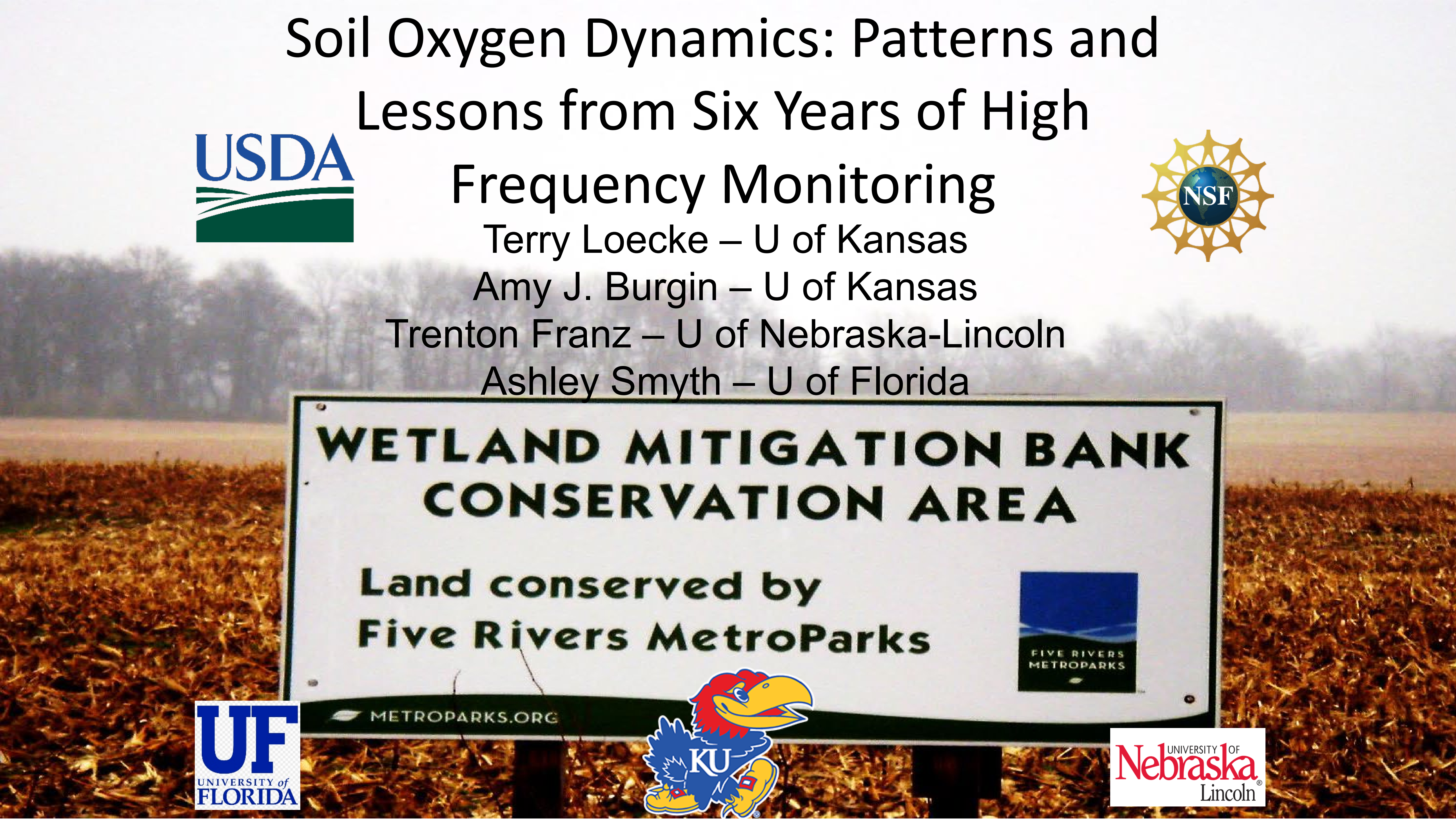
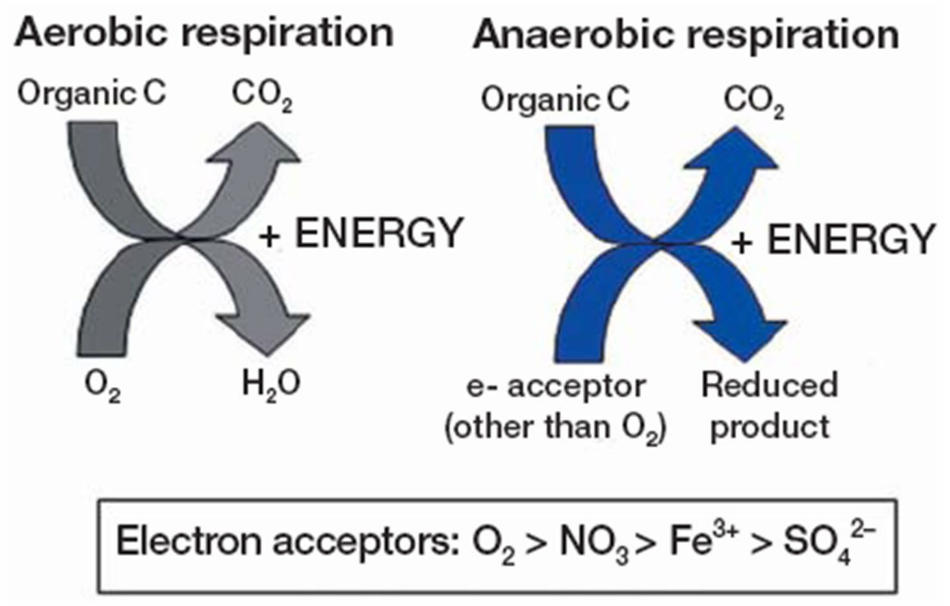
Soil Oxygen Dynamics: Patterns and Lessons from Six Years of High Frequency Monitoring

Terry Loecke – U of Kansas
Amy J. Burgin – U of Kansas
Trenton Franz – U of Nebraska-Lincoln
Ashley Smyth – U of Florida



Importance of Soil O_2

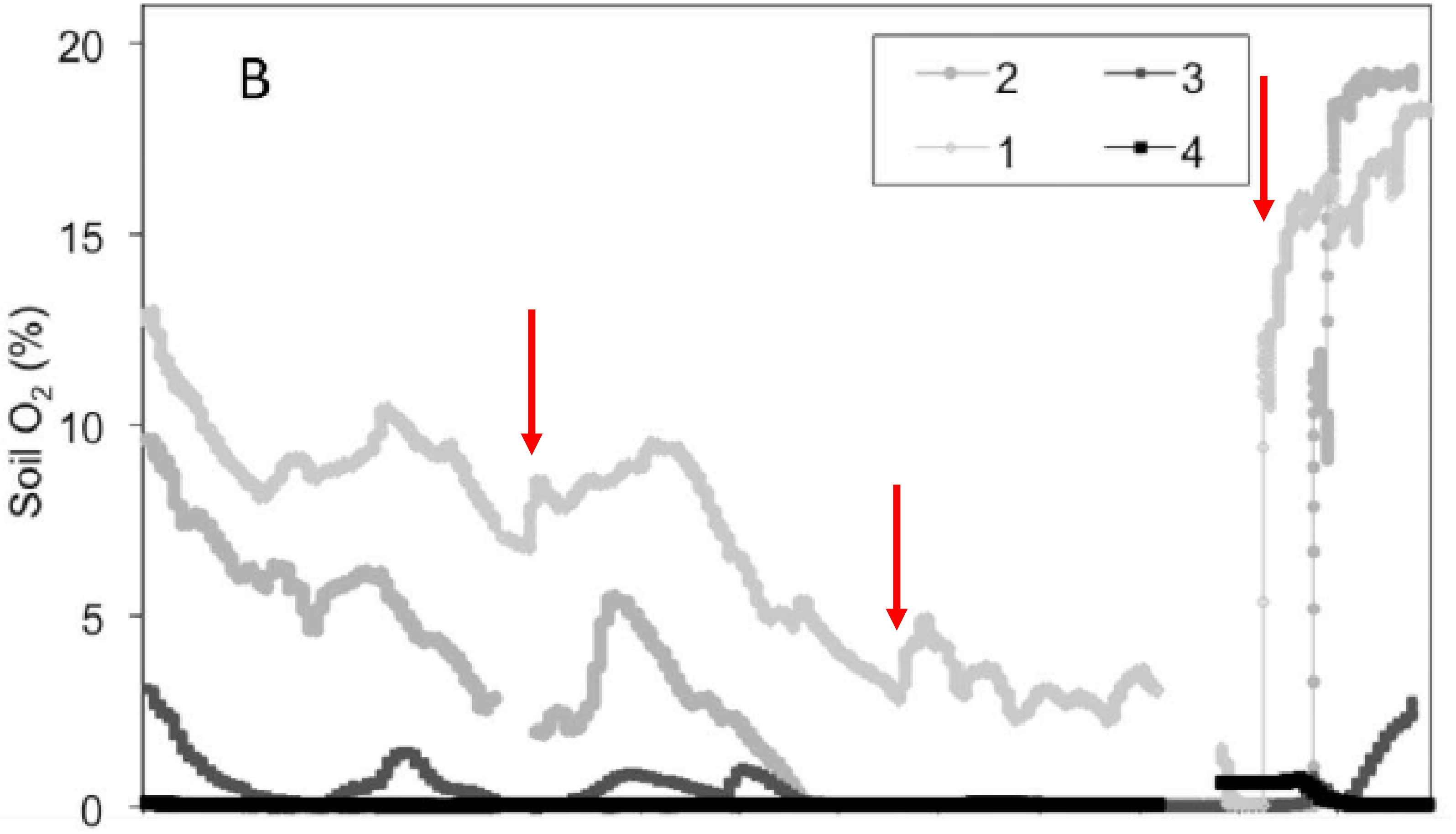
Aerobic vs. Anaerobic



Burgin et al. 2007 *Frontiers in Ecology and the Env.*

GHG	Aerobic	Variable	Anaerobic	Processes
CH_4	+	+ / - , ?	-	$CO_2 + 4 H_2$ -> $\mathbf{CH_4} + 2H_2O$ $\mathbf{CH_4} + O_2$ -> $CO_2 + H_2O$
CO_2	-	+, ?	+	$C_6H_{12}O_6 + O_2$ -> $CO_2 + H_2O$ $C_6H_{12}O_6$ + aTEAs -> $CO_2 + H_2O$
N_2O	- / +	-, ?	+	$NO_3 \rightarrow NO_2 \rightarrow NO \rightarrow \mathbf{N_2O} \rightarrow N_2$ $NH_4 + O_2 \rightarrow \mathbf{N_2O} \rightarrow NO_2 \rightarrow NO \rightarrow NO_3$

