The Big Burns Project: causes and consequences of fire-regime variability in Rocky Mountain subalpine forests

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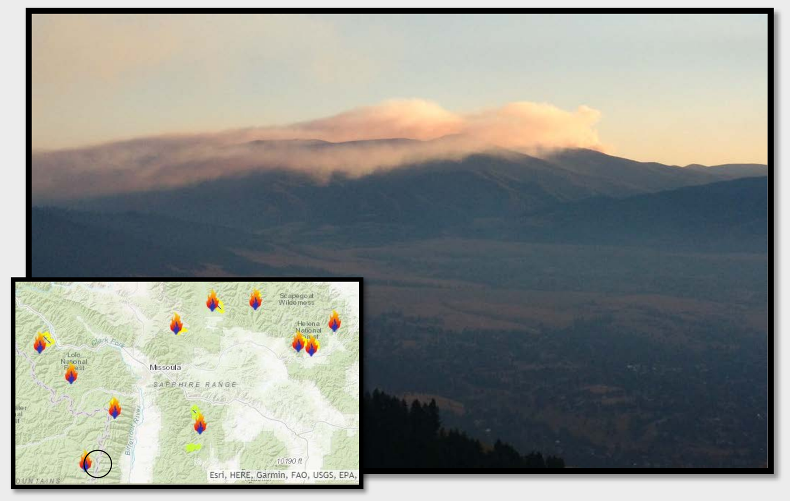
1. Background and Motivation

Recent increases in fire activity highlight major uncertainties about how disturbances will interact with ongoing climate change. In the western U.S., shifting disturbance regimes are predicted to lead to long-lasting directional changes or shifts in biogeochemical states, influencing carbon and nitrogen balance over large spatial and temporal scales. While these ideas have a strong conceptual basis and empirical support on decadal timescales, data have been lacking to test them over longer timescales - and to consider their implications for future projections - until only recently. Here we present preliminary finding from the Big Burns Project, which is investigating coupled climate-fire-ecosystem dynamics over the past several millennia across some of the most fire-prone regions in the Rocky Mountains.



Smoke plume from the Lolo Peak Fire, one of many wildfires around Missoula, MT, as of 2 August, 2017.

2. Conceptual Framework, Research Questions

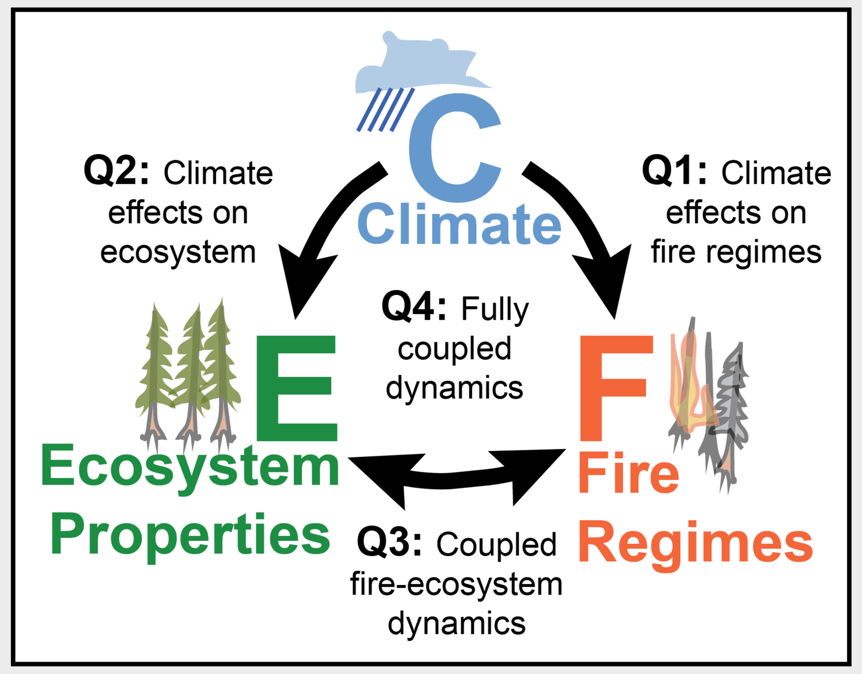
To quantify the coupled climate-fire-ecosystem dynamics that constrain C and nutrient cycling, we are reconstructing and simulating ecosystem dynamics over multiple scales to address four questions:

1. How have the frequency, severity, and spatial synchrony of fire activity in subalpine forests varied over the past 2500 years, and how do these relate to past periods of climate change?

