Carbon Cycling and Potential Soil Accumulation within Greater Everglades Forested Wetlands

By: W. Barclay Shoemaker and Frank Anderson

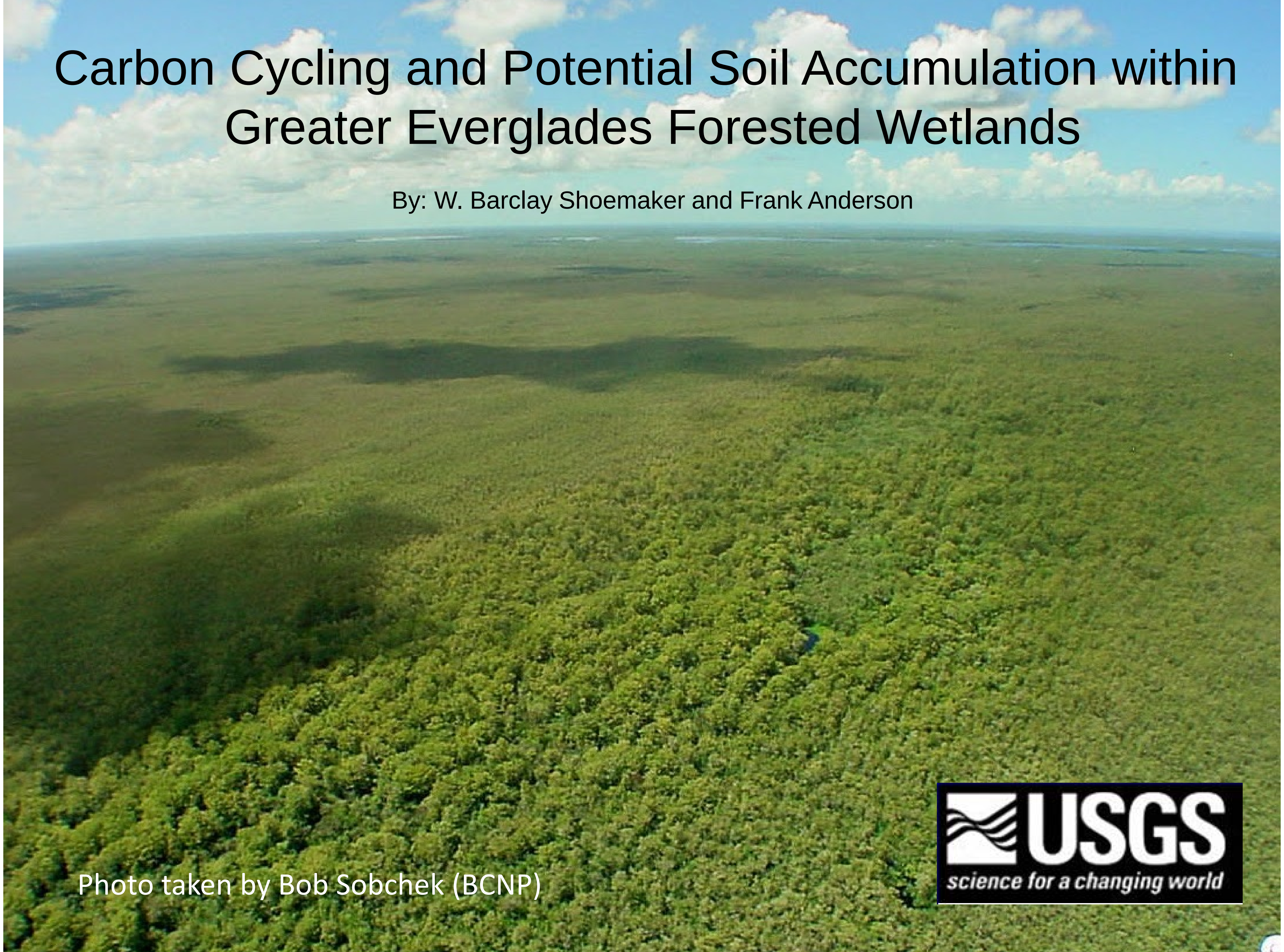

Photo taken by Bob Sobchek (BCNP)

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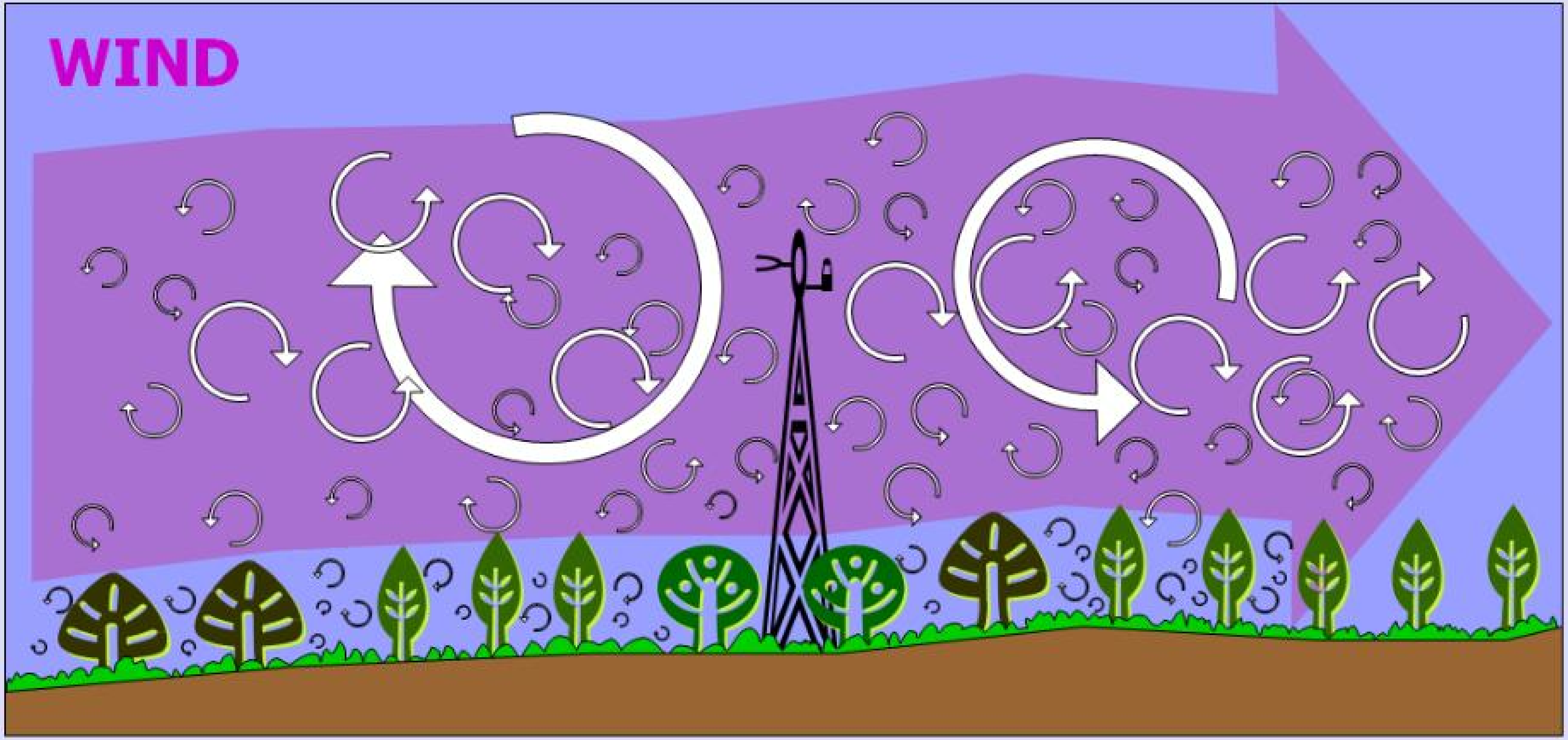
Science Questions

