Soil Biogeochemical Response to Drought Conditions in the Biosphere 2 Rainforest

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BIOSPHERE 2 | WATER ATMOSPHERE AND LIFE DYNAMICS

WALD

THE UNIVERSITY OF ARIZONA

The Problem

- Much biogeochemical knowledge is gained from understanding interstitial trace gases in soil
  - N_2O, NO, NH_2OH, NH_3… for N-cycling
  - CO_2, CH_4, HCHO, CH_3OH, CO… for C-cycling
  - Isoprene, monoterpenes, sesquiterpenes, acetone… for metabolites, communications, warfare

- Above-ground flux measurement are an excellent tool for understanding the interface between subsurface and atmosphere

- For understanding subsurface processes – measure right at the source
  - Subsurface probes that leverage atmospheric tools in the subsurface provide deep insights nutrient cycling and other bioprocesses

Biosphere 2 Water Atmosphere and Life Dynamics (WALD)

September 2019 – January 2020 Campaign

Field Site: Biosphere 2 Tropical Rainforest in Arizona, USA

Campaign Aims

- To fully track, from molecules to the ecosystem, mechanisms driving the fate of carbon and water in forest systems under drought
- Investigate the mechanisms that drive plant-soil-microbe relationships

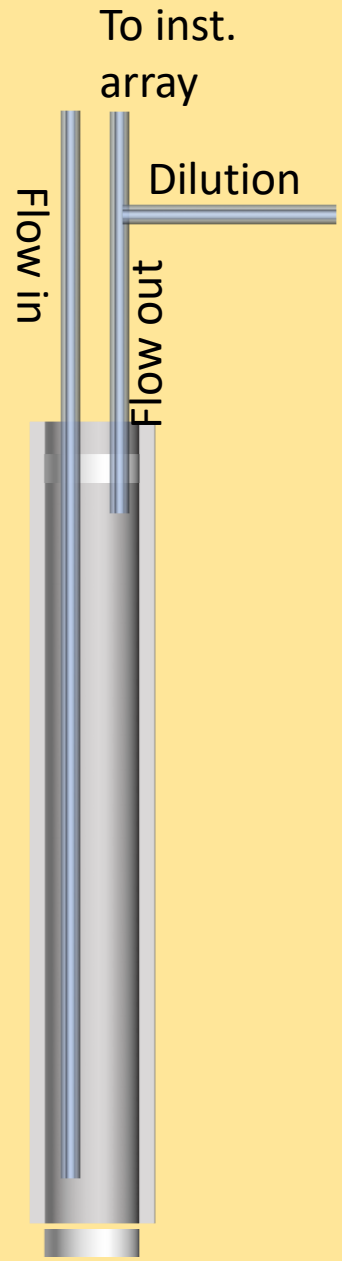
Main Question: What is the impact of drought and rewetting on a Tropical Rainforest?

Aerodyne/University of Arizona Goals

- Deployment of novel soil probes for semi-continuous, real-time measurement of subsurface dynamics
- Address the question: What is the Soil Biogeochemical Response to Drought and Rewetting in Tropical Rainforest?
  - Focus on the impact on nitrogen cycle dynamics of drought and rewetting
  - 2-month drought followed by rewetting
- Observation of Birch effect in field measurement

Diffusive Gas Probes to Explore Subsurface Processes

- Buried hydrophobic porous probes
  - Examine subsurface dynamics by carrying subsurface gas to instruments
- Small, low profile
  - ***Spatially*** and ***temporally***-resolved dynamics with high signal-to-noise



Probe after several months in soil

New version of soil probe -- single ended design

T. H. M. Volkmann and M. Weiler, Hydrol. Earth Syst. Sci., 18, 1819–1833, 2014

Biosphere 2/WALD Campaign
September 2019 – February 2020

12 probes deployed in 2 experiments during Biosphere 2/WALD campaign

A. Rhizosphere vs. Outside Root Zone (control)

3 probes in Palm Rhizosphere

3 probes in Palm Control (non-rhizosphere)

B. Effect of Soil Depth on Soil Dynamics

5 probes at different depths in soil pit

20, 50, 100, 200 and 300 cm depth

1 probe measuring ambient air

Measurement Details

Dual-laser Tunable Infrared Laser Direct Absorption Spectrometers (TILDAS)