Soil O_2 - rise faster than fall



Burgin and Groffman 2012 JGRB

O_2 across Aquatic-Terrestrial Interfaces

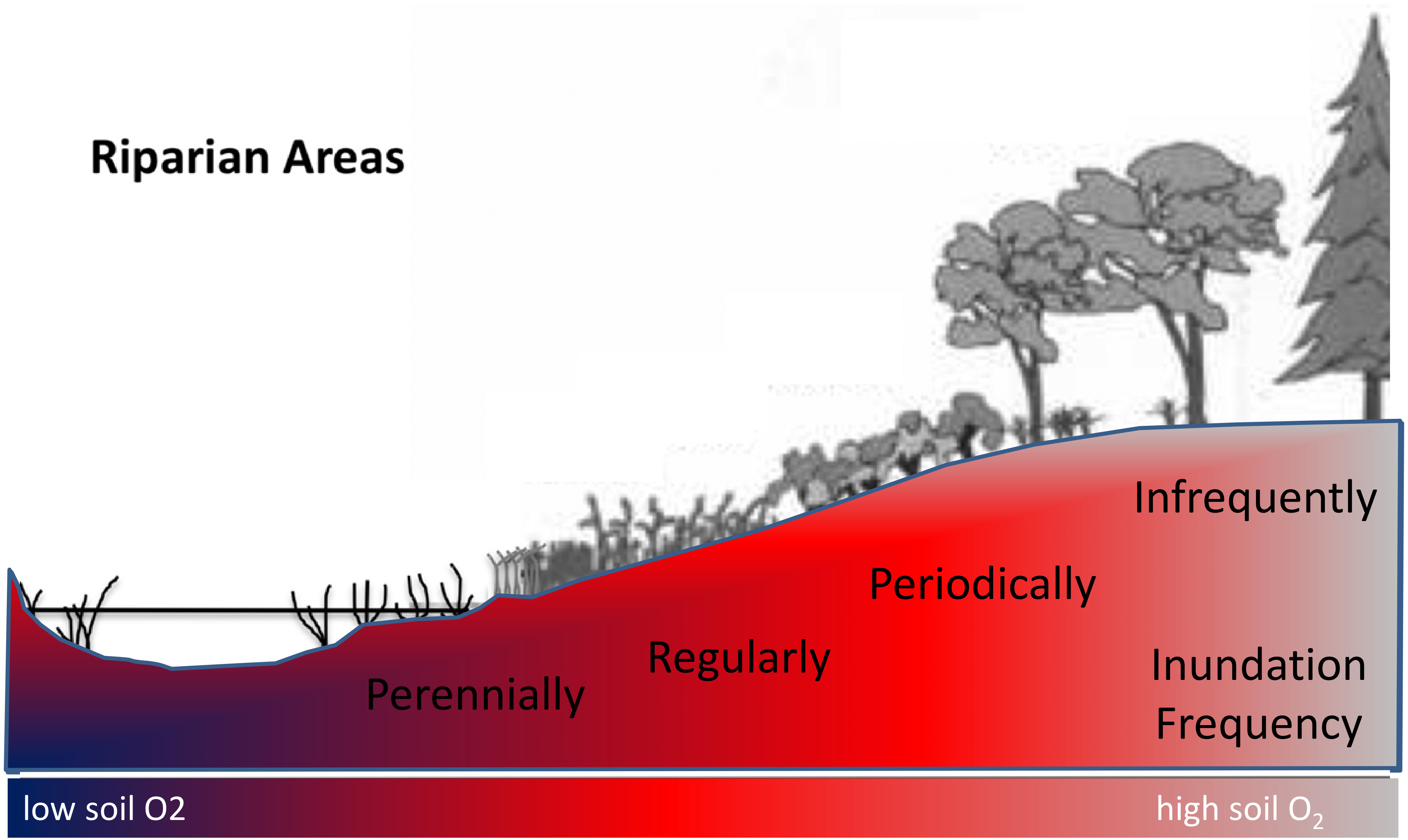


Figure from Bettez and Groffman 2012 – ES&T

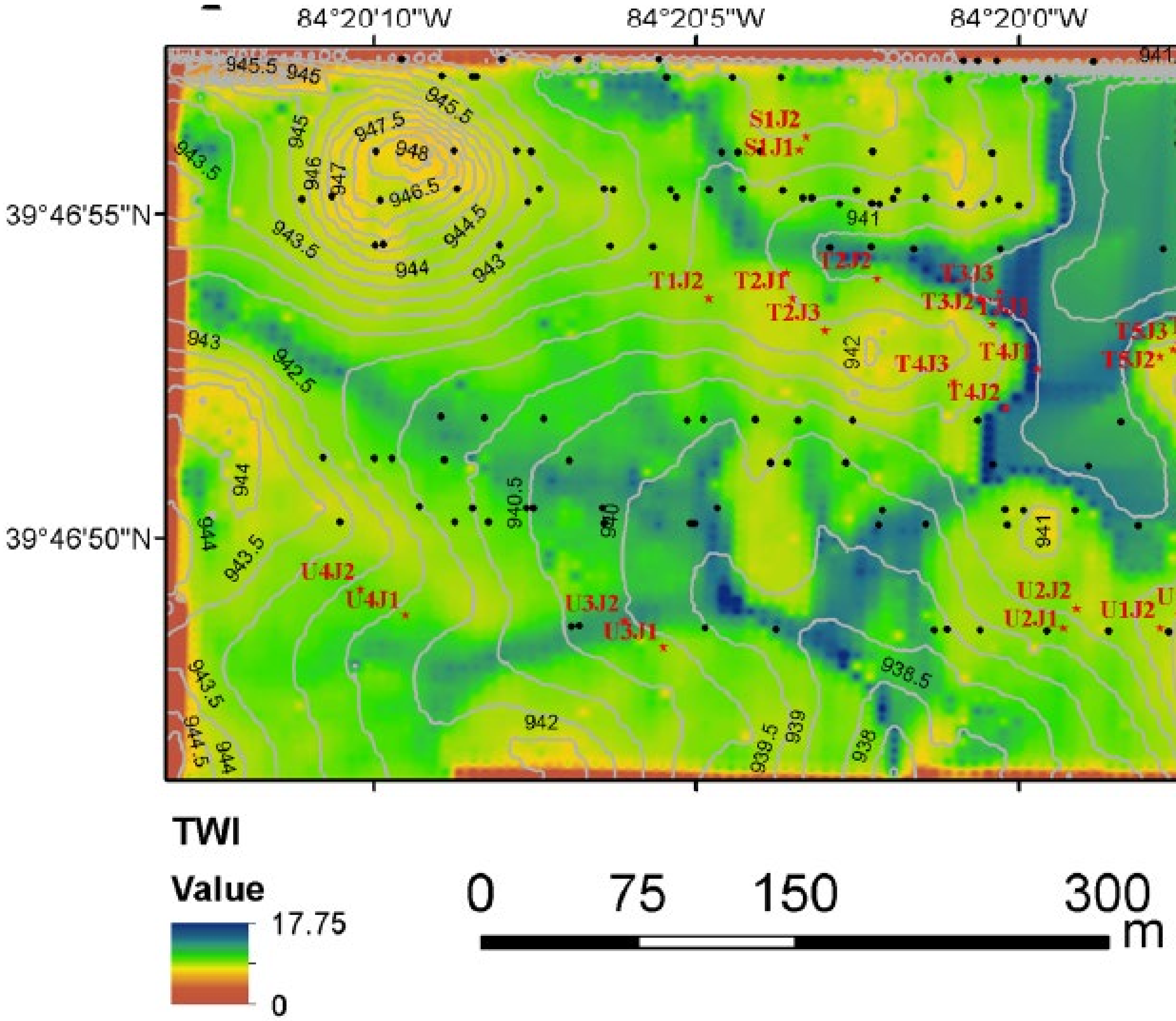
Wetland Restoration

2011

2012

1880's

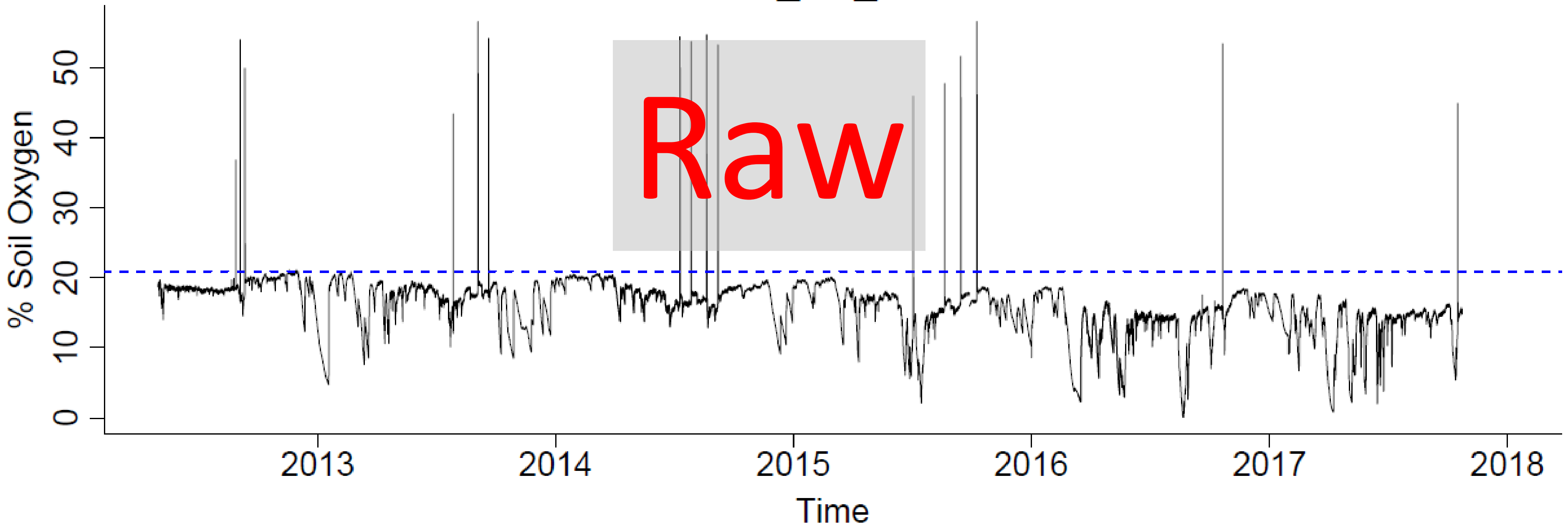