1. Are forested wetlands carbon sinks and methane sources ?

2. Is the carbon-cycle building topography ?

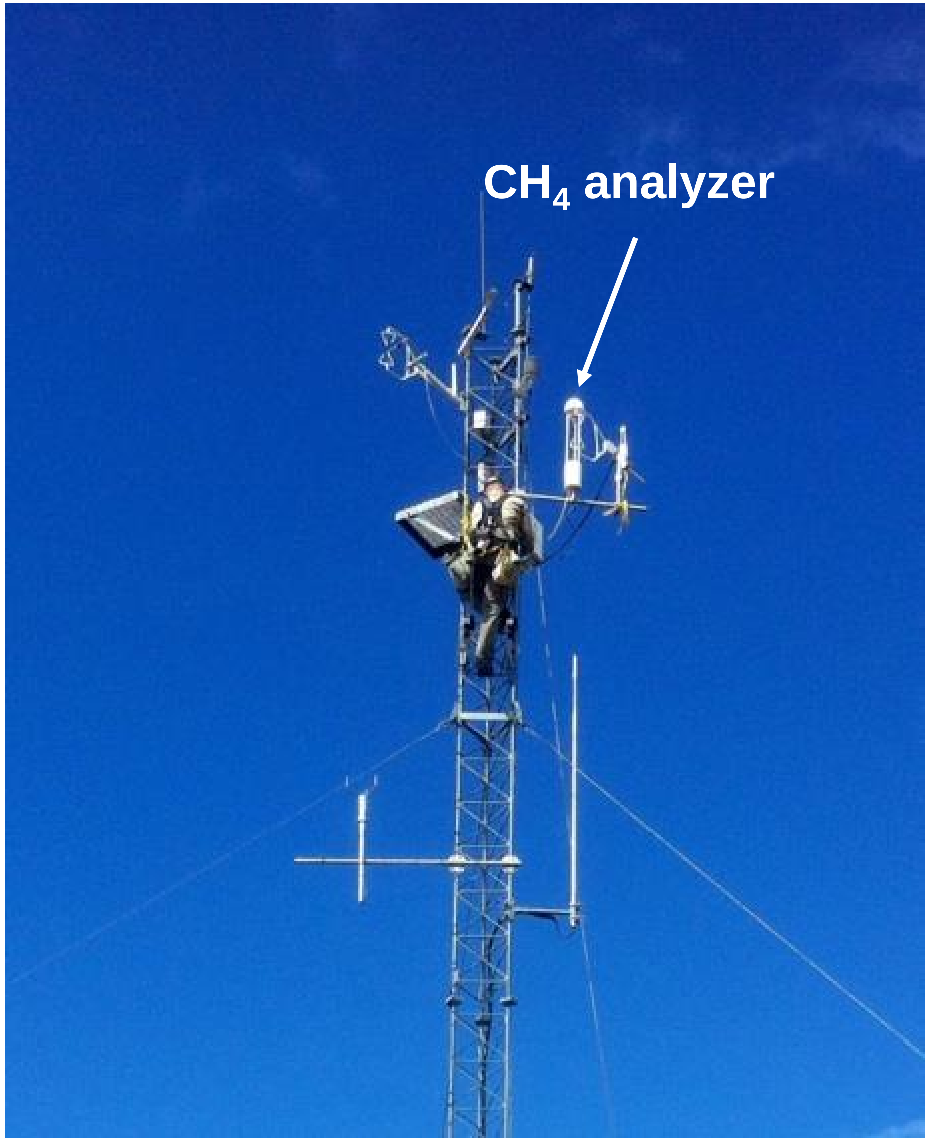
3. How do topography changes compare with sea-level rise ?

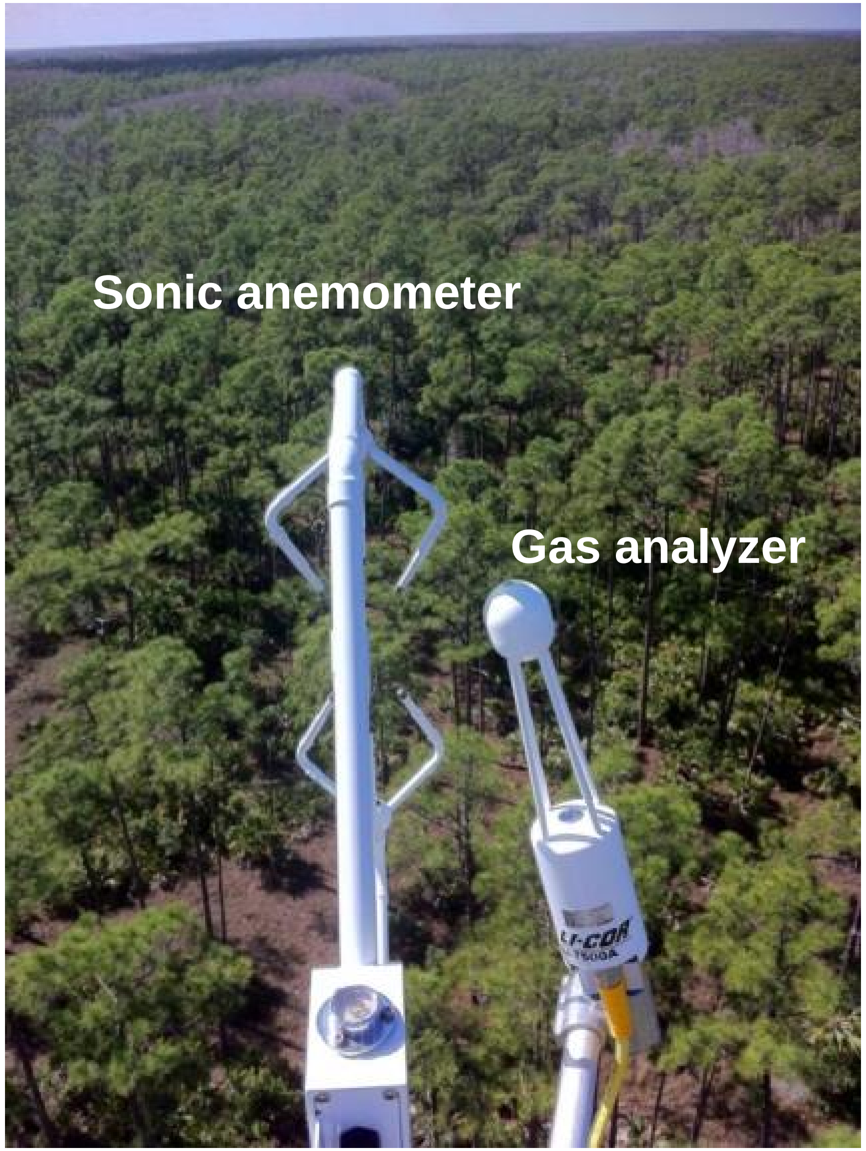
AIR FLOW IN ECOSYSTEM



- Air flow can be imagined as a horizontal flow of numerous rotating eddies
- Each eddy has 3D components, including a vertical wind component
- The diagram looks chaotic but components can be measured from the tower

