New Synthetic Biology Tools to Scale up Microbial Processes in Soils and Sediments

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Newly-developed synthetic biology tools allow microbes to report on their behavior or their environmental conditions by releasing low-reactivity gases. These gas-reporting biosensors open up new possibilities in Earth system science research because they have the potential to provide ecologically scalable information about specific metabolic pathways. In this presentation we will provide a general introduction to the use of synthetic biology in Earth system science, a description of gas-reporting biosensors, and finally discuss the specific research steps needed to realize the scaling potential of gas reporters.

Microbes can be programmed through synthetic biology to report on their behavior, informing researchers when their environment has triggered changes in their gene expression (e.g. in response to shifts in O_2 or H_2O), or when they have participated in a specific step of an elemental cycle (e.g. when they have expressed enzymes that underlie steps of the N cycle). This use of synthetic biology has the potential to significantly improve our understanding of microbes' roles in elemental and water cycling because it allows

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reporting on the environment from the perspective of a microbe, matching the measurement scale exactly to the scale that a microbe experiences. However, microbes have historically been coded to report by expressing fluorescent or luminescent proteins (e.g. green fluorescent protein). Because it is hard to detect these optical reporters in marine sediments or soils, the use of programmed microbes (biosensors) has been limited in the Earth system sciences.

The development of gas-reporting biosensors allows real-time, noninvasive monitoring of microbial processes in sediments and soils. Gas-reporting biosensors also provide information that is easily scaled up: for example, gas reporters make it possible to know dynamically what fraction of the microbial population is expressing specific genetic pathways, and how this fraction changes with changes in incubation conditions.

We will provide an overview of the potential uses of gas-reporting biosensors in soil and sediment lab experiments, and will report the development of the systematics of these sensors. Successful development of gas biosensors for laboratory use will require addressing issues including: engineering the intensity and selectivity of microbial gas production to maximize the signal to noise ratio; normalizing the gas reporter signal to cell population size, managing gas diffusion effects on signal shape; and developing multiple gases that can be used in parallel.