N_2O and isotopes

- $^{14}N^{14}N^{16}O$ (446)
- $^{14}N^{15}N^{16}O$ (456, “alpha”)
- $^{15}N^{14}N^{16}O$ (546, “beta”)
- $^{14}N^{14}N^{18}O$ (448)

CH_4, $^{13}CH_4$

CO_2

Real time monitoring of δ456 and δ546

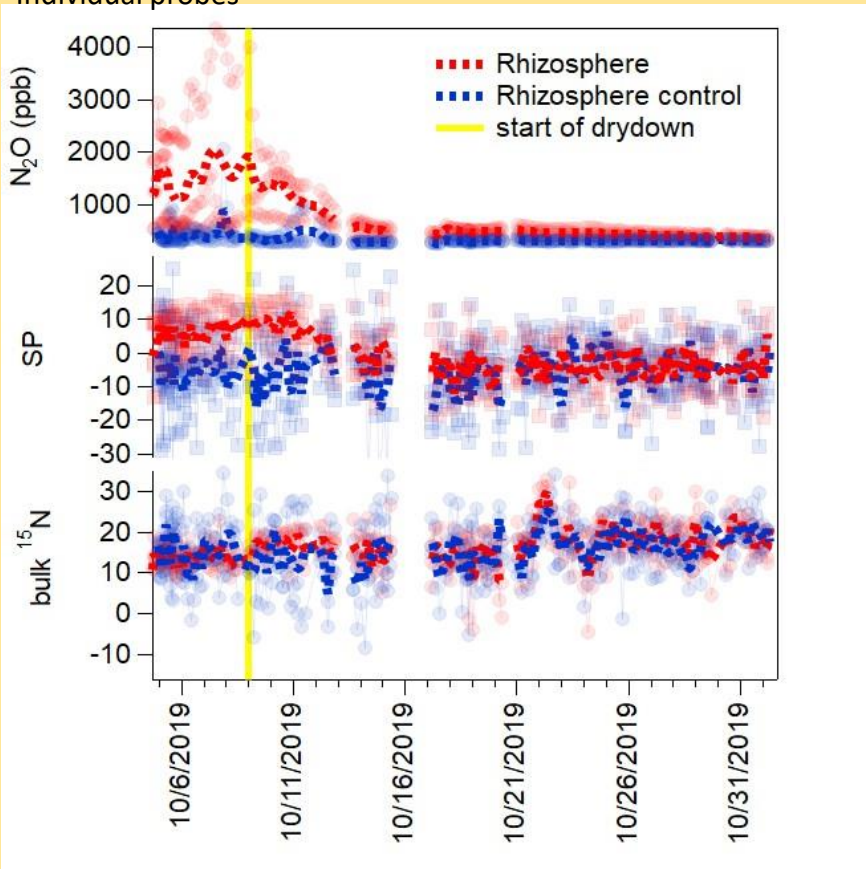
to yield δ^{15}N-bulk and SP= (δ456- δ546)

Timing: Measurement every 4 hours at each probe

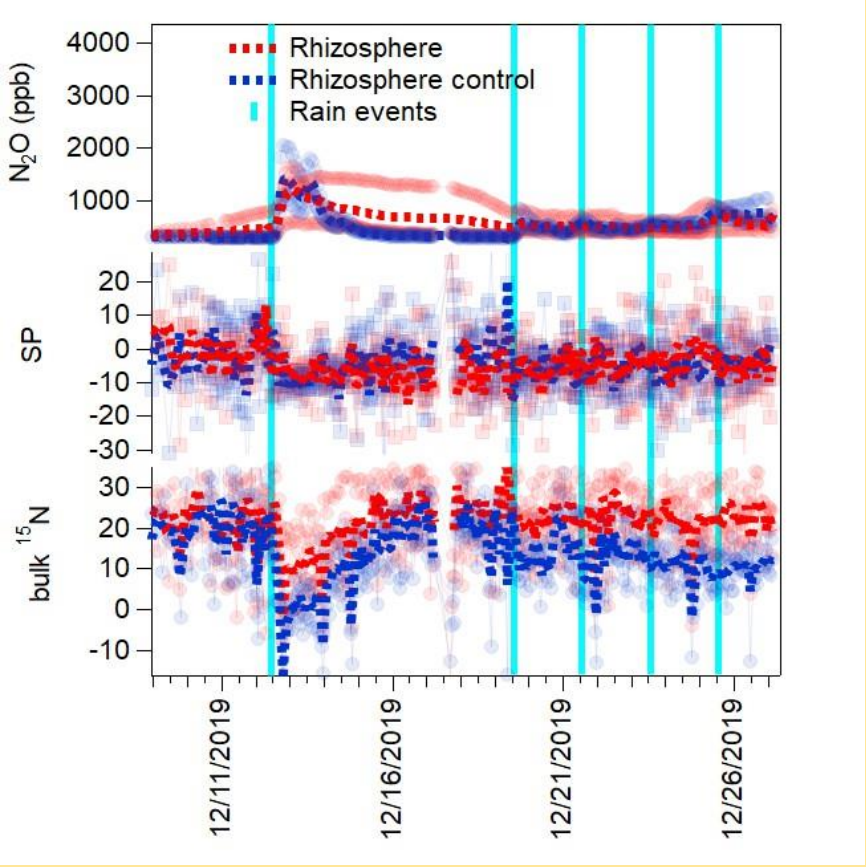
Developed a plug flow measurement scheme to sample from each probe with minimal impact on surrounding soil.

