Process Based Belowground Carbon Dioxide Modeling in a Desert Ecosystem

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Introduction

• Belongdown CO2 concentrations were measured every 15 minutes at a desert grassland site at the southern edge of Canyonlands National Park in Utah using Vaisala GMT220 series solid-state NDIR sensors (Helsinki, Finland).
• Measurements were collected at 5 and 15 cm depth within the rooting zones of two dominant grass species, Stipa hymenoides and Hilaria jamesii, as well as the interspaces between the two.
• Rain events cause belowground carbon dioxide levels at all measurement sites to rise from 500 ppm to 1500 ppm with a response time of 8 hours to a gradual return to quasi-steady state levels in subsequent days.
• We developed and simulated a one-dimensional diffusion model with a production term to determine if the rise in CO2 concentrations following a rain event was due to physical or biological processes.
• The model was simulated from April-November 2003.

Mathematical Formulation

CO2 is transported through the soil according to the classical diffusion equation with a production term:

\[
\frac{\partial C}{\partial t} = D_e \frac{\partial^2 C}{\partial z^2} + S(z,t)
\]

- \( D_e \) is effective diffusion coefficient
- \( S(z,t) \) is CO2 production due to microbial respiration, rooting density, and soil respiration
- We numerically calculated CO2 using finite differences with volumetric soil water content, bulk density, and soil temperature as inputs.

References


Simulation with a Process Based Source

• Incorporating a process-based biological term helps reduce CO2 levels after rain events. The rain acts as a biological switch to activate soil microbes until the soil dries out.

Simulation with a Constant Source

• During summer rain pulses physical processes dominate in determining belowground CO2 concentrations. As the soil dries following pulses, biological responses dominate more.

Future research includes a better characterization of model inputs (rooting density, soil microbial activity, and soil respiration).

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