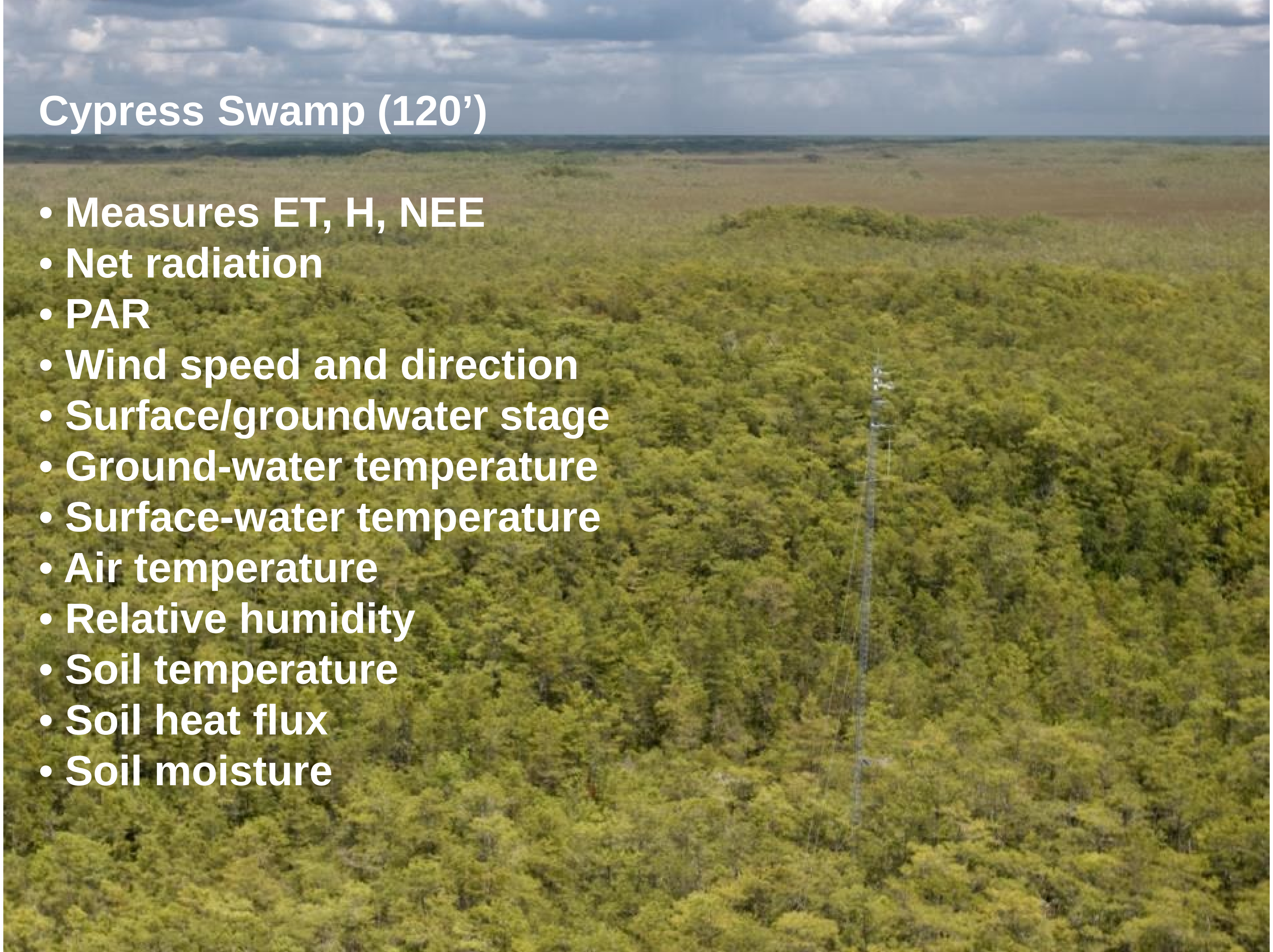
EDDY-COVARIANCE SENSORS





Dwarf Cypress (55’ tower)

- Measures ET, NEE, CH_4
- Net radiation
- PAR
- Wind speed and direction
- SW/GW stage
- GW temperature
- SW temperature
- Air temperature
- Relative humidity
- Barometric pressure
- ORP



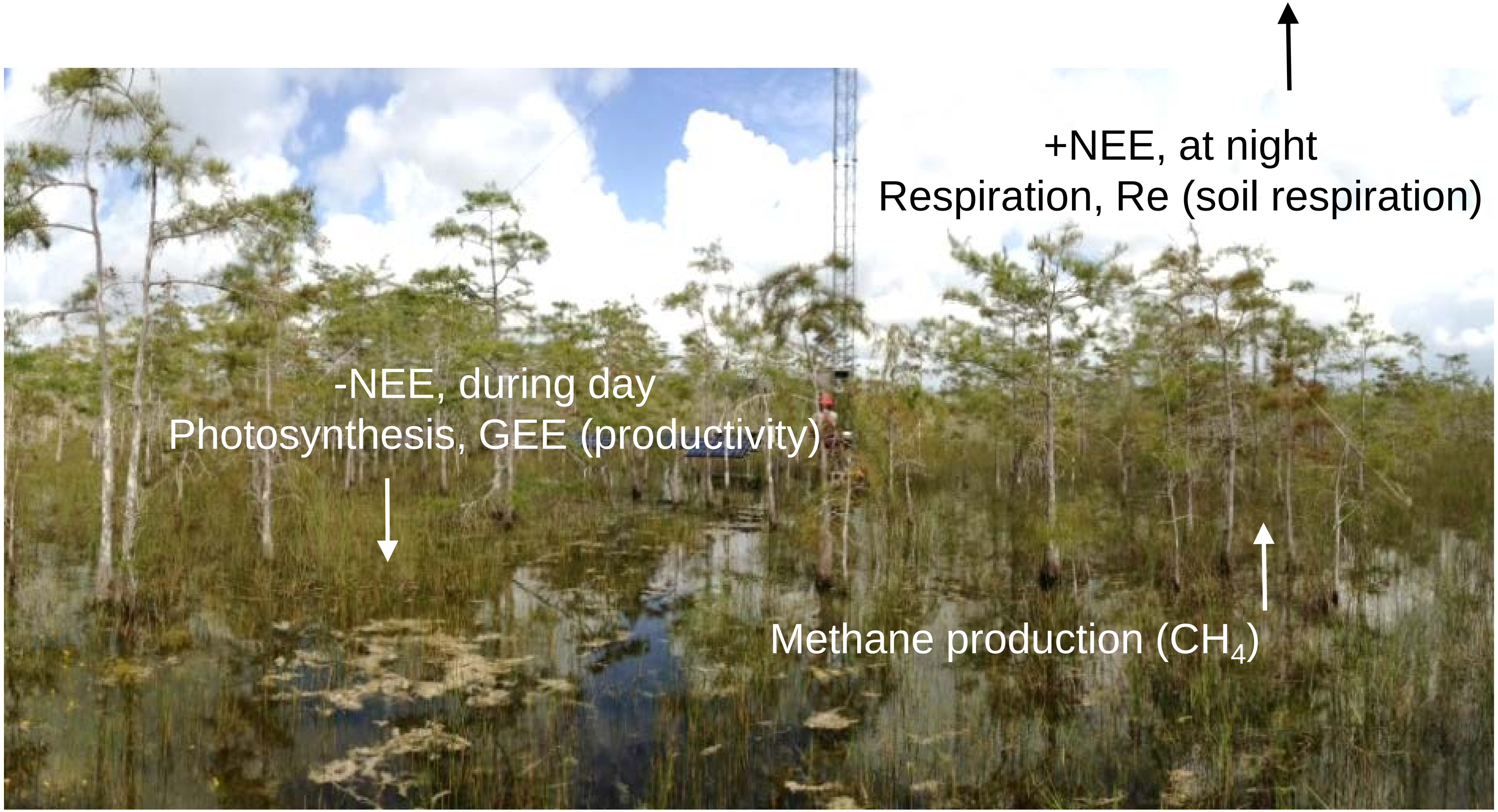
Cypress Swamp (120’)