Restored Wetland, Dayton, OH

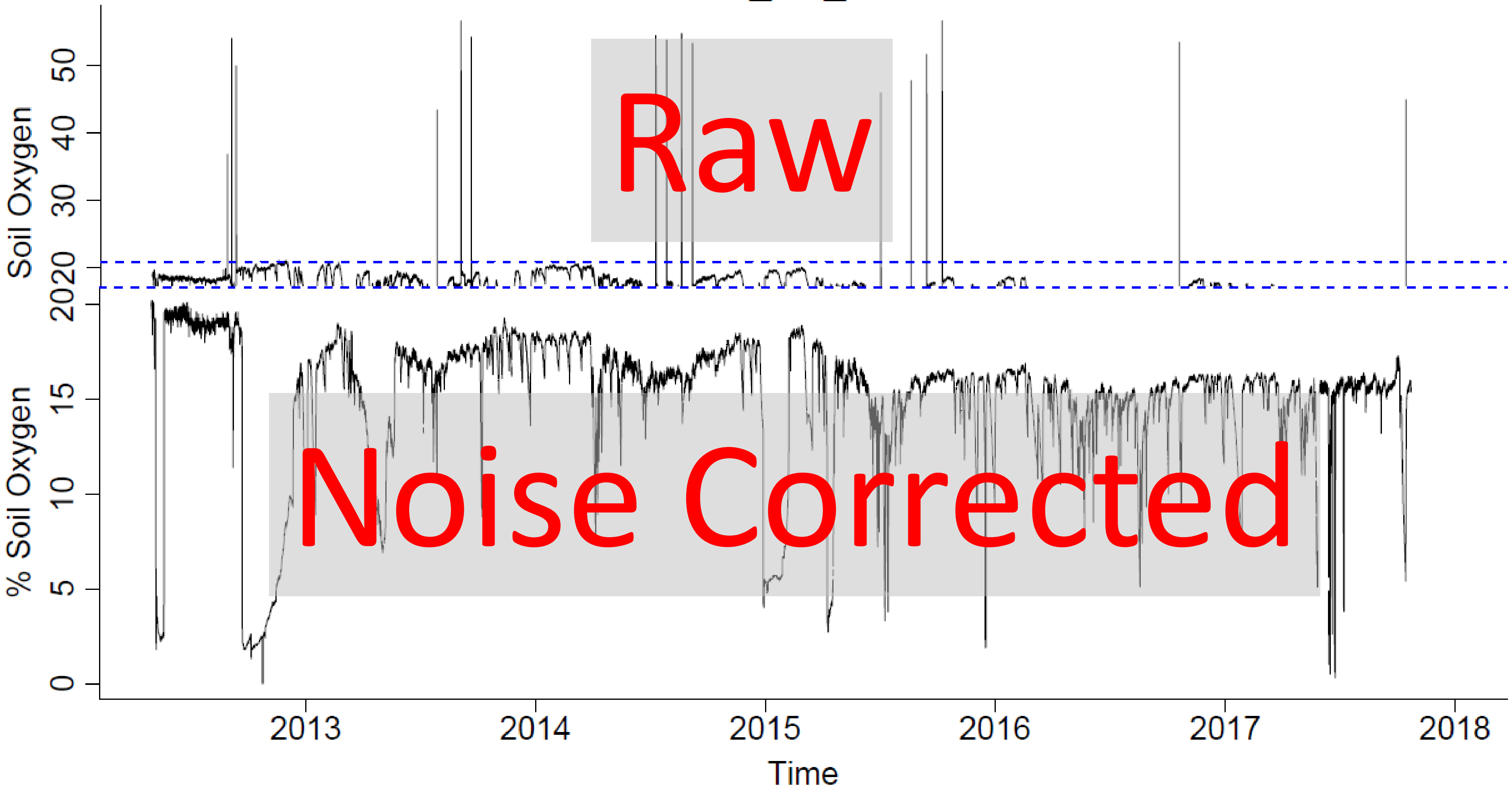


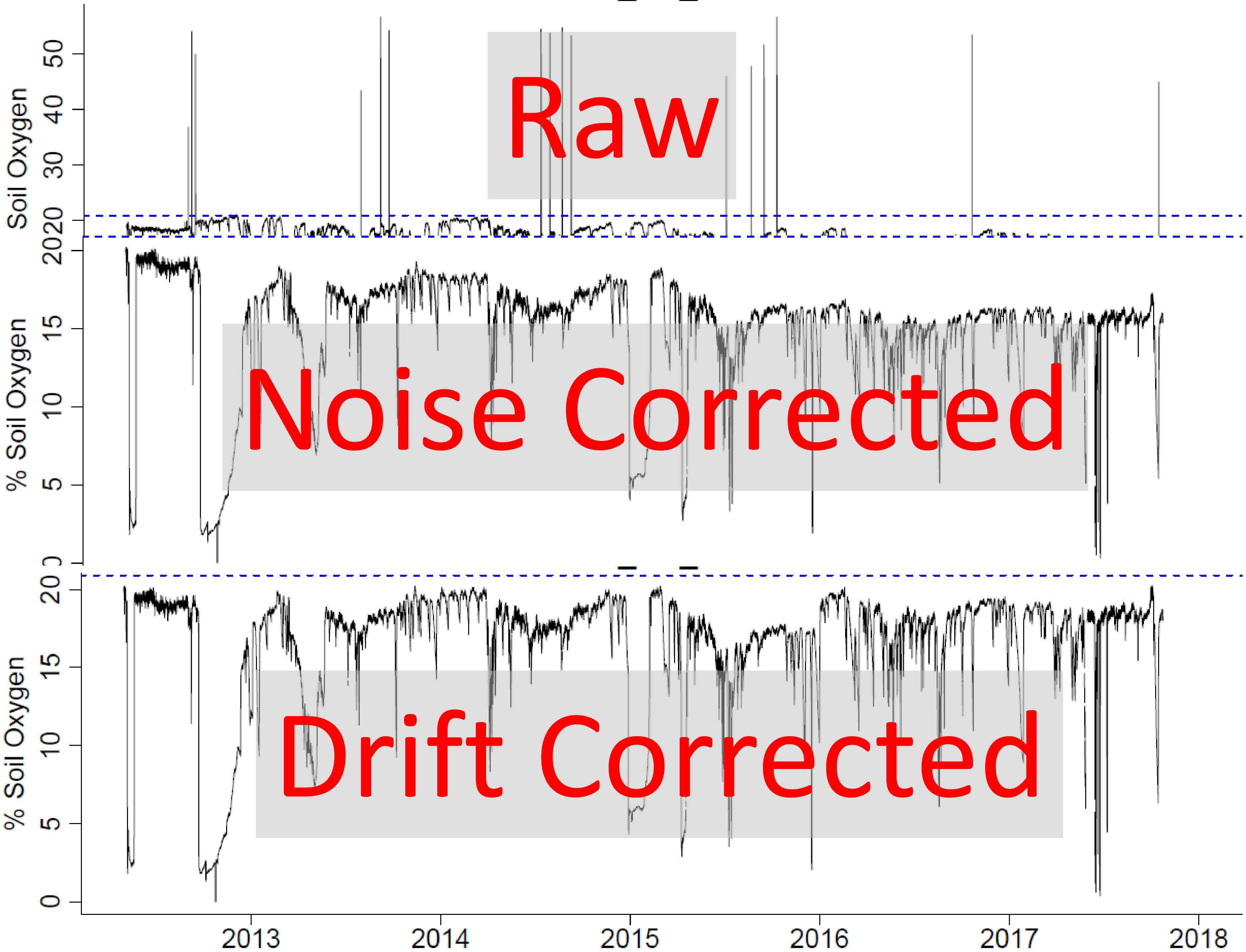
Soil Sensor Network

- 24 Apogee soil O_2 sensors at 10 cm depth
- 28 soil moisture, temperature, and conductivity at 10, 30, 50, and 80 cm
- 12 Water table height
- Weather station: wind, temperature, PAR

