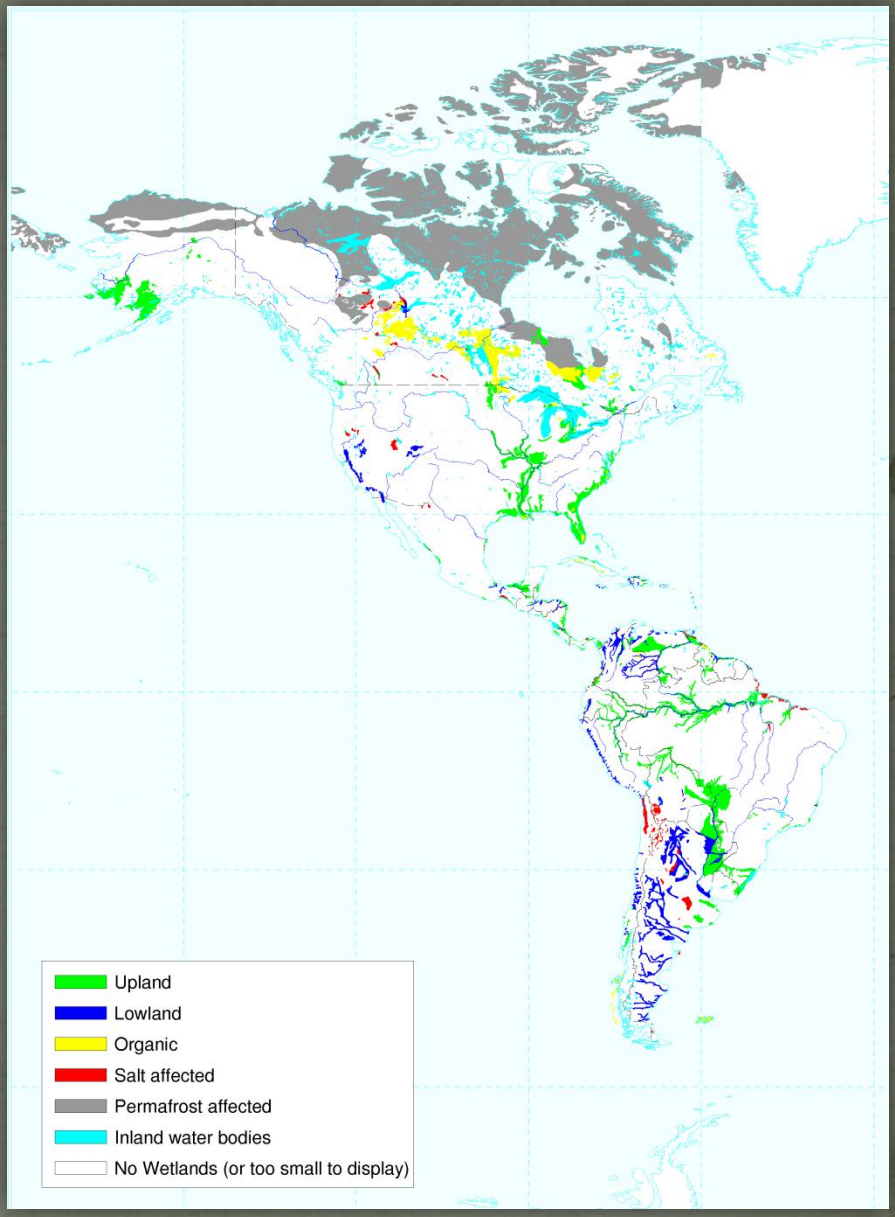
Overview

- Introduction
  - Importance
  - Review
- Research Questions & Goals
- Methodology
  - Interstitial Gas Dynamics
  - Gas Flux
- Results
- Closing

Importance

- Carbon Cycling
  - Peatlands regarded as both sinks and sources of atmospheric Carbon, depending on conditions.
  - Northern Peatlands alone store estimated 450 Gtonnes, about 75% of the global mass of atmospheric Carbon. (International Peat Society (I.P.S.), 2008; Joosten and Couwenberg, 2009)



Modified from Global Wetlands map, NRCS, USDA

Greenhouse Gasses (GHG's)

- Known GHG's released from peatlands include Carbon Dioxide (CO_2), Methane (CH_4), Nitrogen Oxides (NO_x)
- Uncertainties:
  - Spatial variability and Timing of releases
    - What are the driving forces - atmP, T, ??
    - Gasses released at same time throughout system, or localized?
  - Effects of Climate Change on gas production
    - Increased T, Saltwater Encroachment, etc?
  - **ESPECIALLY** regarding Sub-Tropical peats (*e.g.*, Everglades)
    - Northern Peatlands better represented in literature

Background Concepts (Cont'd)

- Diffusive Fluxes (Small)
  - Gas slowly rises to surface through diffusion
  - Small Volumes released over time
    - Some CH_4 lost to dissolution and methanotrophic bacteria
- Ebullition events (Large)
  - Steady or Episodic "gas bubbling" events
  - Higher concentration of CH_4
    - Global warming potential of CH_4 is **25x** that of CO_2.
      - (IPCC, 2007)

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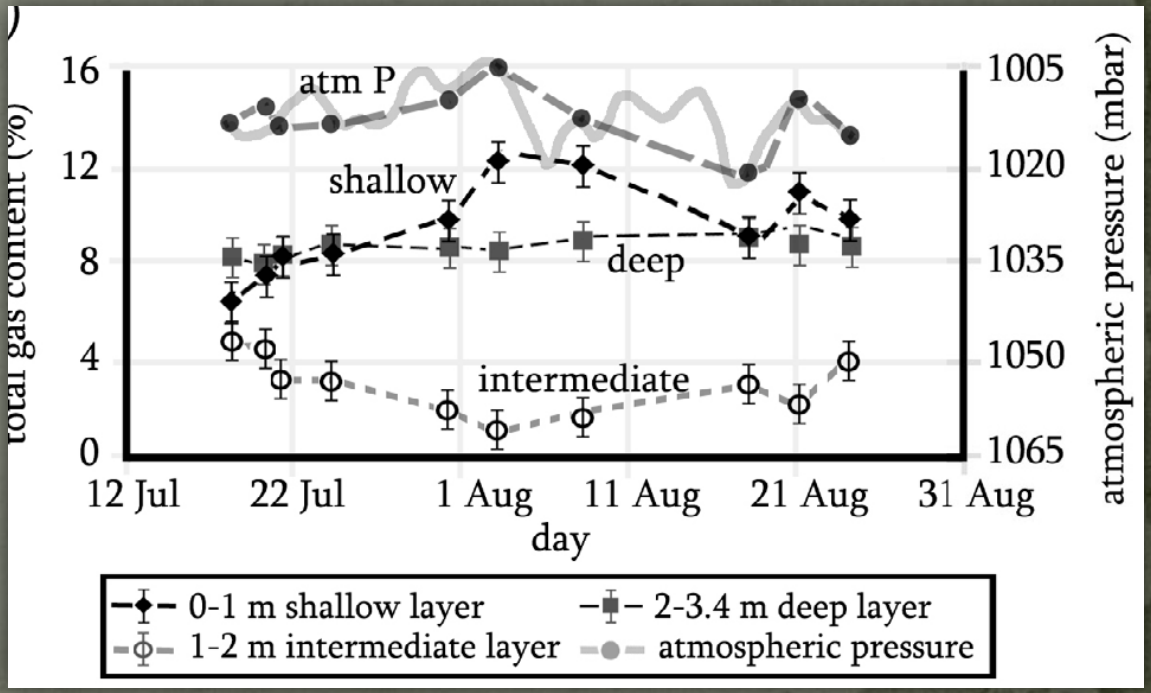
Research Goal