Response of Palm Rhizosphere vs. Palm Control to Dry down and Rewetting

Rhizosphere = avg of rhizo. probes
Control = avg of control probes
Faded markers: Individual probes

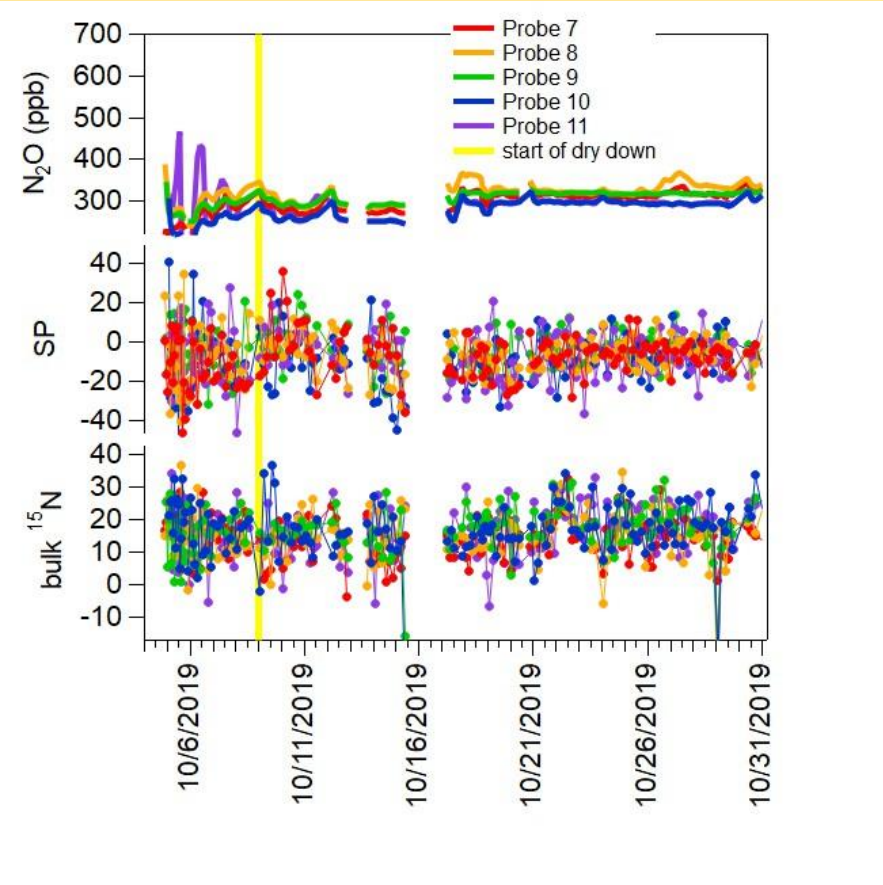


Drop in N_2O in soil during dry down with shift in Rhizosphere SP



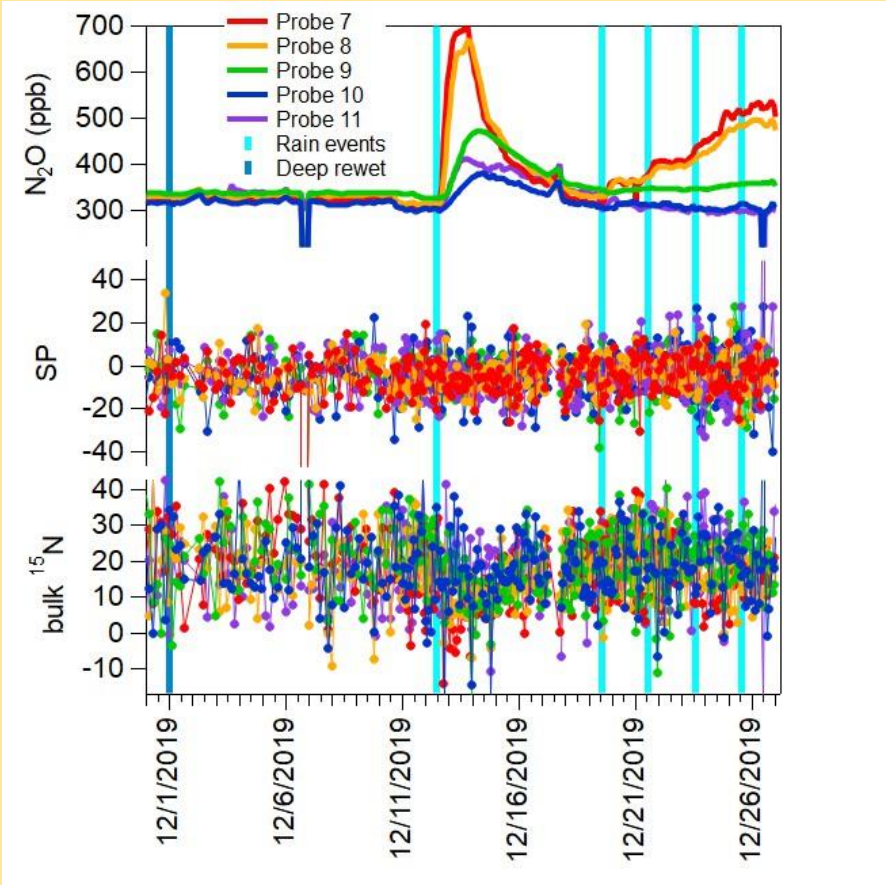
- Birch effect after rain, and increase in rhizosphere N_2O
- δ^{15}N-bulk: after rain, Control returns to pre-drought level while Rhizosphere remains higher
- 1 Rhizosphere probe had larger, sustained N_2O incr.