- Measures ET, H, NEE
- Net radiation
- PAR
- Wind speed and direction
- Surface/groundwater stage
- Ground-water temperature
- Surface-water temperature
- Air temperature
- Relative humidity
- Soil temperature
- Soil heat flux
- Soil moisture

Pine upland (120’ tower)

- Measures ET, NEE
- Net radiation
- SW/GW stage
- GW temperature
- SW temperature
- Air temperature
- Relative humidity
- Soil moisture
- Soil temperature
- Soil heat flux

Carbon Cycling Conceptual Model



NEE is net ecosystem C exchange, measured with gas analyzer

http://www.biogeosciences-discuss.net/11/15753/2014/bgd-11-15753-2014.html

Missing NEE gap-filled with Artificial Neural Networks (ANN)

ANNs are non-linear regression models based on **season, time of day, net radiation, water temperature, air temperature**, and **vapor pressure deficit**.

Missing weather data supplemented from nearby weather stations (Oasis Visitor Center, others).

Do i=1,20 (Repeat 20 times with different sets of weather data

Do j=1,10 (Initialize starting values for ANN weights) ← Avoids local minima

Model 1 | Model 2 | Model 3 | Model 4 — Complexity increased

End Do (Initialize starting values for ANN weights)

↓

Complex models with an NEE accuracy gain less than 5% are removed.

End Do (Repeat 20 times with different sets of weather data

↓

Missing NEE replaced with a median value from the 20 resultant predictions.

For more information, contact:
Frank Anderson (fanders@usgs.gov)

Neural Network gap-filling

AGU PUBLICATIONS

JGR

Journal of Geophysical Research: Biogeosciences

RESEARCH ARTICLE

10.1002/2015JG003083

Key Points:
- Wetland energy and carbon fluxes varied seasonally and between study periods
- Standing dead plant material may have reduced overall wetland productivity
- Large measured methane emissions offset the radiative cooling from photosynthetic carbon uptake

Supporting Information:
- Supporting Information S1

Correspondence to:
F. E. Anderson,
fanders@usgs.gov

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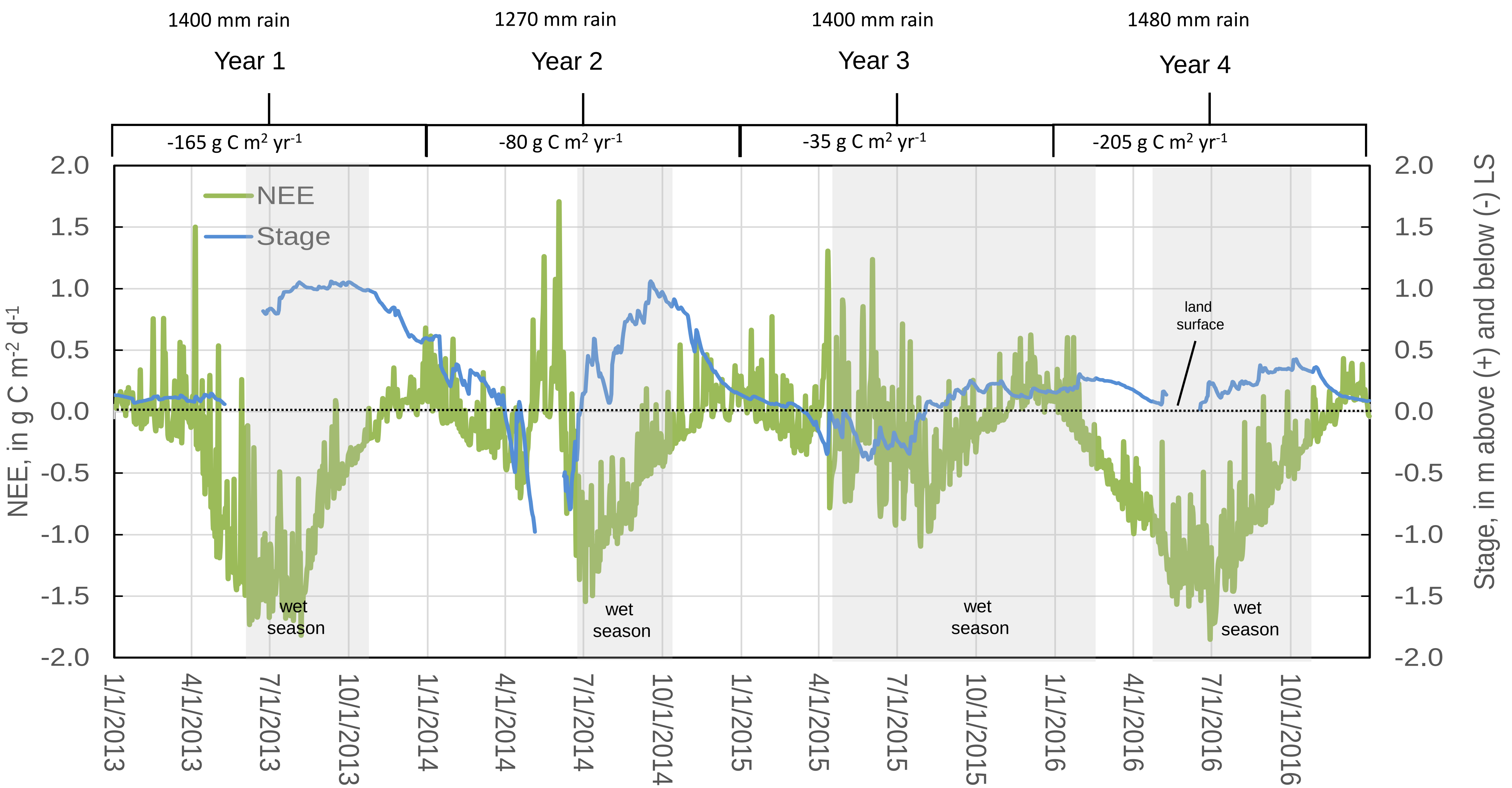
Variation of energy and carbon fluxes from a restored temperate freshwater wetland and implications for carbon market verification protocols