- Improve Temporal Resolution of current datasets investigating biogenic gas releases (i.e. ebullition) in peat soils of the Everglades

  - ***Note High resolution of AtmP compared to gas content and deformation data



From: Comas *et al*, 2011

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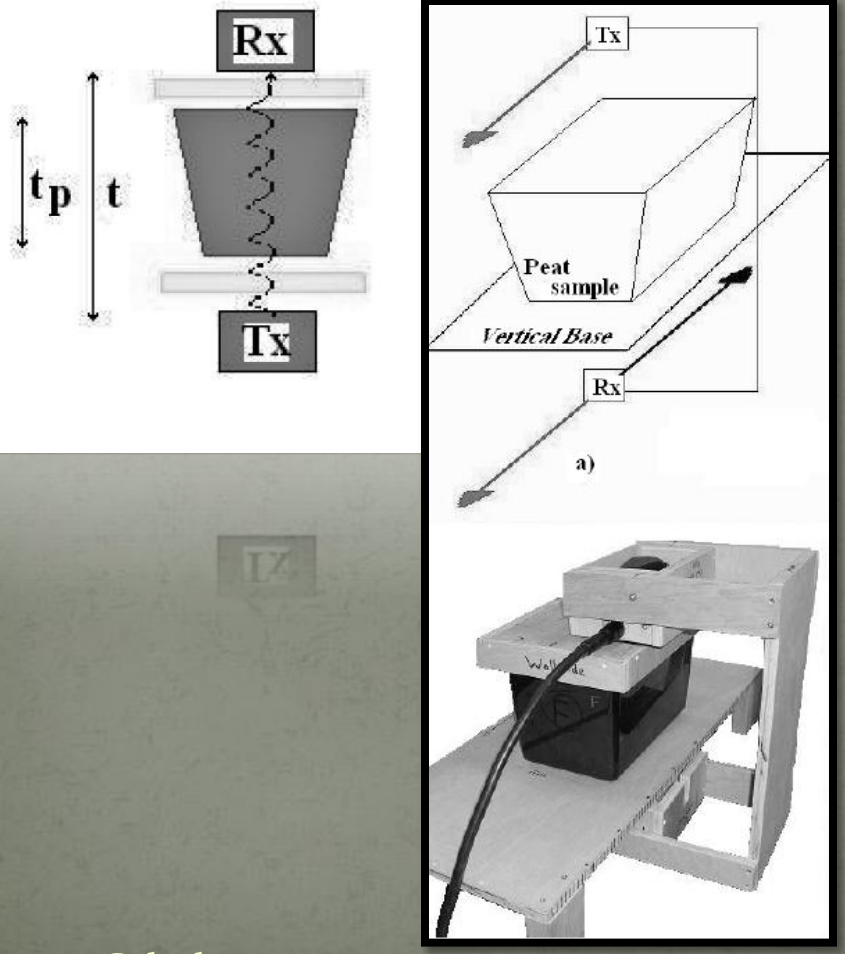
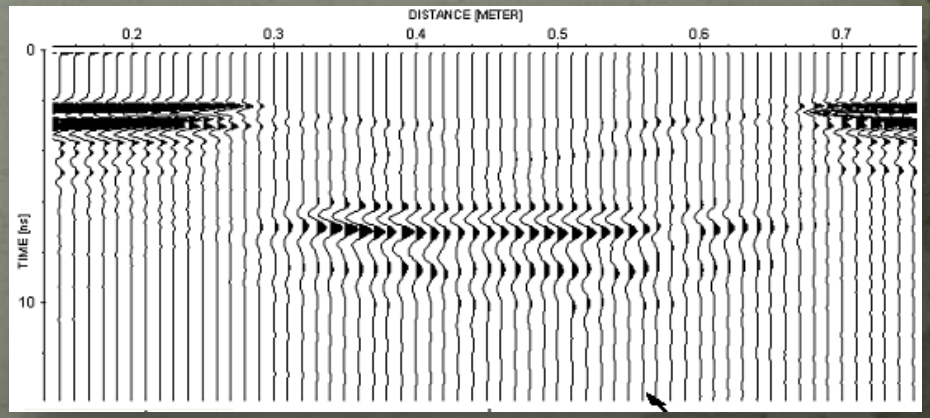
Methodology (Interstitial Gas Dynamics)

- Ground Penetrating Radar (GPR)
  - Pros:
    - Non-Invasive
    - Indirectly provides estimation for % gas volume within peat matrix
  - Cons:
    - Labor Intensive
    - Measures are usually manual.
      - Requires users on-site.

Methodology (GPR)



- GPR Theory
  - Based on Electromagnetic (EM) pulses sent from Transmitter to Receiver.
  - As pulses are received, travel times are recorded and a plot is produced for interpretation

