Soil Biogeochemical Response to Drought Conditions in the Biosphere 2 Rainforest

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The Problem

• Much biogeochemical knowledge is gained from understanding interstitial trace gases in soil
  • $\text{N}_2\text{O}$, NO, $\text{NH}_2\text{OH}$, $\text{NH}_3$... for N-cycling
  • $\text{CO}_2$, $\text{CH}_4$, HCHO, $\text{CH}_3\text{OH}$, 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
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](image1)

New version of soil probe -- single ended design

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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)

- \( \text{N}_2\text{O} \) and isotopes
  - \( ^{14}\text{N}^{14}\text{N}^{16}\text{O} \) (446)
  - \( ^{14}\text{N}^{15}\text{N}^{16}\text{O} \) (456, “alpha”)
  - \( ^{15}\text{N}^{14}\text{N}^{16}\text{O} \) (546, “beta”)
  - \( ^{14}\text{N}^{14}\text{N}^{18}\text{O} \) (448)
- \( \text{CH}_4, \text{^{13}CH}_4, \text{CO}_2 \)

Real time monitoring of δ456 and δ546
to yield δ\(^{15}\text{N}\)-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 $\text{N}_2\text{O}$ in soil during dry down with shift in Rhizosphere SP

- Birch effect after rain, and increase in rhizosphere $\text{N}_2\text{O}$
- δ$^{15}$N-bulk: after rain, Control returns to pre-drought level while Rhizosphere remains higher
- 1 Rhizosphere probe had larger, sustained $\text{N}_2\text{O}$ incr.
Response of Soil at Different Depths to Dry down and Rewetting

N₂O at all depths approached ambient N₂O with dry down.
SP and δ¹⁵N same at all depths

Deep rewet-- bottom probes respond slightly while others do not
SP and δ¹⁵N same at all depths
δ¹⁵N had small decrease with initial rain and then recovery
Soil Respiration Response to Drought and Rewet

- CO₂ 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 CO₂.
- 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
  • $\delta^{15}\text{N}$ 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$_2$O isotopic signatures across depths
  • Timing of Birch effect response as function of depth was observed
  • Probes closer to surface with greatest increase in N$_2$O after rain
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