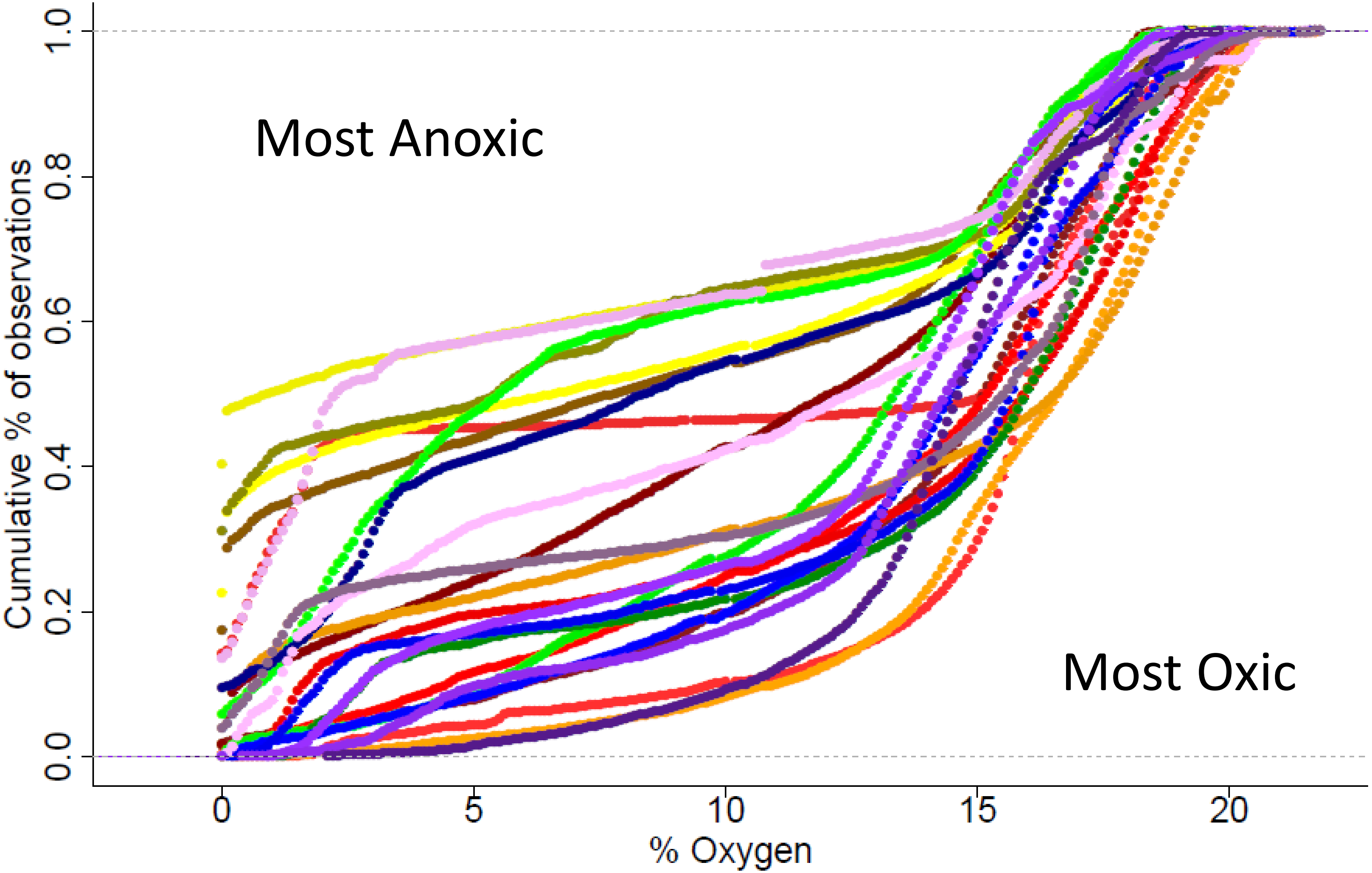
- Taking weekly GHG flux since 2010

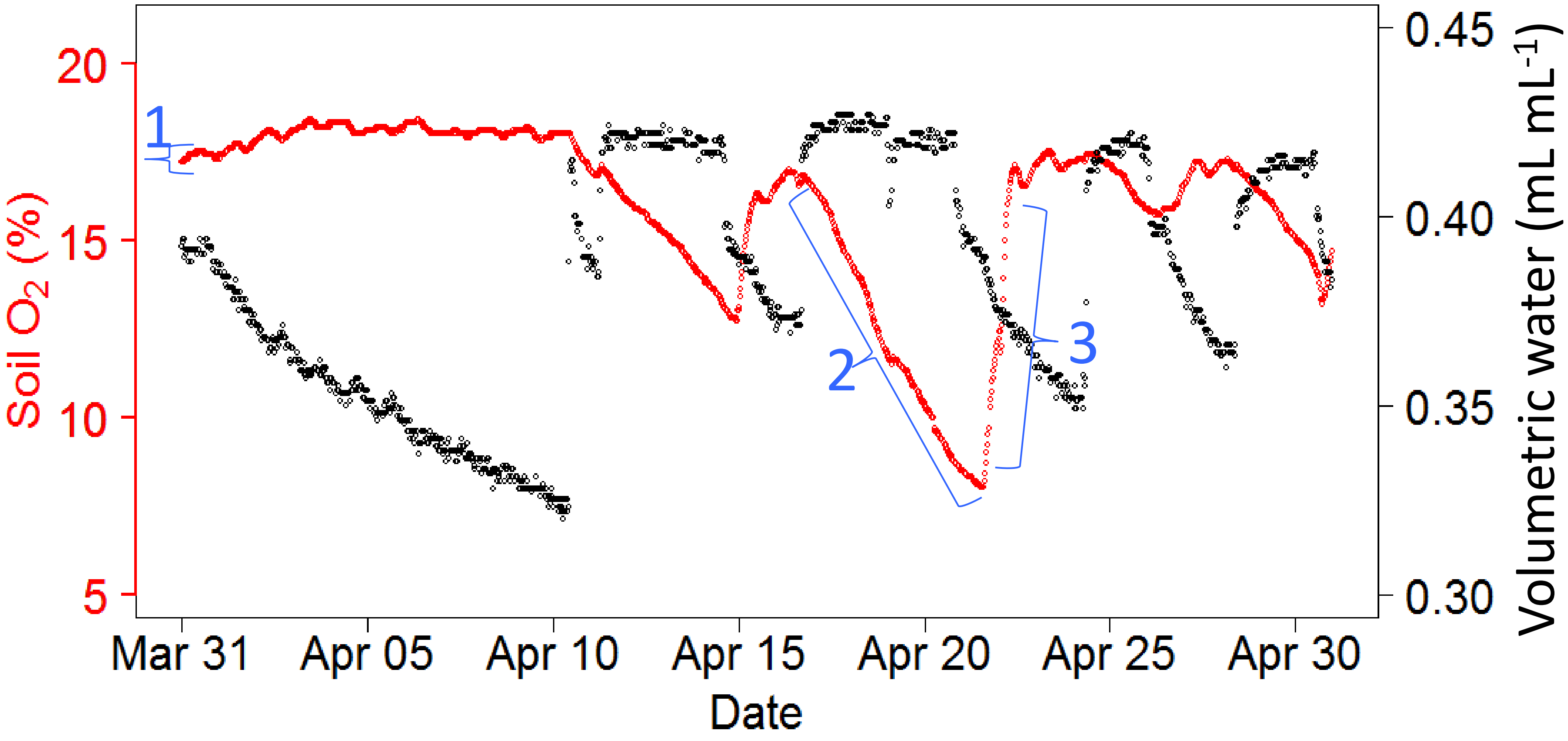

Raw
% Soil Oxygen
0
10
20
30
40
50
2013
2014
2015
2016
2017
2018
Time


Raw
Noise Corrected
Soil Oxygen
50
40
30
20
% Soil Oxygen
20
15
10
5
0
2013
2014
2015
2016
2017
2018
Time


Raw
Soil Oxygen
20
30
40
50
Noise Corrected
% Soil Oxygen
0
5
10
15
20
Drift Corrected
% Soil Oxygen
0
5
10
15
20
2013
2014
2015
2016
2017
2018

Diversity of soil O_2 conditions

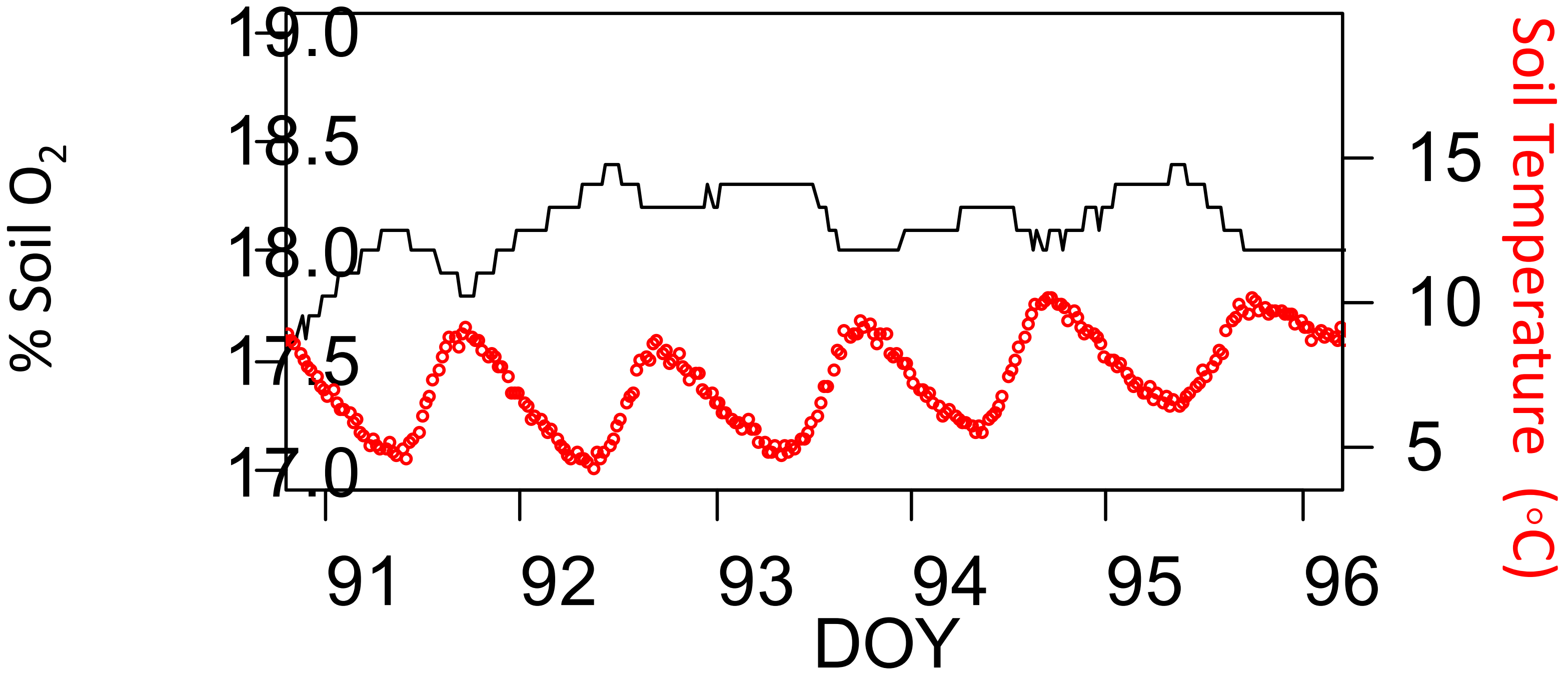




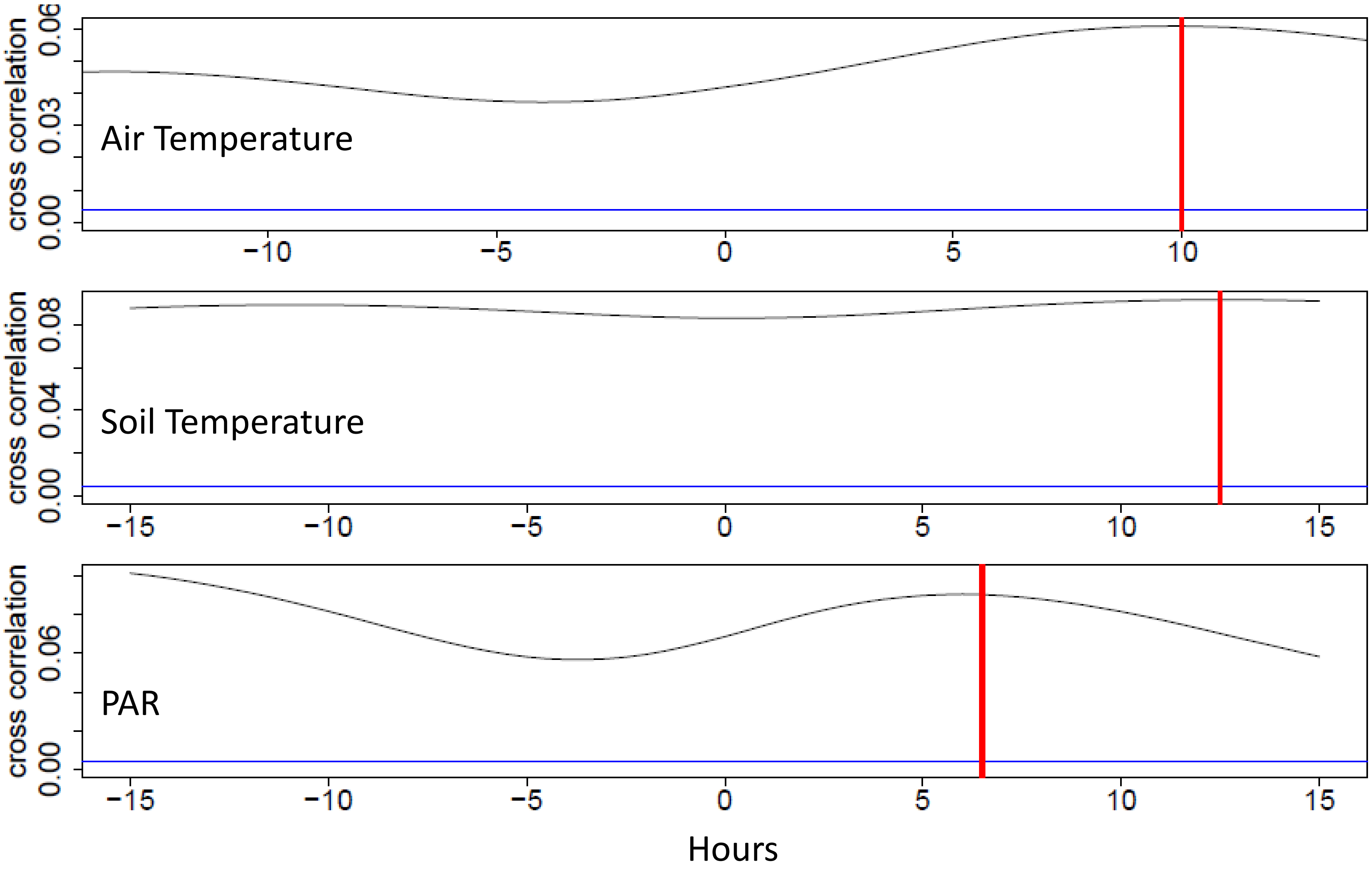
3-repeatable patterns only observed w/ near-continuous monitoring