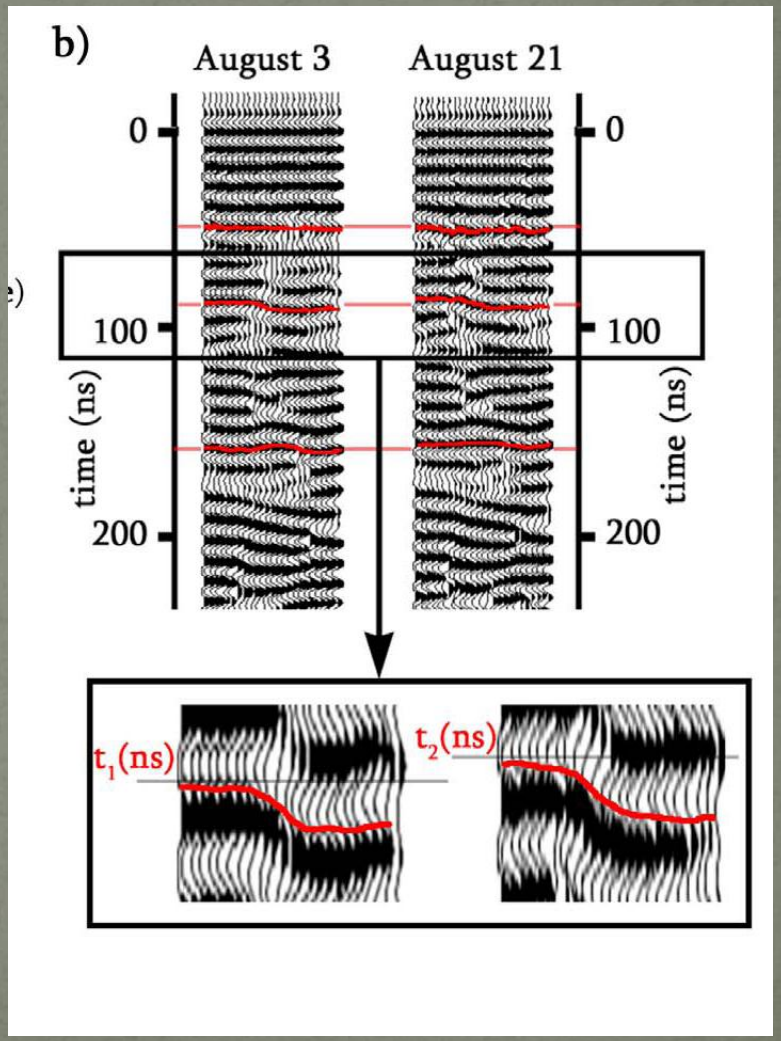


Images: Cabolova, 2010

Methodology (GPR)

- More GPR Theory
  - EM wave travels fastest through Air, Slowest through Water.
  - Therefore,

    Change in Velocity means a change in Gas Volume



From: Comas *et al*, 2011

Methodology (GPR)

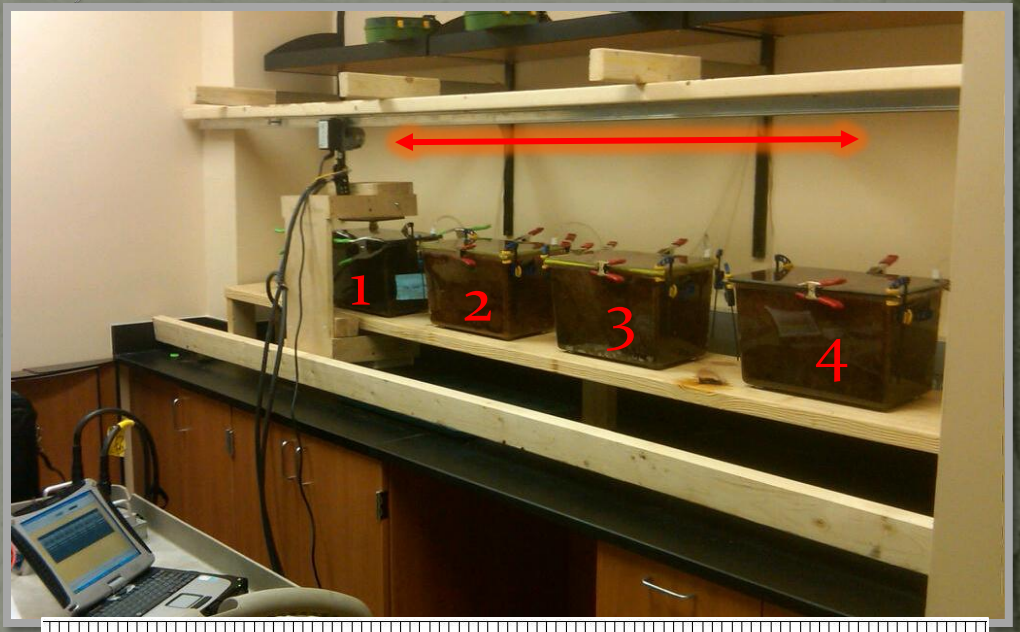
- Estimating gas content from GPR velocity
  - Complex Refractive Index Model (CRIM):

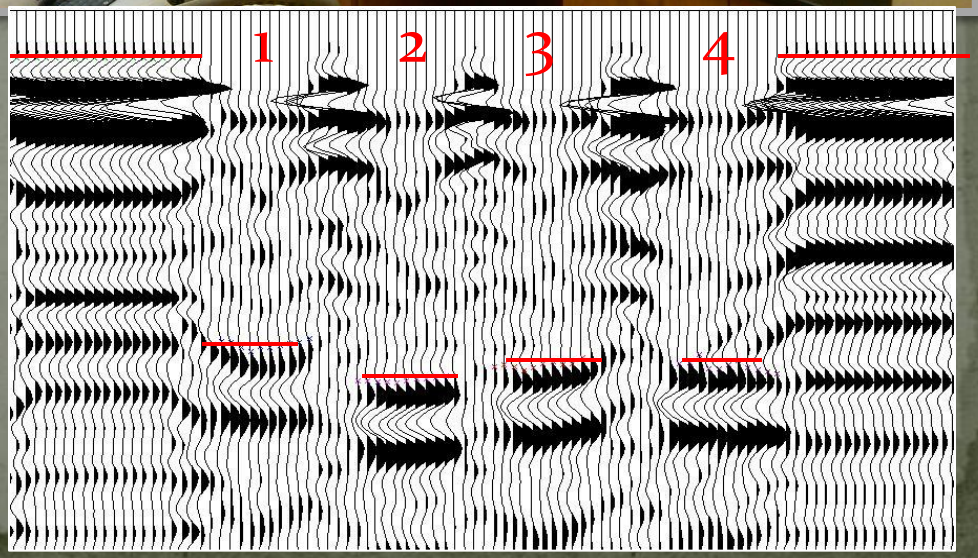
$$\varepsilon_{r(b)}^{\alpha} = \theta\varepsilon_{r(w)}^{\alpha} + (1-n)\varepsilon_{r(s)}^{\alpha} + (n-\theta)\varepsilon_{r(a)}^{\alpha}$$

  - Expresses bulk permittivity (ε_{rb}) as % gas composition
  - Accounts for variables measured in the lab:
    - Porosity (n)
    - Temperature as a component of permittivity of water (ε_{rw})

Methodology (GPR)