Response of Soil at Different Depths to Dry down and Rewetting



Measurement Depths

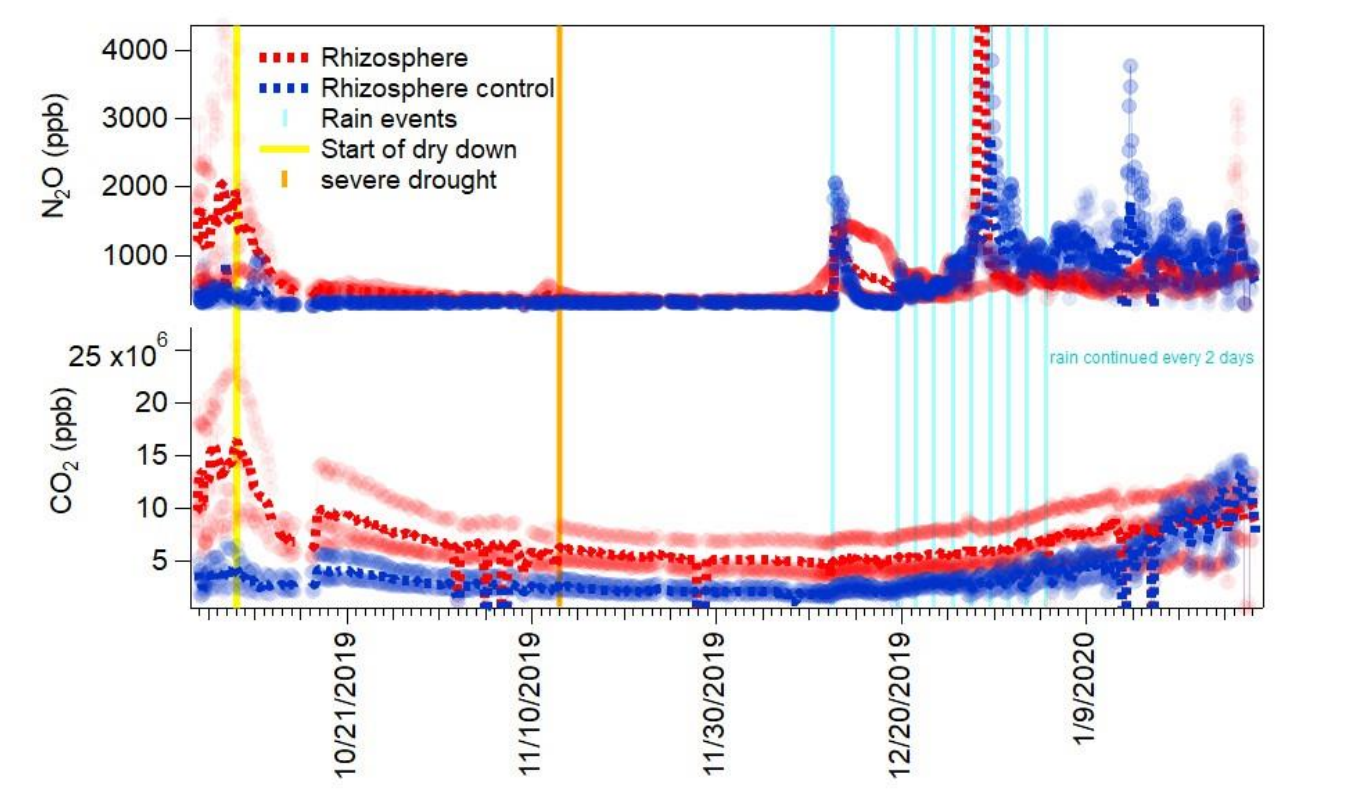
Probe 7	20 cm
Probe 8	50 cm
Probe 9	100 cm
Probe 10	200 cm
Probe 11	300 cm



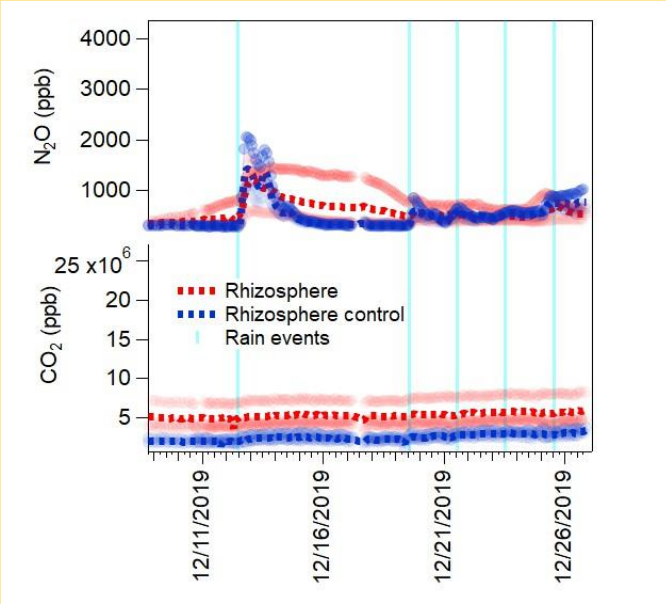
N_2O at all depths approached ambient N_2O with dry down.
SP and $\delta^{15}N$ same at all depths

Deep rewet-- bottom probes respond slightly while others do not
SP and $\delta^{15}N$ same at all depths
$\delta^{15}N$ had small decrease with initial rain and then recovery

Soil Respiration
Response to Drought and Rewet



Start of Rewetting



- CO_2 decreased with dry down. It very slowly increased after rain.
- Respiration is slow to recover from system drought with the control region presenting a faster increase in CO_2.
- Possible negative rhizosphere priming in rhizosphere region

Summary

- Subsurface probes provided continuous measurement of soil dynamics for the entire drought and rewetting periods (5 months)
- Rhizosphere vs. control
  - Birch effect with the return of rain
  - $\delta^{15}N$ of control returned to pre-drought level, but rhizosphere remained elevated
  - Observed a slow recovery of soil respiration especially in rhizosphere area– possible negative rhizosphere priming
- Soil depth response
  - Little difference in N_2O isotopic signatures across depths
  - Timing of Birch effect response as function of depth was observed
  - Probes closer to surface with greatest increase in N_2O after rain

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