1. Diurnal fluctuation – daily pulse
2. Lag in O_2 depletion
3. Rapid reaeration – “big gulp”

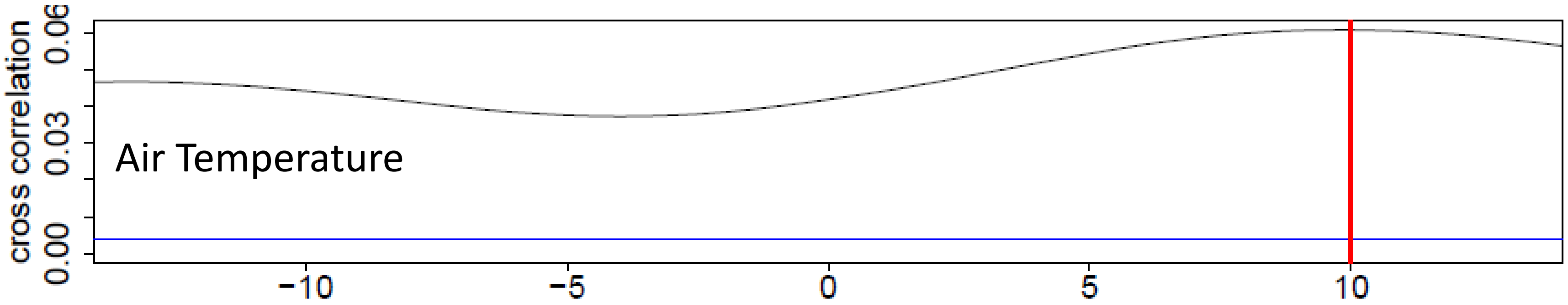
1. Diurnal variation in soil O_2



1. Diurnal variation in soil O_2



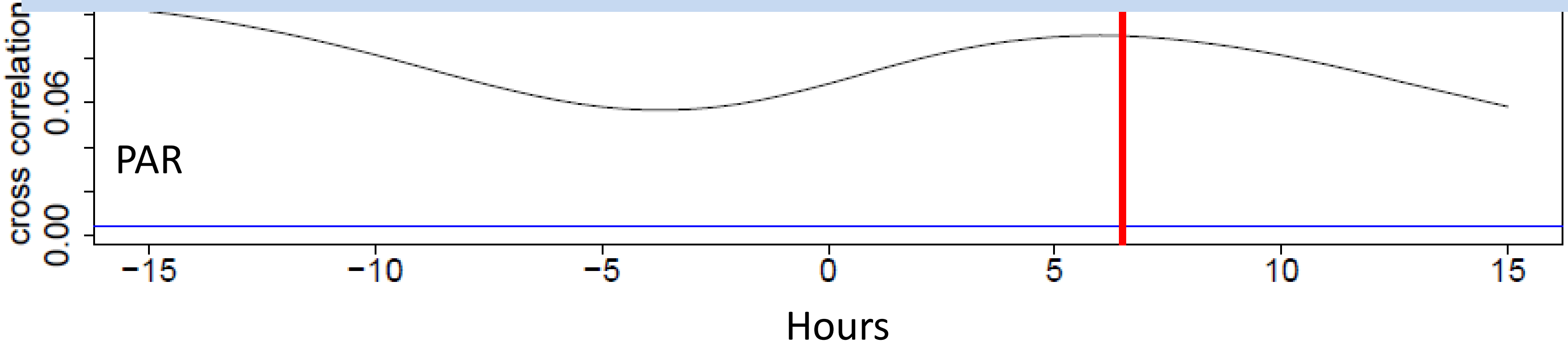
1. Diurnal variation in soil O_2

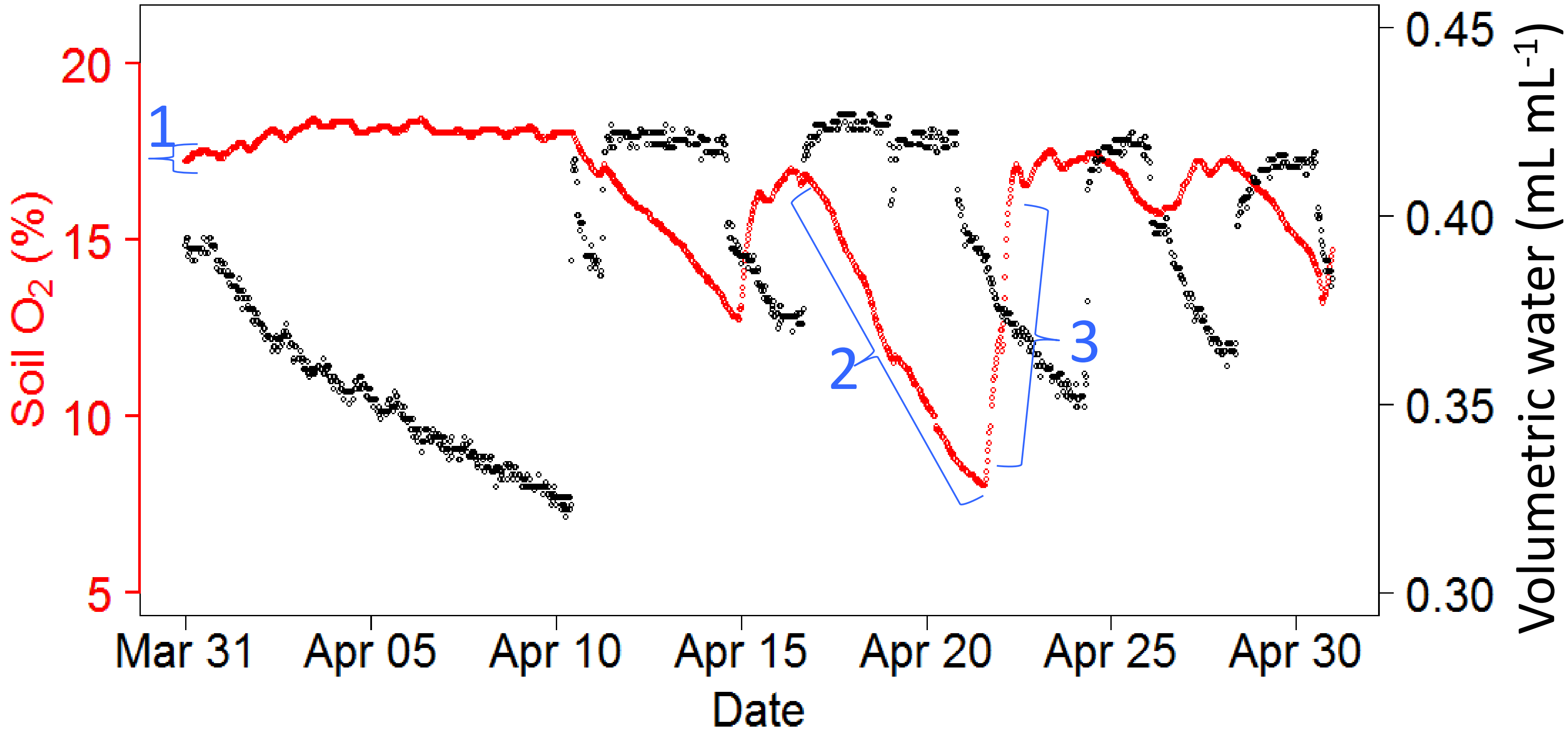


Daily max O_2 lags behind daily min air temp by 2 hours and 1.5 hours behind daily min soil temp.

- Temperature response not temperature artifact.

PAR also important, max PAR lags max O_2 by 6.5 hours.