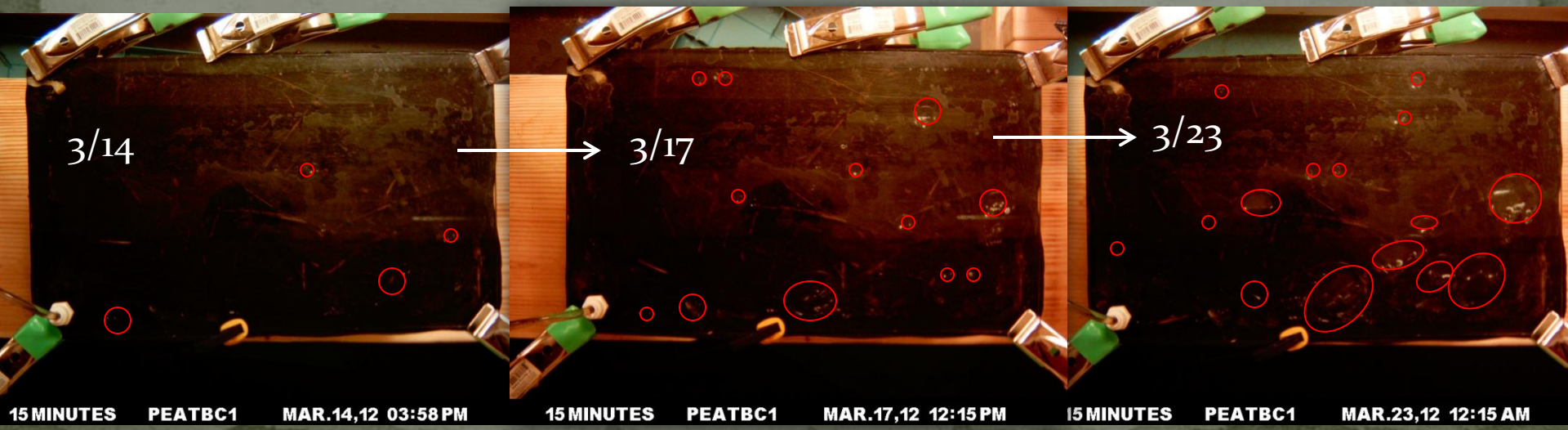
- Increasing Temporal Resolution for GPR data:
  - Motorized rail system carries antennas back and forth across samples





Other Methods

- Gas traps: gas collects in top of container
  - Volume is measured with syringe (weekly)
- Gas Chromatography (GC)
  - Finds % CH_4 and CO_2 content
- Time Lapse Cameras
  - Monitor Rate of Gas Accumulation (hourly)



Methodology (Time Lapse Photos)

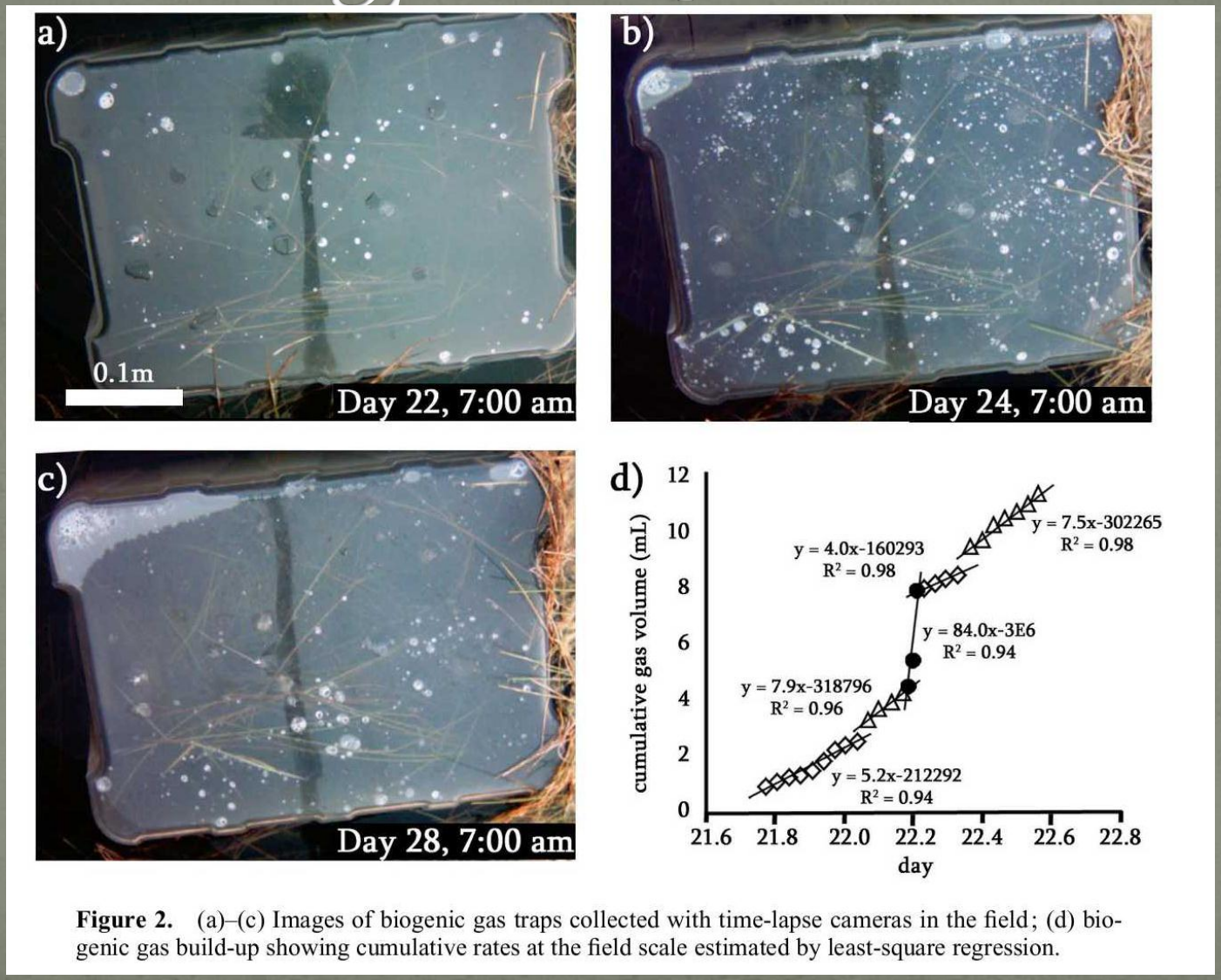


Figure 2. (a)–(c) Images of biogenic gas traps collected with time-lapse cameras in the field; (d) biogenic gas build-up showing cumulative rates at the field scale estimated by least-square regression.