Frank E. Anderson[1], Brian Bergamaschi[1], Cove Sturtevant[2], Sara Knox[2], Lauren Hastings[3], Lisamarie Windham-Myers[4], Matteo Detto[5], Erin L. Hestir[6], Judith Drexler[1], Robin L. Miller[1], Jaclyn Hatala Matthes[2], Joseph Verfaillie[2], Dennis Baldocchi[2], Richard L. Snyder[7], and Roger Fujii[1]

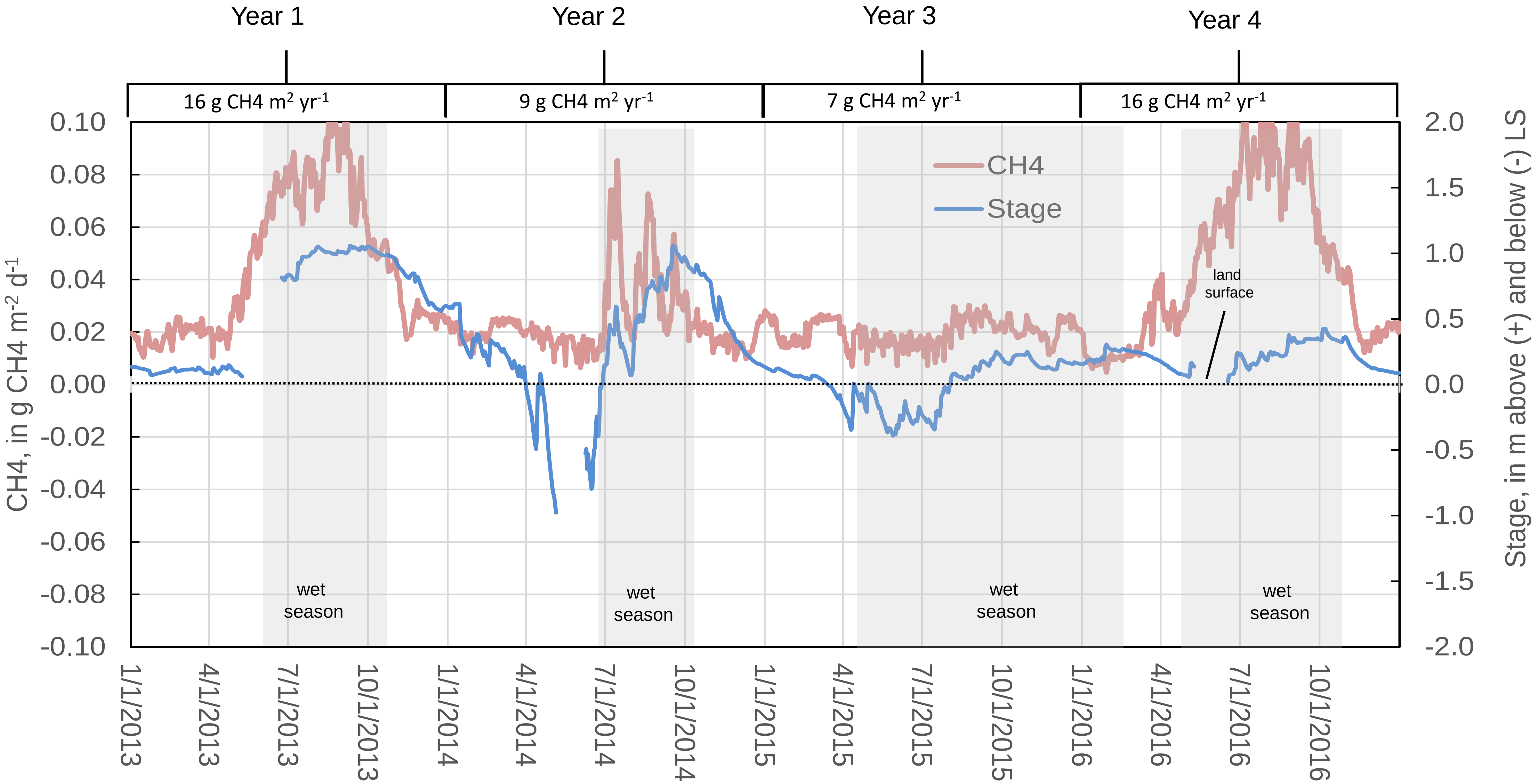
[1]U.S. Geological Survey, Sacramento, California, USA, [2]Ecosystem Science Division, Department of Environmental Science, Policy and Management, University of California, Berkeley, California, USA, [3]Delta Stewardship Council, Sacramento, California, USA, [4]U.S. Geological Survey, Menlo Park, California, USA, [5]Smithsonian Tropical Research Institute, Panama City, Panama, [6]Department of Marine, Earth and Atmospheric Sciences, North Carolina State University, Raleigh, North Carolina, USA, [7]Department of Land, Air and Water Resources, University of California, Davis, California, USA

Abstract Temperate freshwater wetlands are among the most productive terrestrial ecosystems, stimulating interest in using restored wetlands as biological carbon sequestration projects for greenhouse gas reduction programs. In this study, we used the eddy covariance technique to measure surface energy carbon fluxes from a constructed, impounded freshwater wetland during two annual periods that were 8 years apart: 2002–2003 and 2010–2011. During 2010–2011, we measured methane (CH_4) fluxes to quantify the annual atmospheric carbon mass balance and its concomitant influence on global warming potential (GWP). Peak growing season fluxes of latent heat and carbon dioxide (CO_2) were greater in 2002–2003 compared to 2010–2011. In 2002, the daily net ecosystem exchange reached as low as $-10.6\ g\,C\,m^{-2}\,d^{-1}$, which was greater than 3 times the magnitude observed in 2010 ($-2.9\ g\,C\,m^{-2}\,d^{-1}$). CH_4 fluxes during 2010–2011 were positive throughout the year and followed a strong seasonal pattern, ranging from $38.1\ mg\,C\,m^{-2}\,d^{-1}$ in the winter to $375.9\ mg\,C\,m^{-2}\,d^{-1}$ during the summer. The results of this study suggest that the wetland had reduced gross ecosystem productivity in 2010–2011, likely due to the increase in dead plant biomass (standing litter) that inhibited the generation of new vegetation growth. In 2010–2011, there was a net positive GWP ($675.3\ g\,C\,m^{-2}\,yr^{-1}$), and when these values are evaluated as a sustained flux, the wetland will not reach radiative balance even after 500 years.