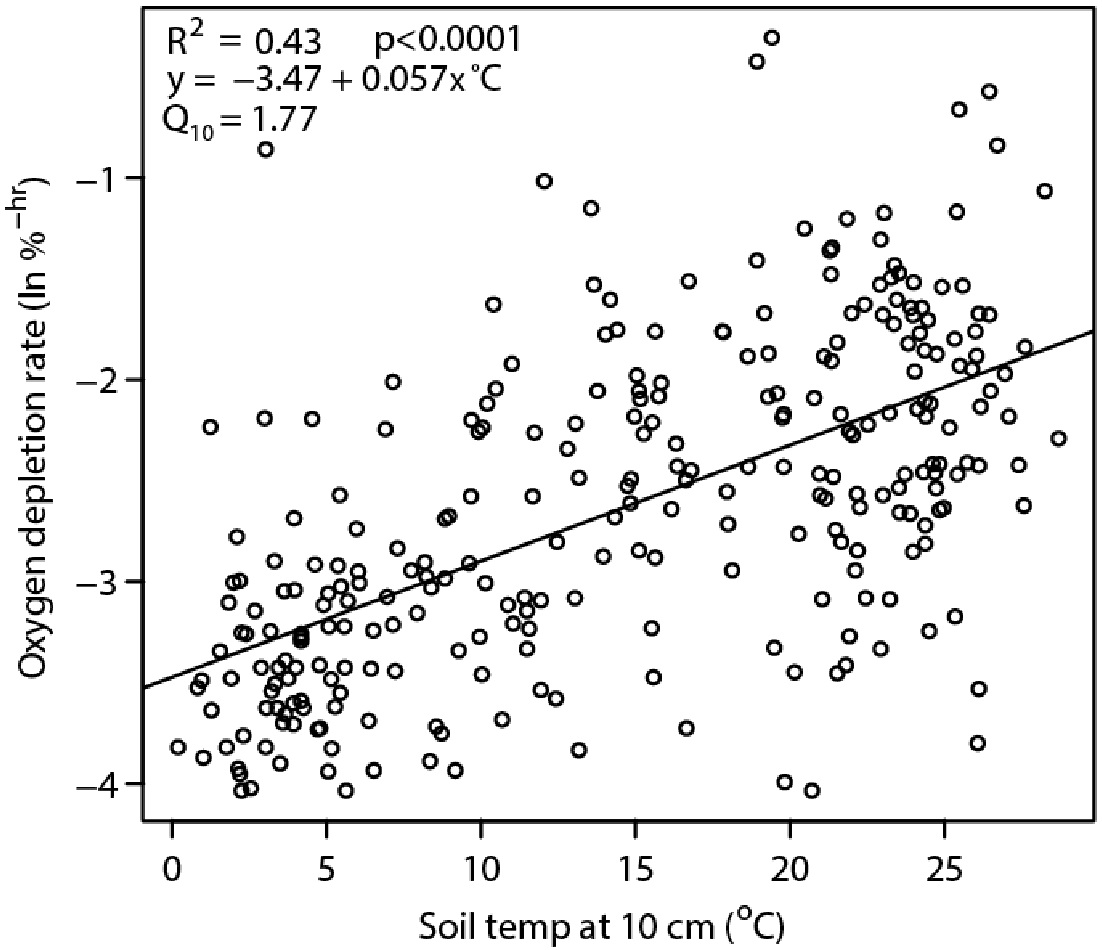


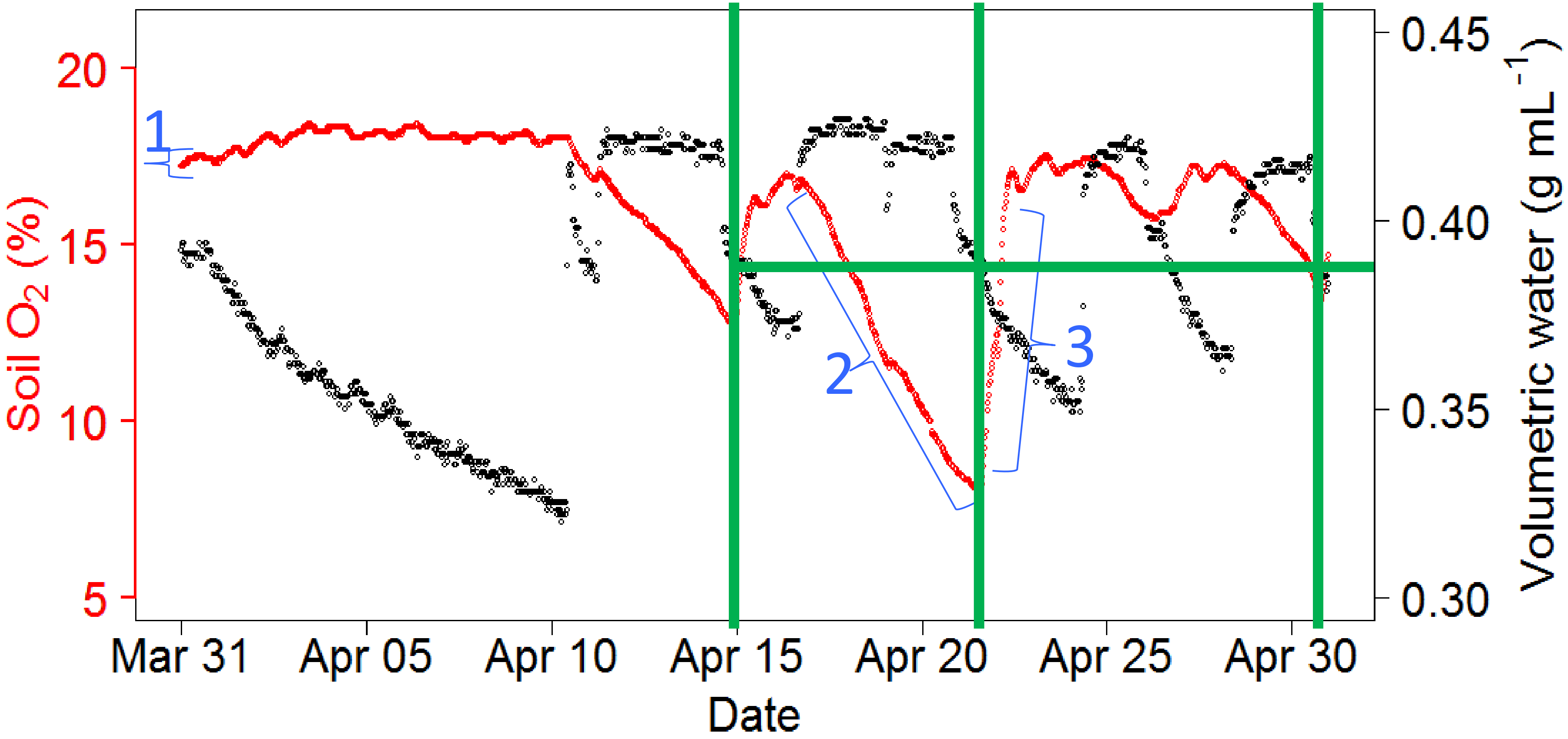


3-repeatable patterns only observed w/ near-continuous monitoring

1. Diurnal fluctuation – daily pulse
2. Lag in O_2 depletion
3. Rapid reaeration – “big gulp”

2. Temperature control on soil O_2 depletion in saturated soils

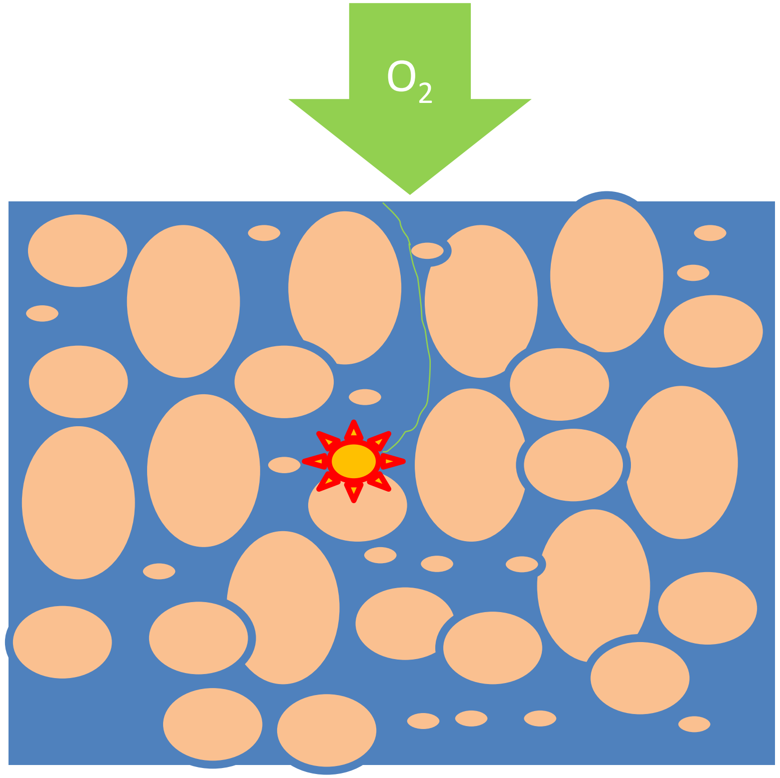




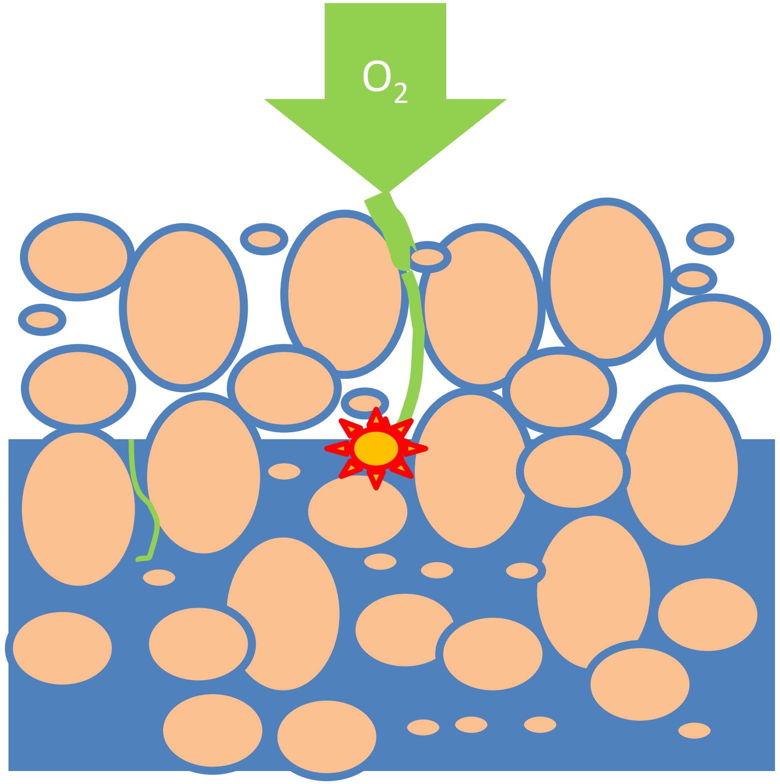
3-repeatable patterns only observed w/ near-continuous monitoring