Image: Comas and Wright, 2012

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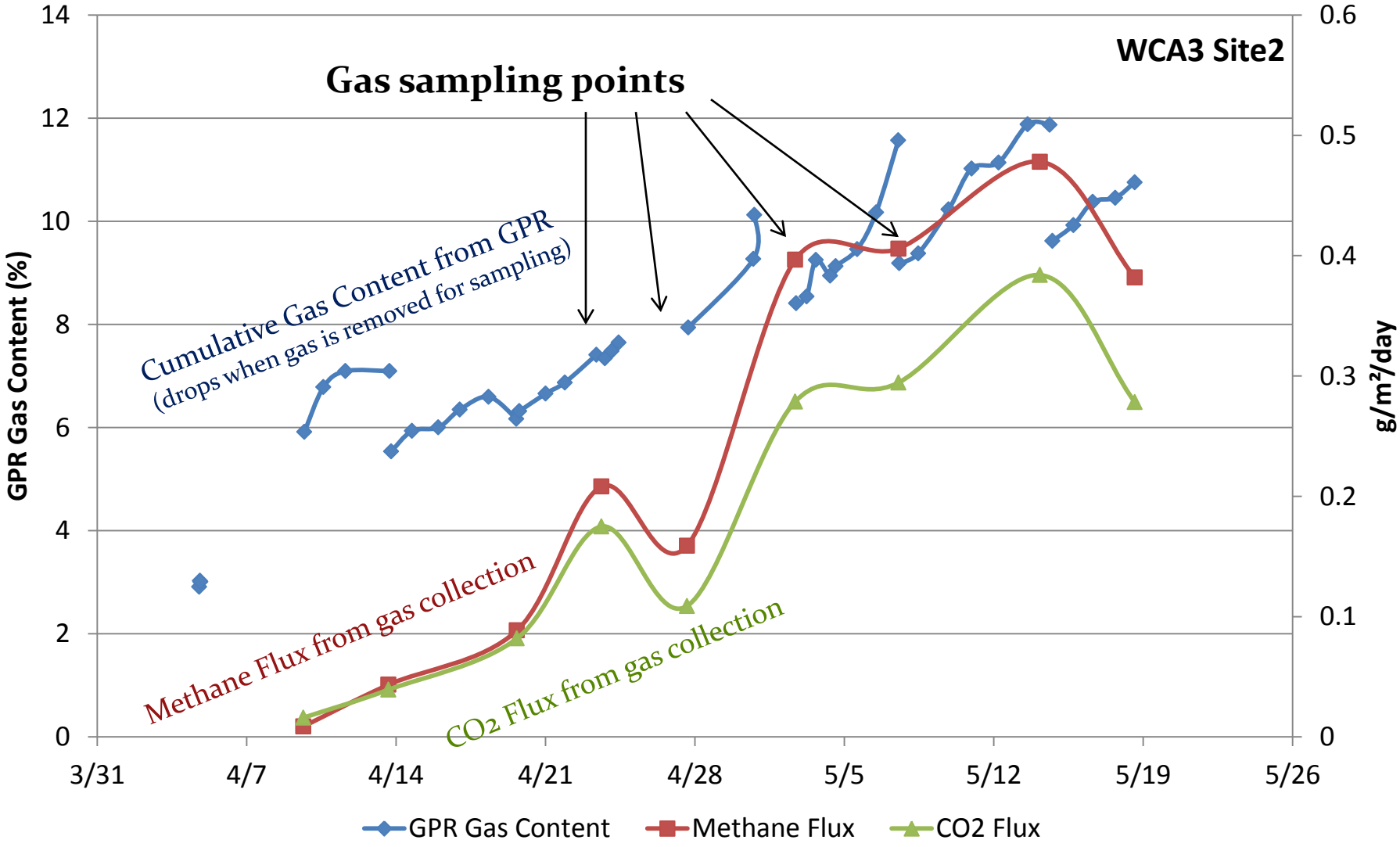
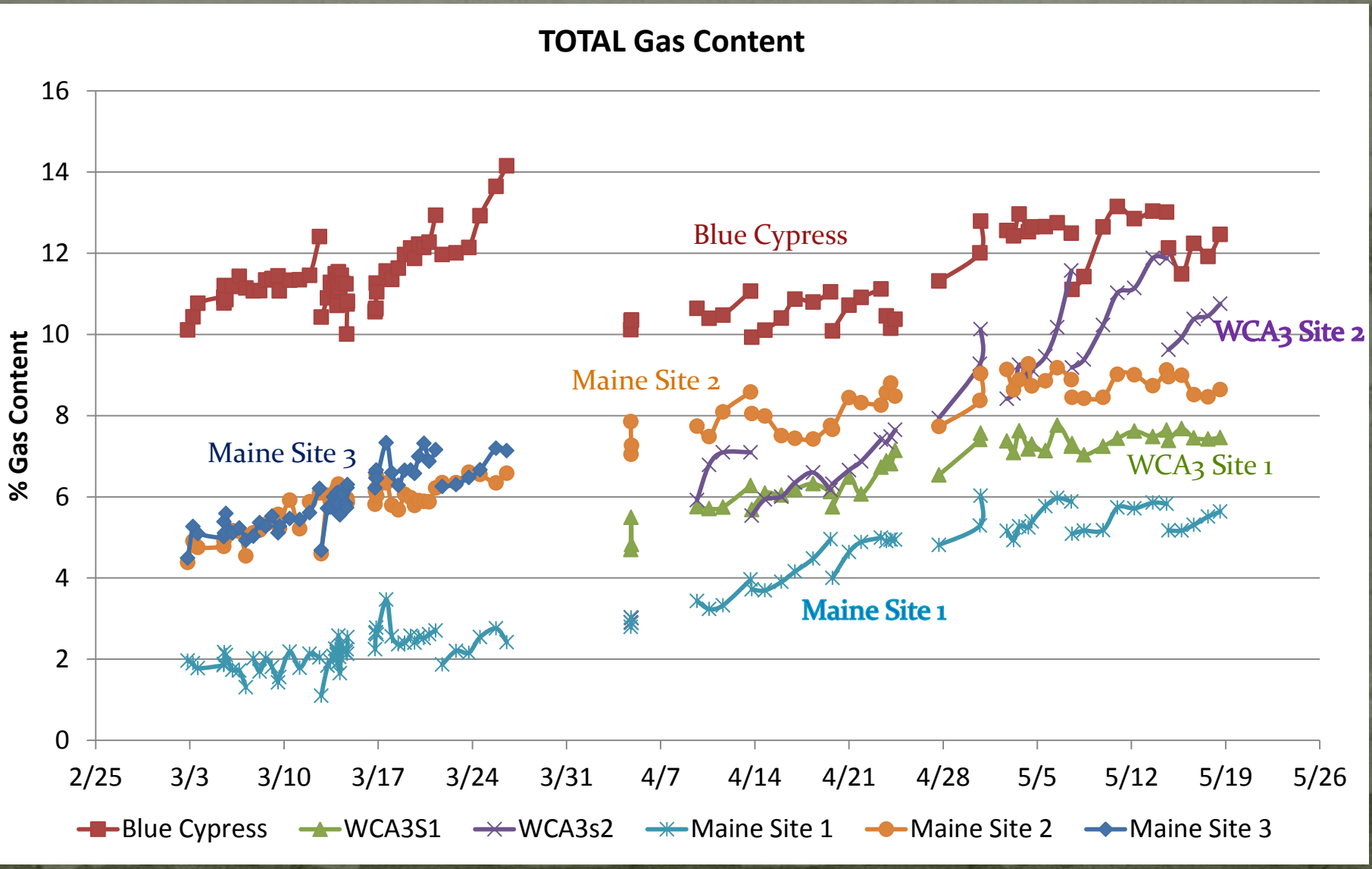
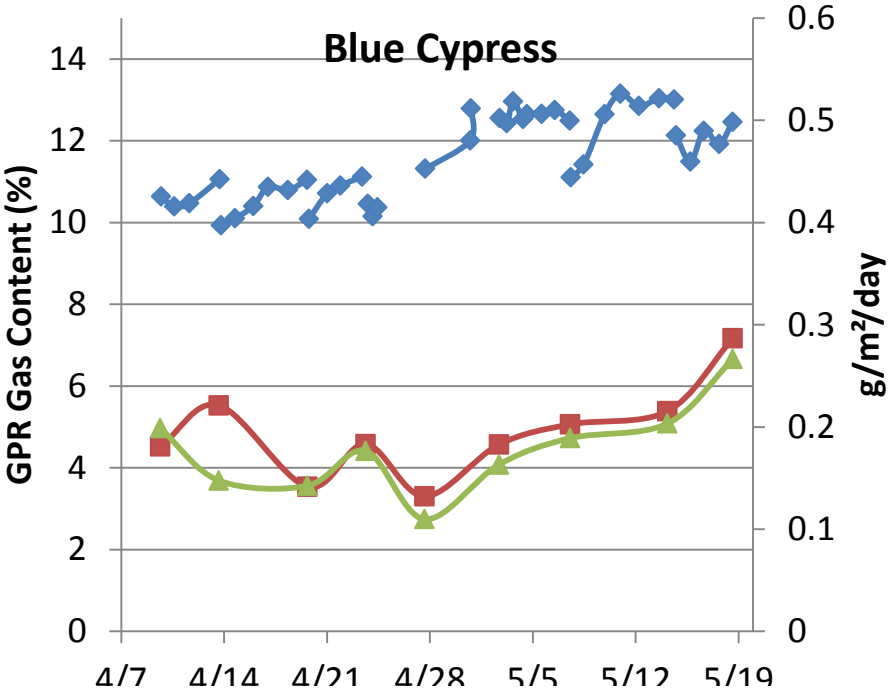
Results

