ABSTRACT: Increases in atmospheric carbon dioxide concentrations ($c_a$) will lead to changes in the climate that alters mean air temperature ($T_a$) and precipitation ($P$) patterns. The ability of terrestrial ecosystems to absorb $c_a$ is sensitive to these climatic conditions, as well as to $T_a$, thereby creating a feedback that has the potential to accelerate warming. To describe this feedback, the primary pathways by which elevated $c_a$, $T_a$, and changing $P$ patterns simultaneously impact ecosystem photosynthesis and respiration must be quantified. This work will produce a synthesis that capitalizes on the strengths of different models and incorporates the important feedbacks of the soil-plant-atmosphere system at pertinent spatial and time scales.

Our initial work (year 1) on using an optimization modeling approach to capture leaf-level stomatal responses to elevated $c_a$, changes in $T_a$, vapor pressure deficit and leaf water potential was presented using a meta-analysis on published data sets spanning many climatic conditions and species types.

Our current work (year 2) is focused on bridging the leaf-level processes completed and presented in year 1 to the soil-root system, thereby providing a mathematically usable form for coarse-scale models. Manuscripts dealing with (i) soil and plant hydraulics constraining ecosystem productivity, (ii) physical limits to water transport and carbon uptake, (iii) the interplay between more negative xylem water potentials providing a larger driving force for water transport but also causing cavitation that limits hydraulic conductivity, (iv) modeling interfacial fluxes between the roots and the soil have all been published within the context of optimality formulations or hypotheses.

Over the course of the coming year, the other components of this project will be considered, including modeling of autotrophic and heterotrophic respiratory processes. Autotrophic processes reflect changes in biomass pools determined using standard biomass budget equations, which are being modified to include carbon allocation rules derived from resource optimization theories that explicitly consider soil and foliage nutrition. For heterotrophic processes, three interacting soil carbon pools must be considered at minimum: litter, more stabilized SOM, and microbial biomass. Rates of decomposition, nitrogen mineralization, nitrification, and de-nitrification are being modeled together with soil moisture and temperature. Our final goal is to use a novel dimension reduction approach to simplify the multi-dimensional phase-space of this detailed model to a system of a few ordinary differential equations and prepare this simplified model for incorporation into existing climate-carbon models.