1. Diurnal fluctuation
2. Lag in O_2 depletion
3. Rapid reaeration – “big gulp”

3. Big gulps occur during soil drainage

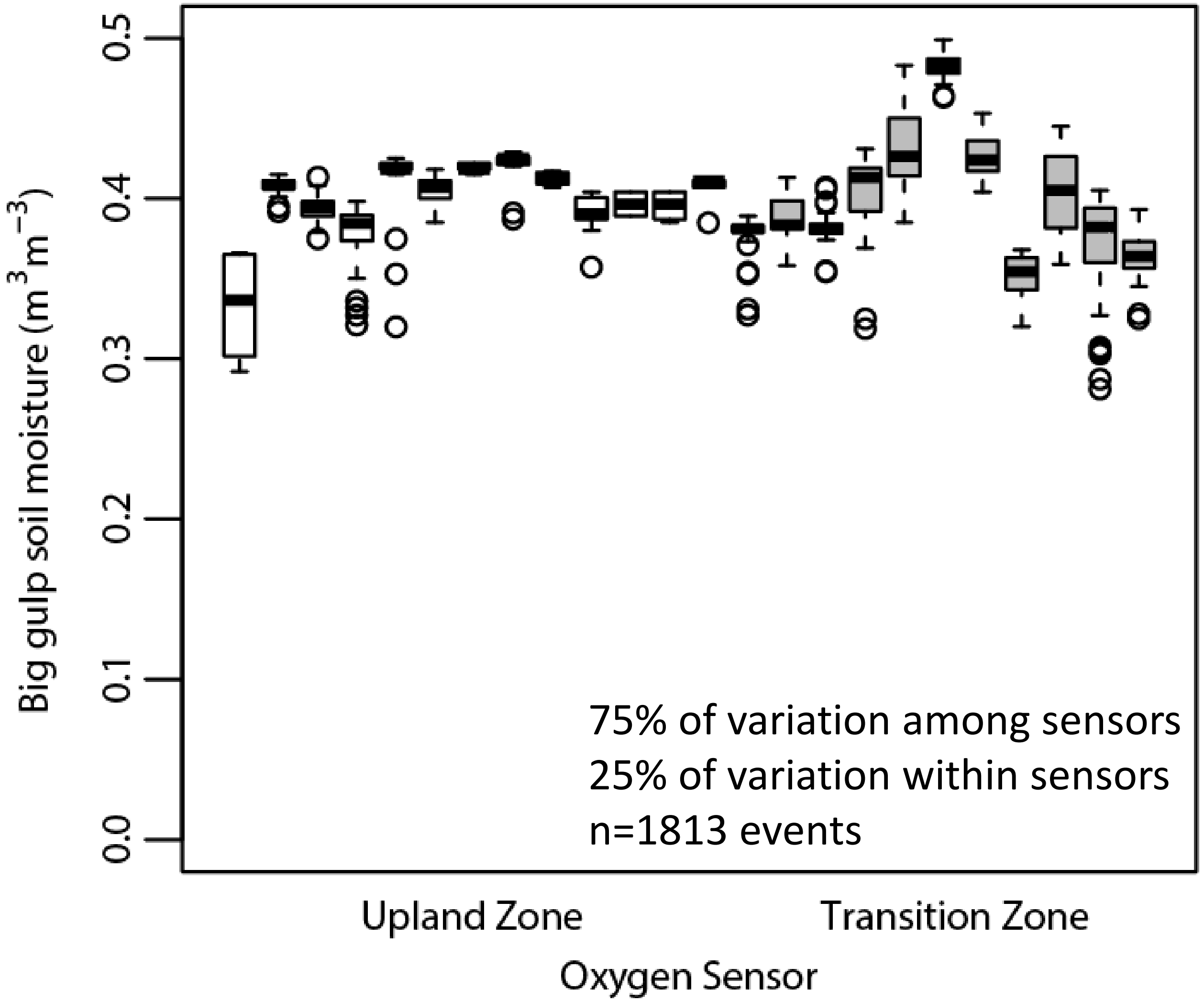


Saturated soil



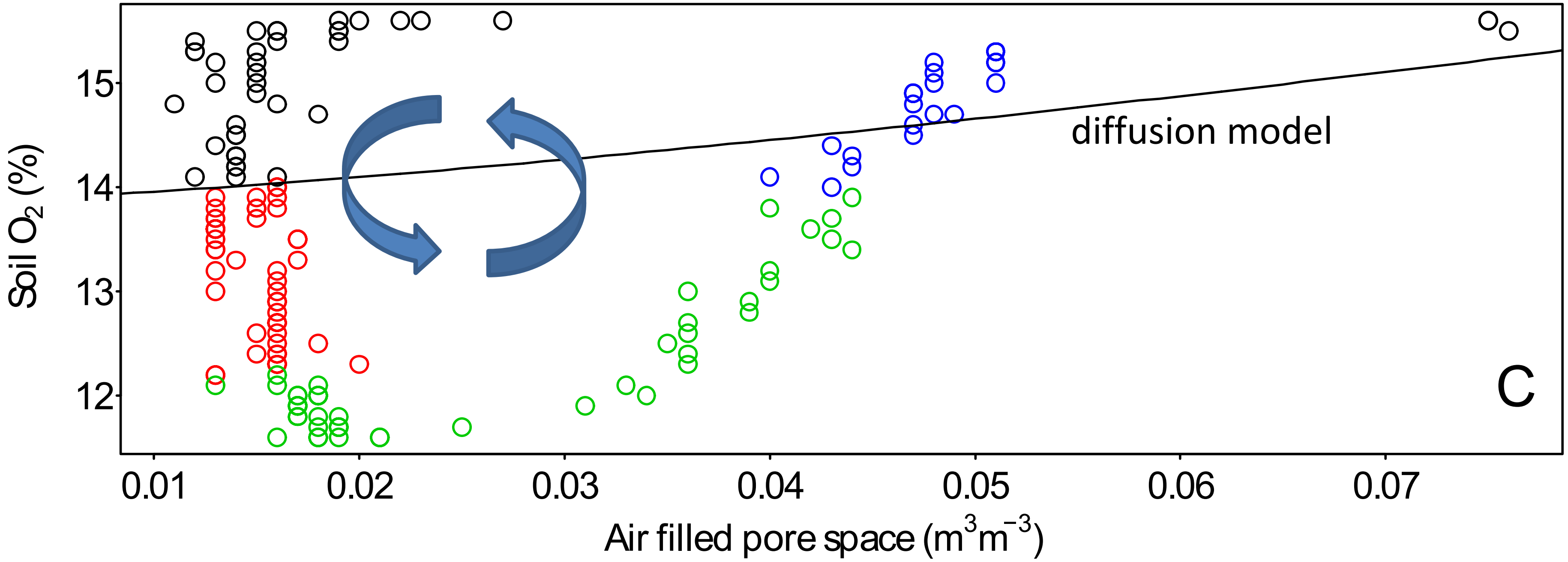
Macropore Drainage

Big gulps consistently occur within narrow threshold of soil drainage

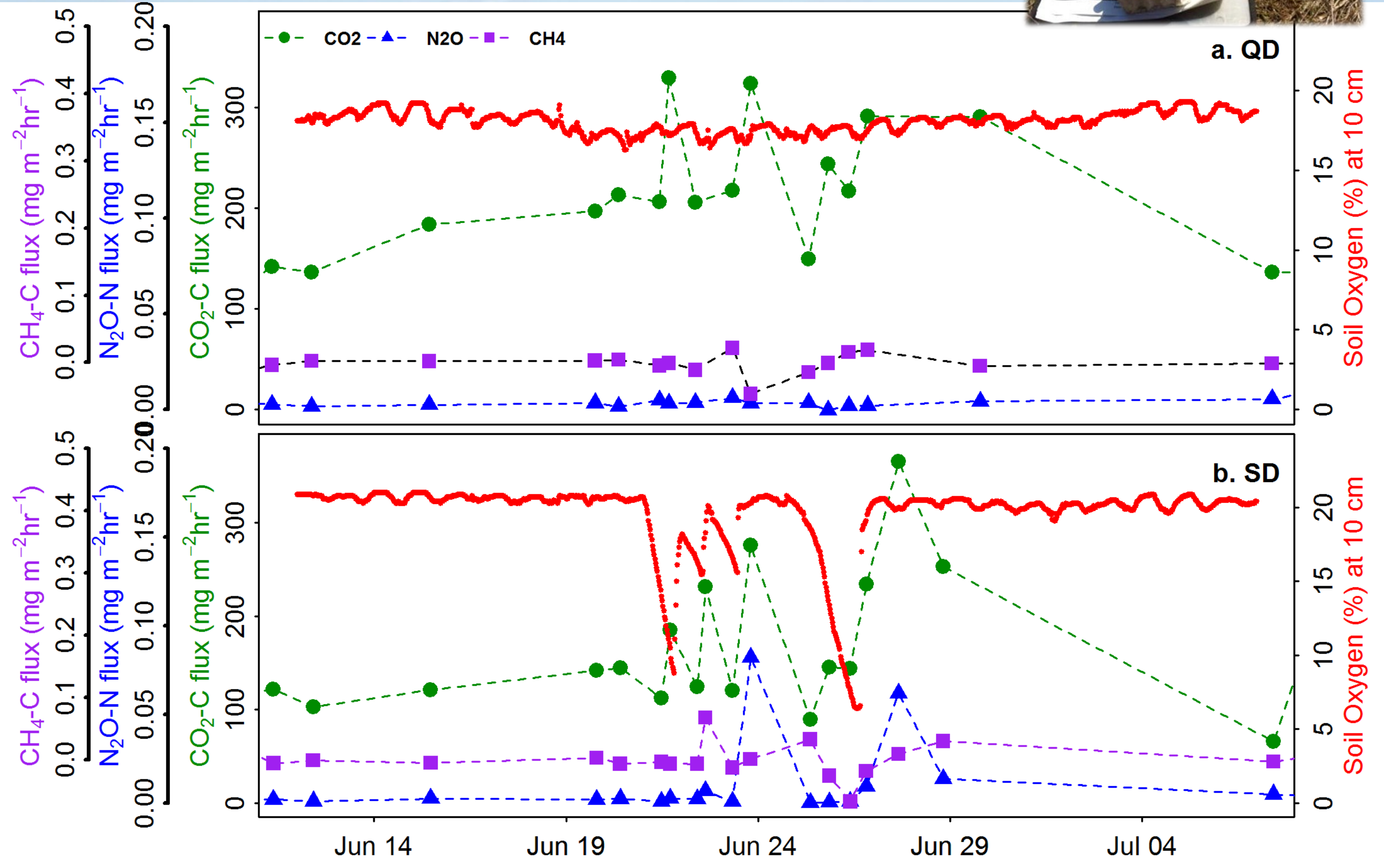


75% of variation among sensors
25% of variation within sensors
n=1813 events

Common diffusion soil O_2 models fail to predict hysteresis between soil moisture and soil O_2



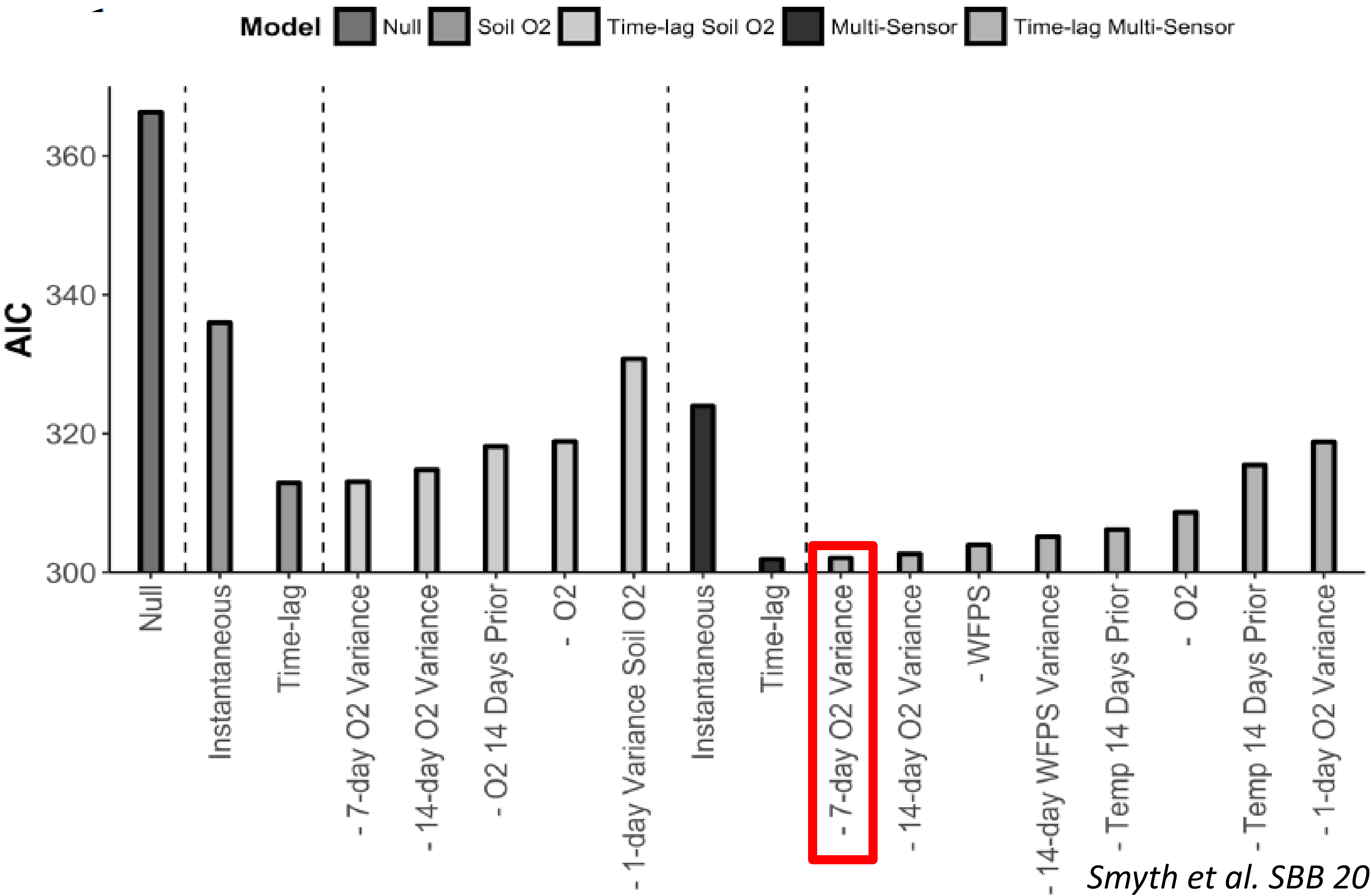
Do big gulps correspond to big burbs?