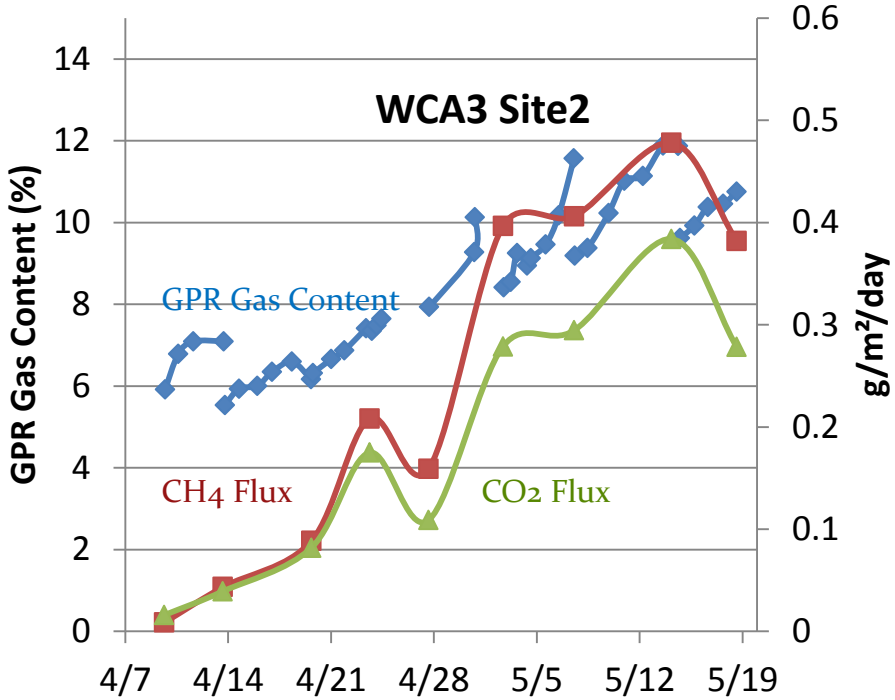
-Slope of gas content line = production rate.

