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Transient and Microfluidic Methane Cycling in the Wetland Rhizosphere

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Wetlands form a massive reservoir of terrestrial carbon (C) on Earth and emit substantial amounts of methane (CH_4) that influence climate change. At a landscape scale, highly variable emissions are often observed. However, there is a limited mechanistic understanding of this variability due to the oversimplification of C dynamics in the wetland rhizosphere. The CH_4 emissions are likely regulated by overlapping tidal and diurnal redox oscillations within microfluidic channels of the wetland rhizosphere. We are exploring this relationship in the mid-Atlantic wetlands of the Smithsonian Environmental Research Center, Maryland, USA. Here, both tidal and diurnal transitions drive transient gas production and exchange processes in the rhizosphere. Meanwhile, microfluidic properties of the soil are controlled by the root and rhizome networks of different vegetation. To gain new insights into global CH_4 emissions, further examination of the transient and microfluidic dynamics of soil C requires multifaceted approaches that include chemical imaging, microfluidic analogs of the rhizosphere, meta-omics, and high-resolution mass spectrometry. Our initial omics results from the field suggest that hydrogenotrophic methanogenesis is favored in the rhizosphere due to interacting tidal and plant-mediated redox oscillations. The CH_4 produced during this process can be converted to CO_2, potentially fueling C fixation at the soil surface by phototrophic bacteria. We are currently validating our field observations through controlled laboratory incubations to determine the balance between CH_4 production, aerobic vs anaerobic oxidation, and C fixation. Transformations in organic C, including exact mass and nominal oxidation state, are being studied with Fourier transform ion cyclotron resonance mass spectrometry (FTICR-MS). We are further investigating these processes with 2D chemical imaging using optode sensors, including the design and testing of microfluidic rhizosphere analogs. Our emerging conceptual framework is that transient and microfluidic dynamics in the wetland rhizosphere drive large-scale variability in wetland CH_4 emissions.