Jarecke, Loecke, & Burgin *SBB 2016*

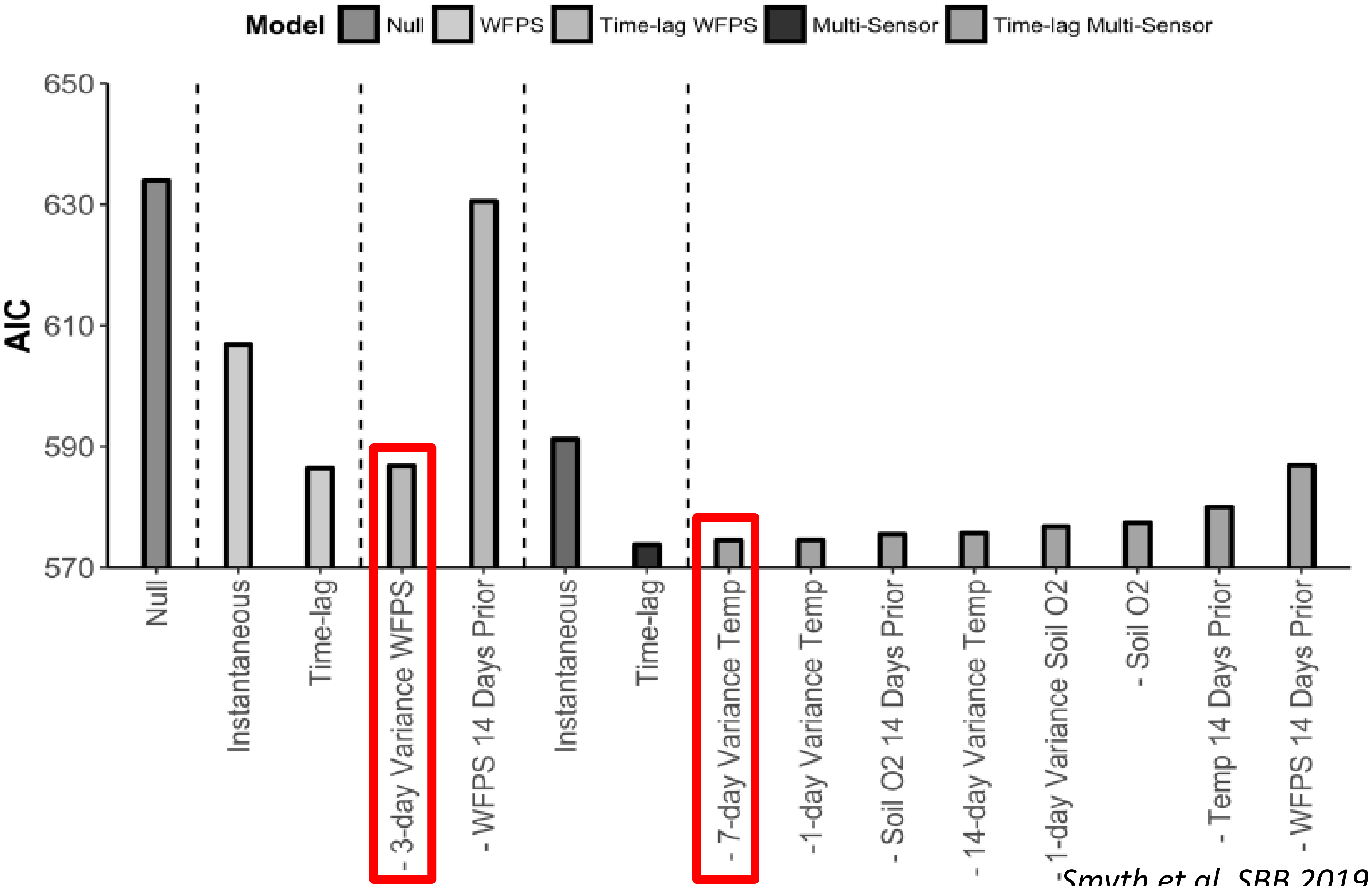
Smyth et al. SBB 2019

O_2 sensor best for CH_4 flux



Smyth et al. SBB 2019

O_2 sensor not best for N_2O flux



Smyth et al. SBB 2019

In-situ soil O_2 monitoring

- Monitoring reveals surprising dynamics not predicted in common BGC models (e.g., DNDC and DAMM)
- Repeatable patterns are related to duration of soil saturation, soil temperature, and soil drainage
- Big Gulps = Big Burbs?
  - General indicator of soil-atmosphere exchange
- Plan for sensor drift

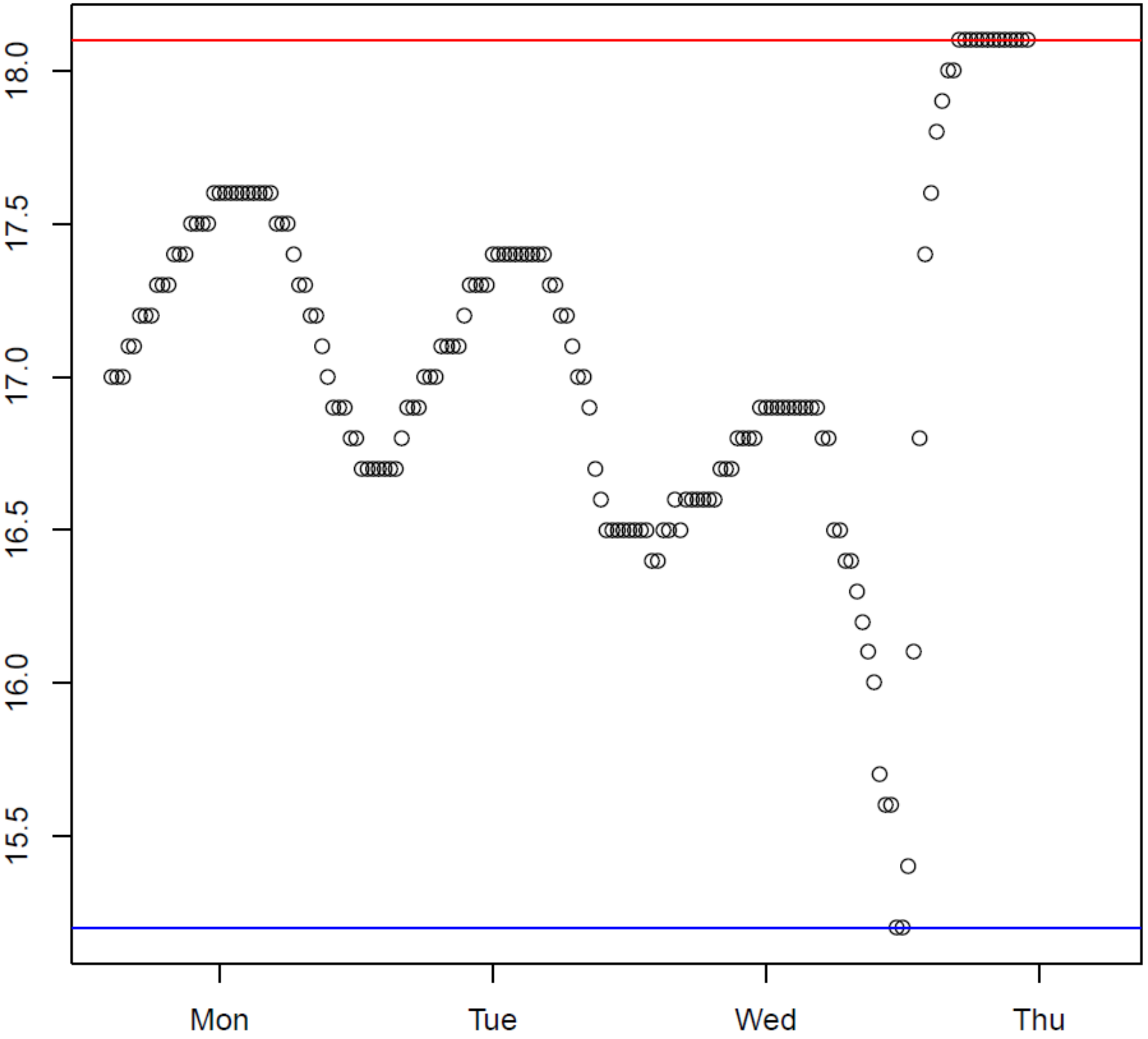
Acknowledgements

- Field and Lab Assistance
  - Emma Overstreet, Craig Adams, Astrea Taylor, Joanna Taylor, Dave Moscicki, Matt Konkler, Mike Enright
- Funding
  - USDA/NASA-C cycling
  - NSF DEB-Ecosystems
  - Five Rivers Metro Parks – Dayton, OH

Soil O2 data - Filtering

- Sensor or Calibration Drift
  - Compare expected to observed
  - Drift correction
- Electrical Noise
  - Insure not related environment
  - Replace as missing

Final Drift Correction



Remove sensor from soil and place in calibration condition

Allow stabilization

Subtract final stable from 20.9%

Apply drift correction

Your abstract submission has been received

Print this page

You have submitted the following abstract to Joint 53rd South-Central/53rd North-Central/71st Rocky Mtn Section Meeting - 2019. Receipt of this notice does not guarantee that your submission was complete or free of errors.

NEAR SURFACE SOIL OXYGEN DYNAMICS: PATTERNS FROM SIX YEARS OF HIGH FREQUENCY MONITORING

LOECKE, Terry D., Kansas Biological Survey & Environmental Studies Program, University of Kansas, 2101 Constant Ave, Lawrence, KS 66047, FRANZ, Trenton, School of Natural Resources, University of Nebraska, 3310 Holdrege St, Lincoln, NE 68583 and BURGIN, Amy J., Kansas Biological Survey & Environmental Studies Program, University of Kansas, 2101 Constant Ave., Lawrence, KS 66047

Soil oxygen (O_2) is a fundamental control on terrestrial biogeochemical cycles including processes producing and consuming greenhouse gases (GHG), yet it is rarely measured. Instead, soil O_2 is assumed to be proportional to soil moisture and physical soil properties. For example, soil O_2 is often inferred from a 25-year old steady-state diffusion model; however, few data exist to test this model in stochastic systems. The variability of soil O_2 may be particularly important to GHG emissions from aquatic-terrestrial interface zones because of the convergence of variable hydrology and rapid biogeochemical processing. Our objective is to gain a better understanding of soil O_2 variation and its role in controlling GHG emissions across aquatic-terrestrial interface zones. Specifically, we hypothesize that in aquatic-terrestrial interface ecosystems, soil moisture predicts O_2 concentration under stable conditions, but under dynamic conditions (e.g., water table fluctuations or precipitation) heterogeneous distributions of water-filled soil pore space complicate this prediction. Furthermore, we hypothesize that GHG emissions will correspond to variation in soil O_2.

Twenty-four near-continuous (30-minute frequency) soil O_2 and moisture sensors were monitored for more than six years. The sensors were installed at 10 cm of depth across an aquatic-terrestrial interface of a constructed wetland in April 2012 and removed in July 2018. Diurnal, precipitation and drainage events, seasonal, and longer-term patterns were in soil O_2 observed. Drought conditions (2012) resulted in minimal soil O_2 variation; however, a diurnal pattern of lower soil O_2 during the day was observed. When precipitation increases within and among sensor soil O_2 variation increases. The relationship between soil moisture and soil O_2 was non-linear during periods of soil drainage and precipitation. Commonly, a rapid (change of 10% over <24 hours) increase in soil O_2 occurred during soil drainage near a common threshold. As soil moisture increased due to precipitation, soil O_2 decreased slower than predicted by simple diffusion models. Soil O_2 was an important predictor of weekly methane and nitrous oxide emissions correspond to variation in soil O_2. These soil O_2 data will be useful for understanding multiple soil biogeochemical functions.

Abstract ID#:
327343

Password:
612217

Meeting:
Joint 53rd South-Central/53rd North-Central/71st Rocky Mtn Section Meeting - 2019

Session Type:
Theme Sessions

Primary Selection:
T16. Microbiomes in the Geosphere

Final Session Number:

Abstract Title:
NEAR SURFACE SOIL OXYGEN DYNAMICS: PATTERNS FROM SIX YEARS OF HIGH FREQUENCY MONITORING

Preferred Presentation Format:
Oral

Discipline Categories:
Soils

Abstract Submission Fee:
Paid (gsa-2019SC-0763-0122-7718-1164)

Presenting Author

Terry D. Loecke
Email: loeckete@ku.edu
Alternate Email: loeckete@gmail.com

University of Kansas
Kansas Biological Survey & Environmental Studies Program
2101 Constant Ave
Lawrence KS 66047
USA

Student? N

Trenton Franz
Email: trenton.franz@unl.edu

University of Nebraska
School of Natural Resources
3310 Holdrege St
Lincoln NE 68583
USA

Student? N

Amy J. Burgin
Email: burginam@ku.edu

University of Kansas
Kansas Biological Survey & Environmental Studies Program
2101 Constant Ave.
Lawrence KS 66047
USA

Student? N

If necessary, you can make changes to your abstract submission until Tuesday, 4 December 2018.

- To access your submission in the future, use the direct link to your abstract submission from one of the automatic confirmation emails that were sent to you during the submission.
- *Or* point your browser to /gsa/reminder.cgi to have that URL mailed to you again. Your username/password are 327343/612217.

Any changes that you make will be reflected instantly in what is seen by the reviewers. You DO NOT need to go through all of the submission steps in order to change one thing. If you want to change the title, for example, just click "Title" in the abstract control panel and submit the new title.

When you have completed your submission, you may close this browser window.

Tell us what you think of the abstract submission process

Home Page