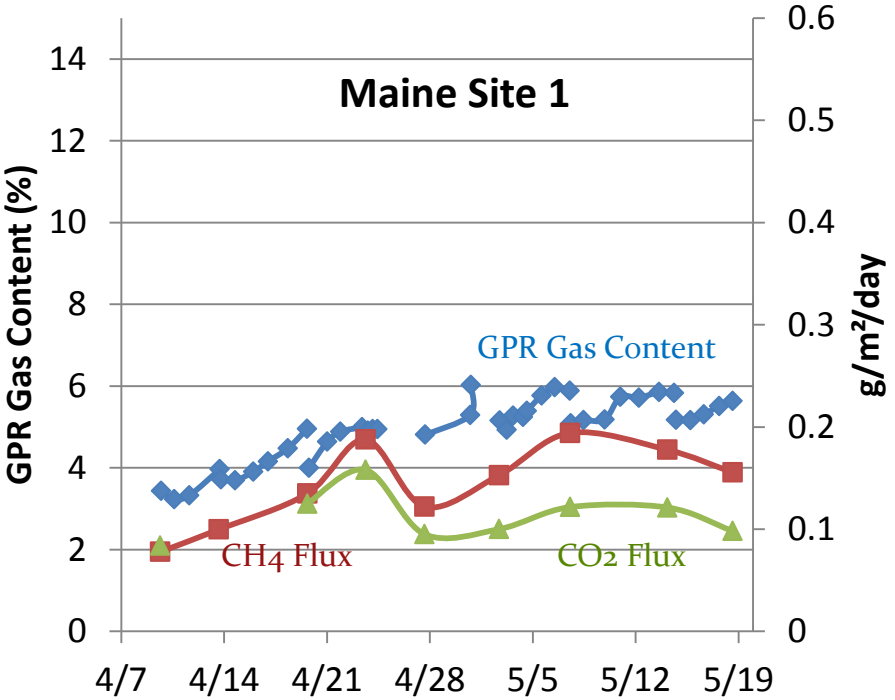


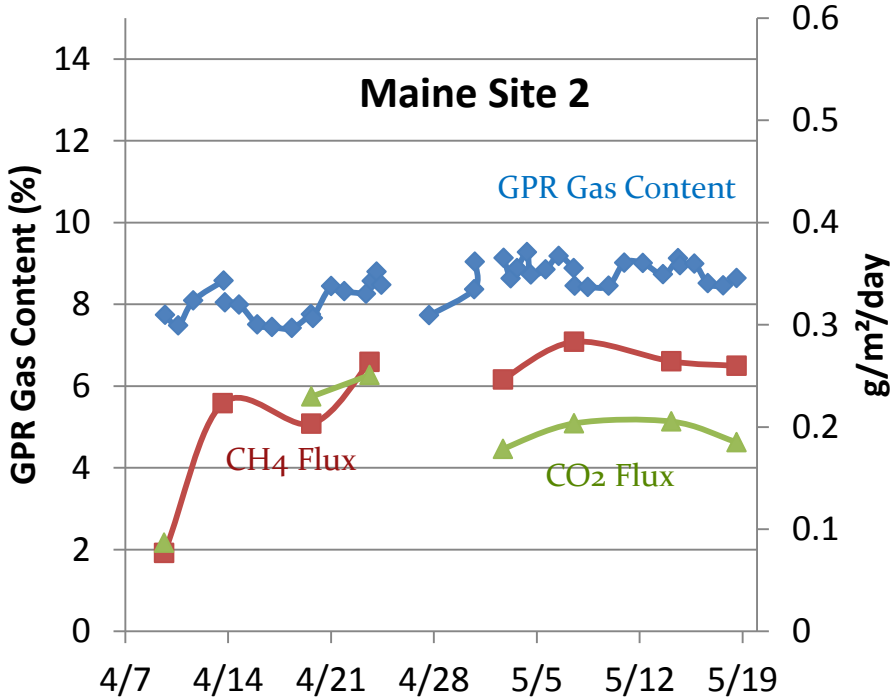
Results


TOTAL Gas Content
% Gas Content
16
14
12
10
8
6
4
2
0
2/25
3/3
3/10
3/17
3/24
3/31
4/7
4/14
4/21
4/28
5/5
5/12
5/19
5/26
Blue Cypress
Maine Site 2
WCA3 Site 2
Maine Site 3
WCA3 Site 1
Maine Site 1
Blue Cypress
WCA3S1
WCA3s2
Maine Site 1
Maine Site 2
Maine Site 3

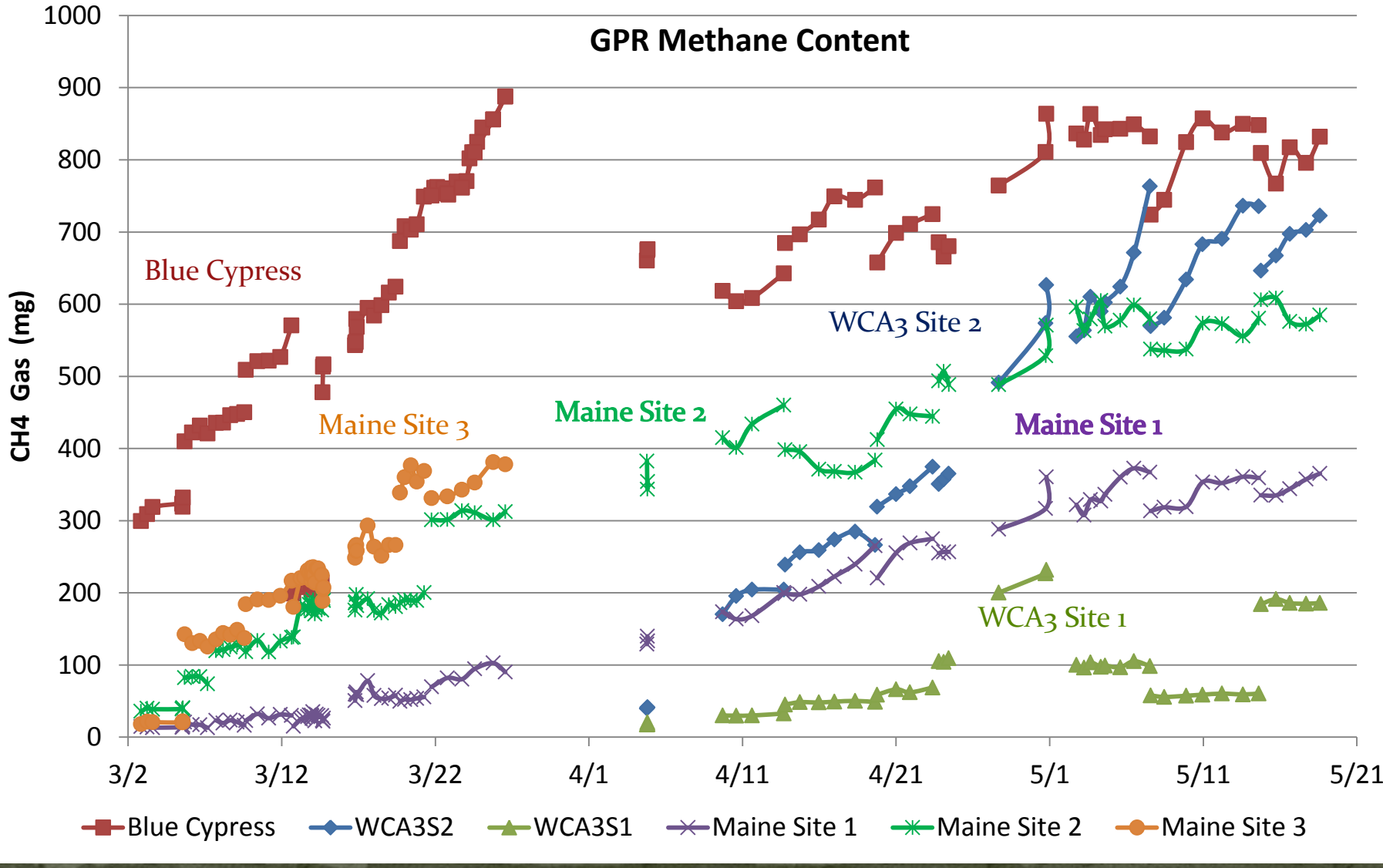

Blue Cypress
GPR Gas Content (%)
g/m²/day
0
2
4
6
8
10
12
14
0
0.1
0.2
0.3
0.4
0.5
0.6
4/7
4/14
4/21
4/28
5/5
5/12
5/19