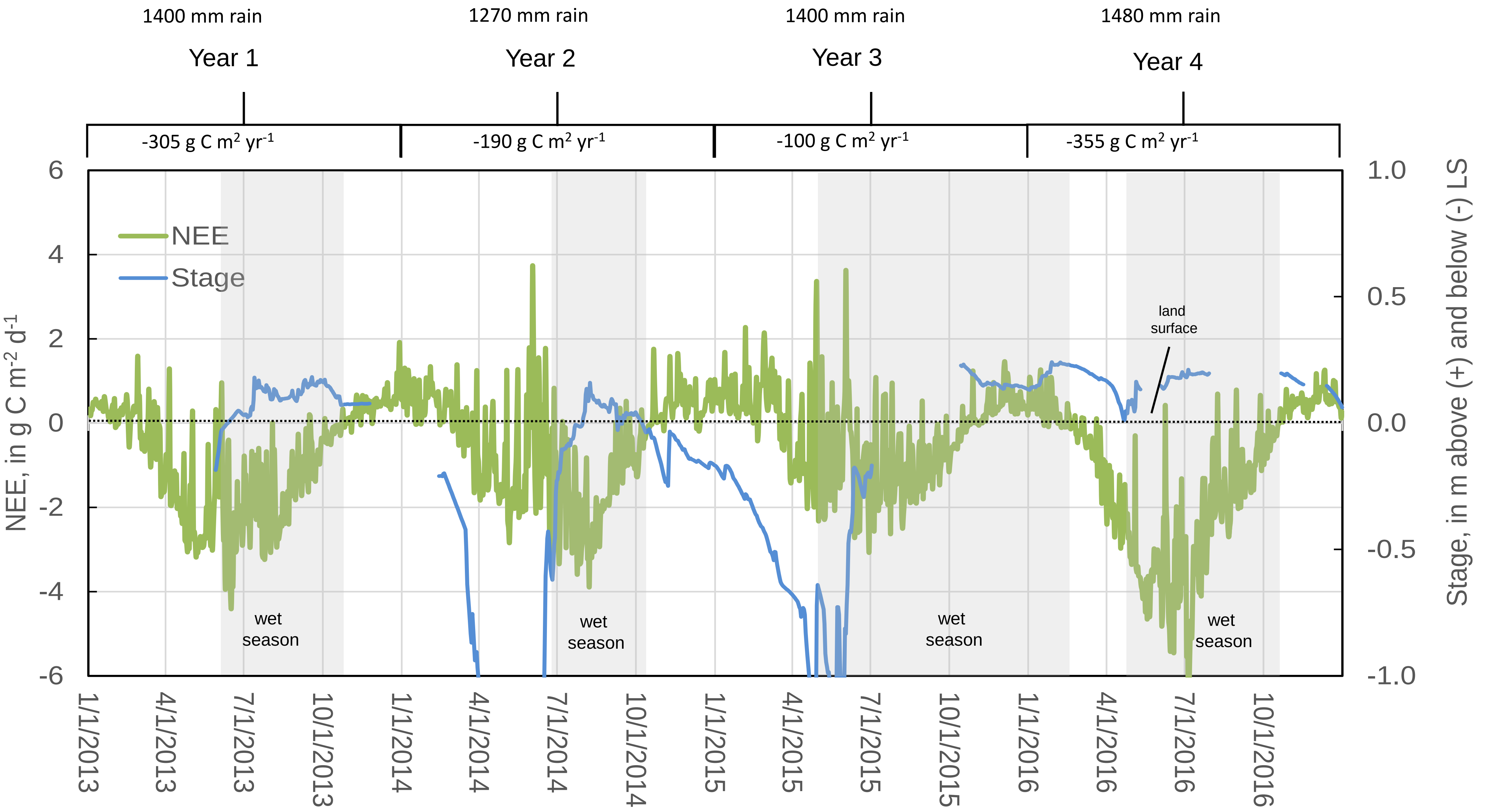
Dwarf Cypress



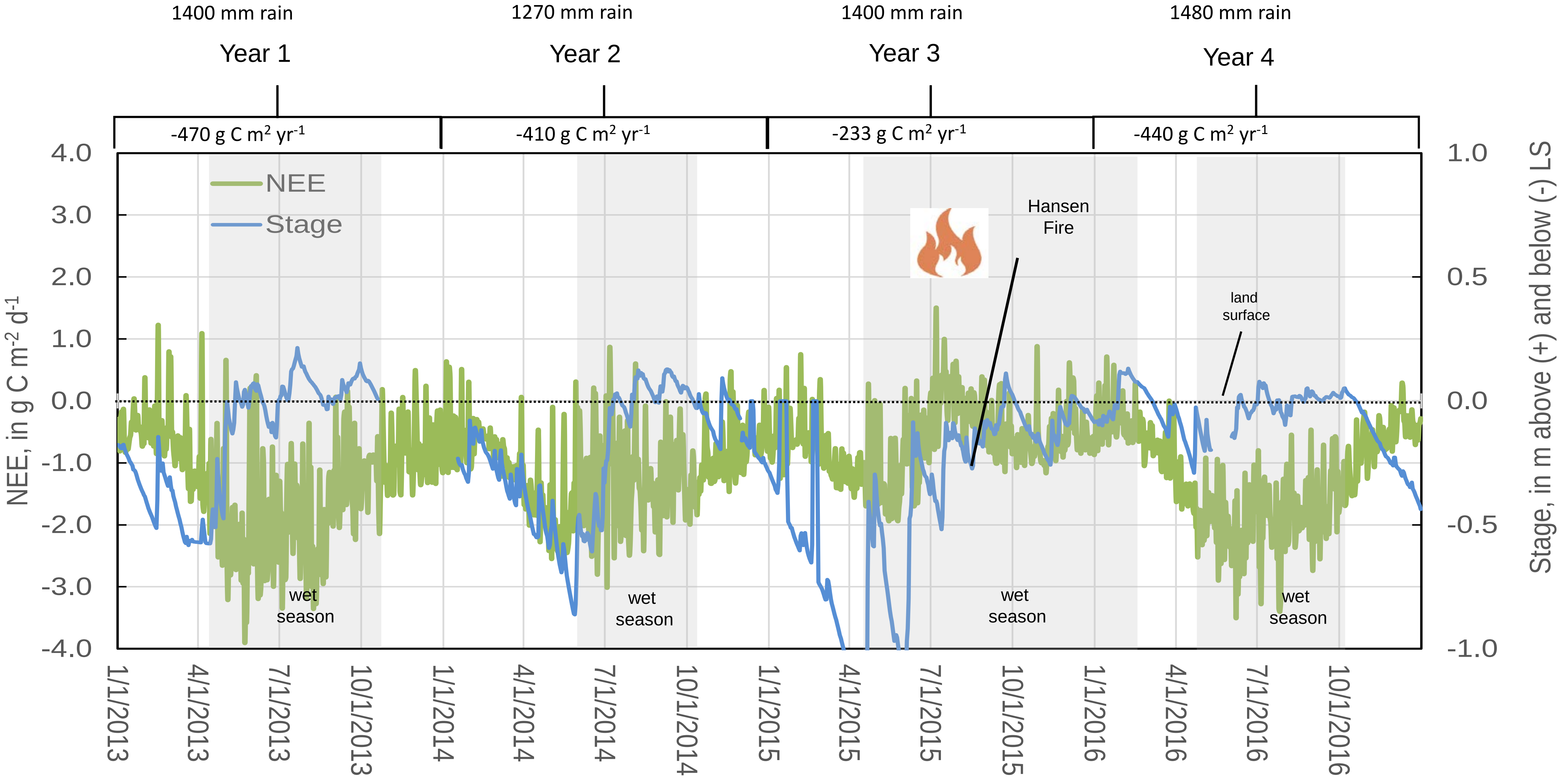
Dwarf Cypress - Methane (CH4)



