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Soil biogeochemistry under variable moisture content and the role of anaerobic processes

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Soil carbon dioxide (CO_2) and methane (CH_4) emissions are a major climate forcing. A predictive understanding of these emissions must consider the role of soil moisture in the production and transport of these gases. In incubation experiments, CO_2 production usually reaches a maximum at intermediate soil moisture, with lower values at both lower and higher soil moisture contents. The standard explanation for this relationship is that aerobic CO_2 production becomes moisture limited at low soil moisture and oxygen (O_2) limited at high soil moisture. However, such an explanation does not consider the role of anaerobic processes, thereby ignoring a potential source of CO_2 (and CH_4). Moreover, few experimental studies separate the effects of soil moisture and O_2 availability on the fluxes of CO_2 and CH_4. To decouple the effects of soil moisture and O_2, we conducted a factorial batch experiment by incubating soil at different moisture contents (from 30 to 100% water-filled pore space; WFPS) under oxic versus anoxic conditions. The results show that, as expected, CO_2 fluxes are maximal at moderate moisture content (65% WFPS) in the oxic incubations. Contrary to previous models, a substantial flux of CO_2 is also observed at 100% WFPS, as high as 60% of the maximum value at 65% WFPS. Fermentation and methanogenesis are the most likely anaerobic pathways for the CO_2 production, as indicated by the CH_4 fluxes, the production of low molecular weight organic acids, and the depletion of terminal electron acceptors. We further propose simple rate expressions for incorporating anaerobic CO_2 and CH_4 production in existing soil biogeochemistry models. Time permitting, this presentation will also cover experimental and numerical modeling results for soil columns under imposed water table fluctuations, with the emphasis placed on representing the effects of the dynamic moisture regime on the production, exchanges, and transport rates of CO_2 and CH_4.