WCA3 Site2
GPR Gas Content (%)
g/m²/day
GPR Gas Content
CH4 Flux
CO2 Flux
0
2
4
6
8
10
12
14
0
0.1
0.2
0.3
0.4
0.5
0.6
4/7
4/14
4/21
4/28
5/5
5/12
5/19

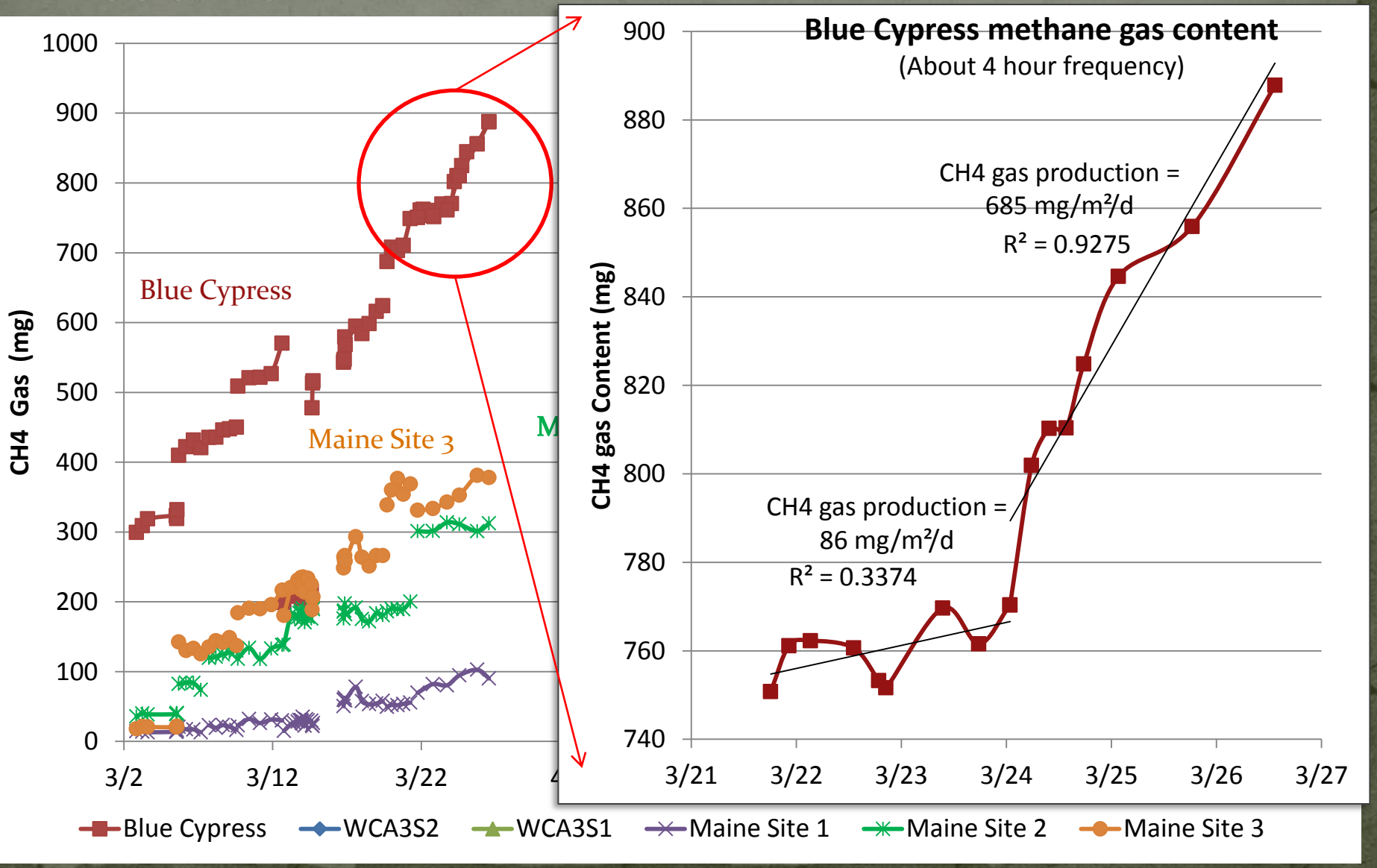

Maine Site 1
GPR Gas Content (%)
g/m²/day
GPR Gas Content
CH4 Flux
CO2 Flux
0
2
4
6
8
10
12
14
0
0.1
0.2
0.3
0.4
0.5
0.6
4/7
4/14
4/21
4/28
5/5
5/12
5/19


Maine Site 2
GPR Gas Content (%)
g/m²/day
GPR Gas Content
CH4 Flux
CO2 Flux
0
2
4
6
8
10
12
14
0
0.1
0.2
0.3
0.4
0.5
0.6
4/7
4/14
4/21
4/28
5/5
5/12
5/19

Results


GPR Methane Content
CH4 Gas (mg)
1000
900
800
700
600
500
400
300
200
100
0
3/2
3/12
3/22
4/1
4/11
4/21
5/1
5/11
5/21
Blue Cypress
Maine Site 3
Maine Site 2
WCA3 Site 2
Maine Site 1
WCA3 Site 1
Blue Cypress
WCA3S2
WCA3S1
Maine Site 1
Maine Site 2
Maine Site 3

Results


CH4 Gas (mg)
1000
900
800
700
600
500
400
300
200
100
0
3/2
3/12
3/22
Blue Cypress
Maine Site 3
Blue Cypress methane gas content
(About 4 hour frequency)
CH4 gas production =
685 mg/m²/d
R² = 0.9275
CH4 gas production =
86 mg/m²/d
R² = 0.3374
CH4 gas Content (mg)
900
880
860
840
820
800
780
760
740
3/21
3/22
3/23
3/24
3/25
3/26
3/27
Blue Cypress
WCA3S2
WCA3S1
Maine Site 1
Maine Site 2
Maine Site 3

Discussion:

- Though still a work in progress, Autonomous GPR methods here show promise for capturing gas dynamics within the peat matrix

- Greenhouse gas emissions from subtropical peat soils (*i.e.* Blue Cypress and WCA3) may be larger and more important than previously thought when compared to emissions from northern peat soils (*i.e.* Maine Sites 1-3)

- Time-lapse cameras are used to better constrain GPR results and monitor gas flux variability at high temporal resolutions

- This study has implications for studies on carbon cycling and greenhouse gas emissions from peat soils

Future Research:

- Lab Scale:
  - Lab-scale setup could include simulating saltwater encroachment, eutrophication, or other factors
  - Monitoring of Hydrological properties also possible (*e.g.*, hydraulic conductivity, *etc.*)

- Field Scale:
  - Study at Loxahatchee Impoundment Landscape Assessment (LILA) slated for 2012-13
    - 2-D GPR grid for investigating spatial variability

Closing

Questions, Comments, Hints and Tips are welcome!

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