Cypress Swamp



Pine Upland



1400 mm rain
Year 1
1270 mm rain
Year 2
1400 mm rain
Year 3
1480 mm rain
Year 4
-470 g C m2 yr-1
-410 g C m2 yr-1
-233 g C m2 yr-1
-440 g C m2 yr-1
NEE
Stage
Hansen Fire
land surface
wet season
wet season
wet season
wet season
NEE, in g C m-2 d-1
Stage, in m above (+) and below (-) LS
4.0
3.0
2.0
1.0
0.0
-1.0
-2.0
-3.0
-4.0
1.0
0.5
0.0
-0.5
-1.0
1/1/2013
4/1/2013
7/1/2013
10/1/2013
1/1/2014
4/1/2014
7/1/2014
10/1/2014
1/1/2015
4/1/2015
7/1/2015
10/1/2015
1/1/2016
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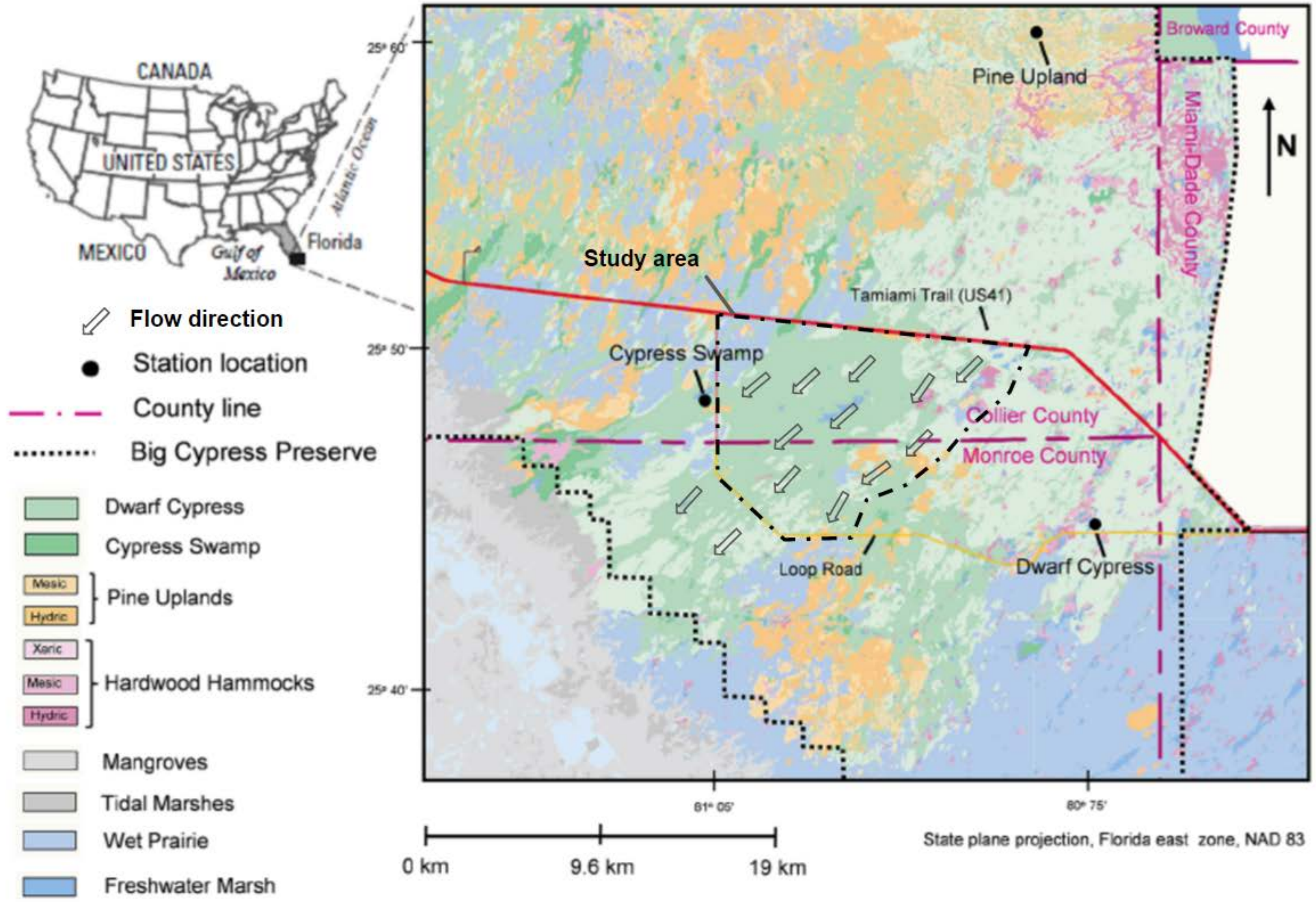
7/1/2016
10/1/2016

Loop Road – Pilot Study



Is the carbon cycle accumulating soil ?

How do soil accumulation rates compare with sea-level rise ?

$$\Delta C = -NEE - F_{net} - F_{CH_4}.$$

ΔC / soil bulk density = topographic gain or loss

Soil bulk density

Samples Before Drying

Samples After Drying

Samples After Furnace

Slide and analysis provided by Matt Sirianni (FAU)

Soil bulk density

Count	Sample	Porosity	g/cm3 Bulk Density	% Organic matter
1	DC_1A	0.84	0.199	25
2	DC_2A	0.82	0.233	21
3	DC_3A	0.69	0.401	14
4	DC_1P	0.68	0.45	
5	DC_2P	0.70	0.38	
6	DC_1D	0.77	0.3	
7	DC_2D	0.72	0.36	
8	CS_1A	0.93	0.092	74
9	CS_2A	0.81	0.24	41
10	CS_3A	0.81	0.243	37
11	CS_1MF	0.83	0.21	
12	CS_2MF	0.81	0.24	
13	CS_1D	0.79	0.27	
14	CS_2D	0.87	0.16	

