Is Q_{10} an intrinsic parameter of biogeochemical processes?

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Temperature is one of the key parameters controlling the occurrence and significance of individual microbial reactions and complex biogeochemical processes. Temperature sensitivities of microbial processes are commonly quantified as Q_{10}, the rate change over a temperature interval of 10 °C [1]. But the applications of Q_{10} remain questionable. For example, global carbon models often fix Q_{10} at 1.5 or 2, but the values determined by laboratory experiments can be as large as 20 [1].

Here we apply biogeochemical modeling to analyze the temperature sensitivity of organic matter degradation to CH_4 and CO_2 and its dependence on pH, microbial interactions, and other biogeochemical factors. We first simulate the thermodynamic responses of individual microbial redox reactions to temperature variations from 0 to 100 °C. These reactions include syntrophic oxidation of organic carbon, respiration of ferric minerals and sulfate, methanogenesis, and anoxic methane oxidation. The thermodynamics of different reactions respond differently to temperature variations, which constrains the Q_{10} values of individual microbial metabolisms. We also simulate the kinetics of syntrophic butyrate oxidation and hydrogenotrophc and acetoclastic methanogenesis at temperatures ranging from 5 to 50 °C. The modeling-derived Q_{10} values vary from 1.2 to 14, within the ranges obtained by previous laboratory and field experiments[2,3].

The results show that the Q_{10} values tend to be larger at lower temperatures, and can be accounted for by the concurrent responses of reaction thermodynamics and biomass concentrations. In addition, the Q_{10} values are also shaped by biogeochemical conditions, including pH, substrate concentrations, and microbial interactions. These results suggest that Q_{10} might not always capture the complexity of temperature sensitivity of biogeochemical processes, and its application deserves additional considerations of how different environmental factors work together in determining the kinetics of biogeochemical processes.

References:
[1] Hamdi, S., et al., 2013. Soil Biology and Biochemistry, 58, pp.115-126.
[2] Bracho, R., et al., 2016. Soil Biology and Biochemistry, 97, pp.1-14.
[3] Gutiérrez-Girón, A., et al., 2015. Geoderma, 237, pp.1-8.