0.33 (samples 1–7) — Calcitic soils due to periphyton

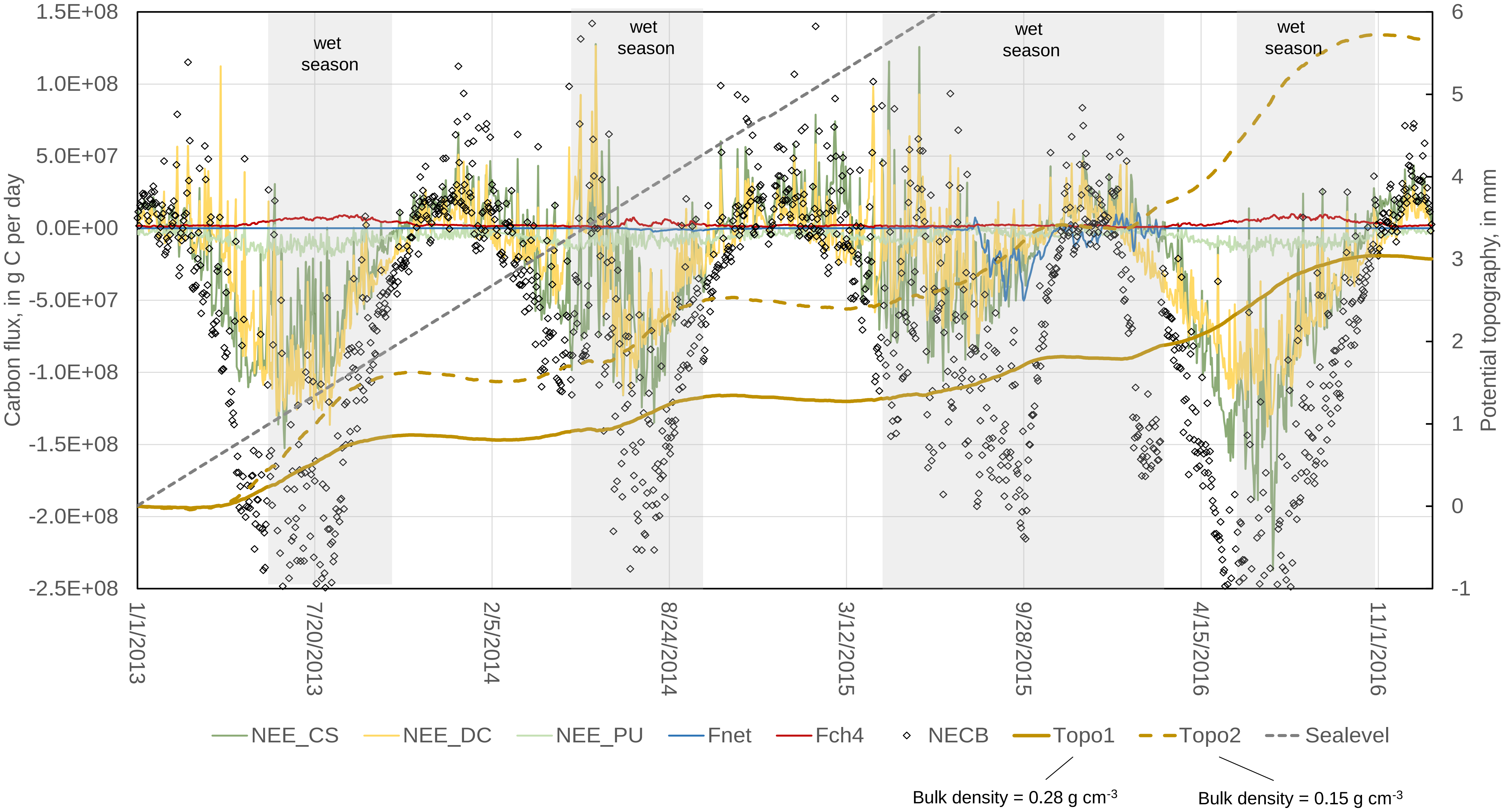
0.21 (samples 8–14)

60% 40%

Weighted average bulk density = 0.28 g/cm3

Slide and analysis provided by Matt Sirianni (FAU)

Loop Road - carbon budget and potential topography changes



Key Findings

1. Cypress and pine forested wetlands are carbon (C) sinks and methane (CH4) sources.

   - Cypress Swamp = -260 g C m^{-2} $year^{-1}$

   - Dwarf Cypress = -120 g C m^{-2} $year^{-1}$; +12 g CH4 m^{-2} $year^{-1}$

   - Pine Upland = -390 g C m^{-2} $year^{-1}$

2. Seasonality in C uptake is primarily driven by photosynthesis and respiration.

   - Flooding reduces respiration (soil oxidation) but increases CH4 emission.

   - Hansen fire suppressed peak photosynthesis at Pine Upland in 2015

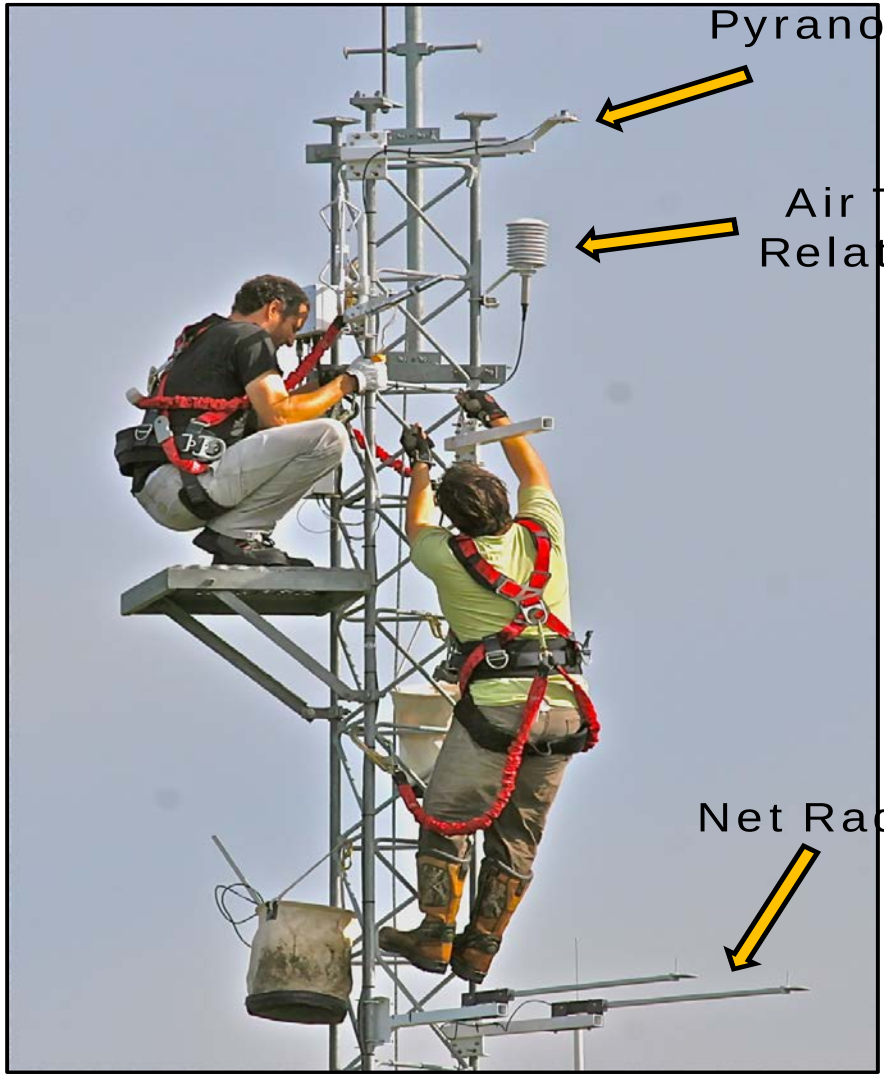
3. Carbon uptake (NEE) rates are equivalent to ~1 mm per year of topography gains in forested wetlands.

   - Accumulation rate is very sensitive to peat bulk-density.

   - Accumulation rate < sea level rise

Conclusions are provisional and subject to change during peer review

THANKS !


Pyranometer
Air Temperature
Relative Humidity
Probe
Net Radiometers