2. How has the composition and productivity of subalpine forests varied over the past 2500 years, and how does this relate to past climate change?

3. How do fire-ecosystem feedbacks affect both fire regimes and other ecosystem properties (e.g., forest composition) and function (e.g., C and nutrient cycling)?

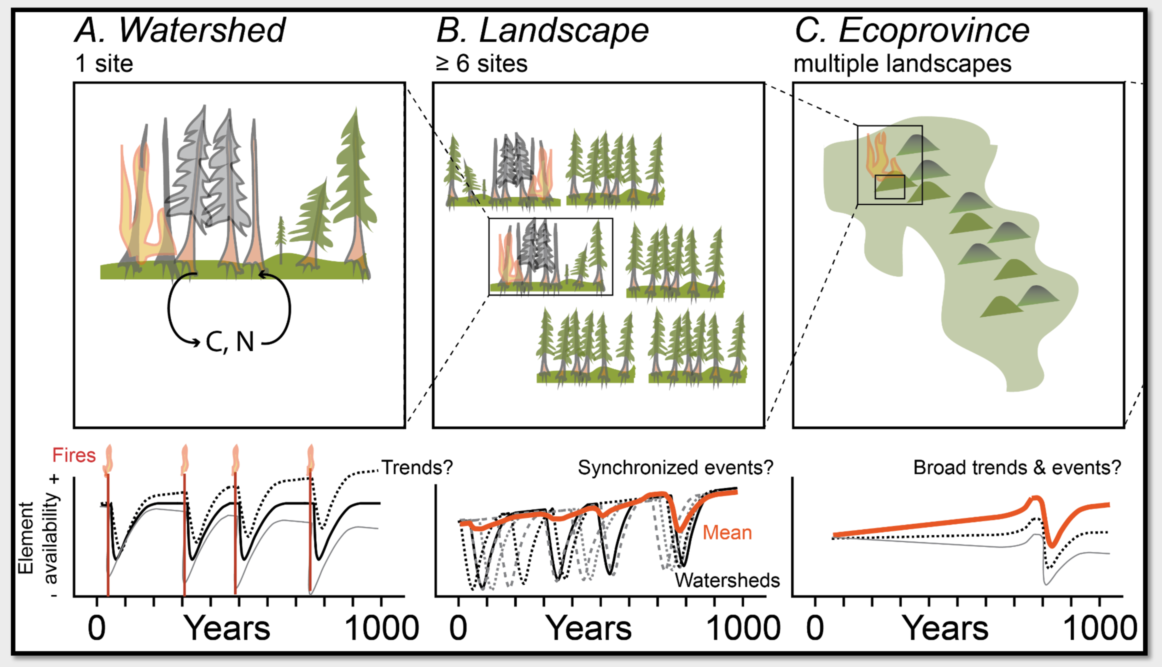
4. How do coupled climate-fire-ecosystem dynamics vary across spatial scales?



Simplified conceptual model of coupled climate-fire-ecosystem dynamics. The project is framed around four questions that evaluate the causes and ecosystem consequences of variability in fire activity, explicitly addressing the coupled dynamics through the development of paleoecological records and the use of ecosystem modeling.

3. Hypotheses

Hypothetical scenarios for spatial (top row) and temporal (bottom row) scaling of coupled climate-fire-ecosystem dynamics. At watershed scales, biogeochemical impacts of wildfire depend upon the fire event and rate of post-fire recovery; alternative trajectories could emerge over decades to centuries, due to variability in the timing and severity of fires relative to the rate of recovery [8]. At landscape scales, patterns will depend upon the degree of synchrony in disturbance and recovery: trajectories at individual sites could cancel out with high stochasticity, or alternatively, synchronous changes across sites could result in similar trends at landscape scales.

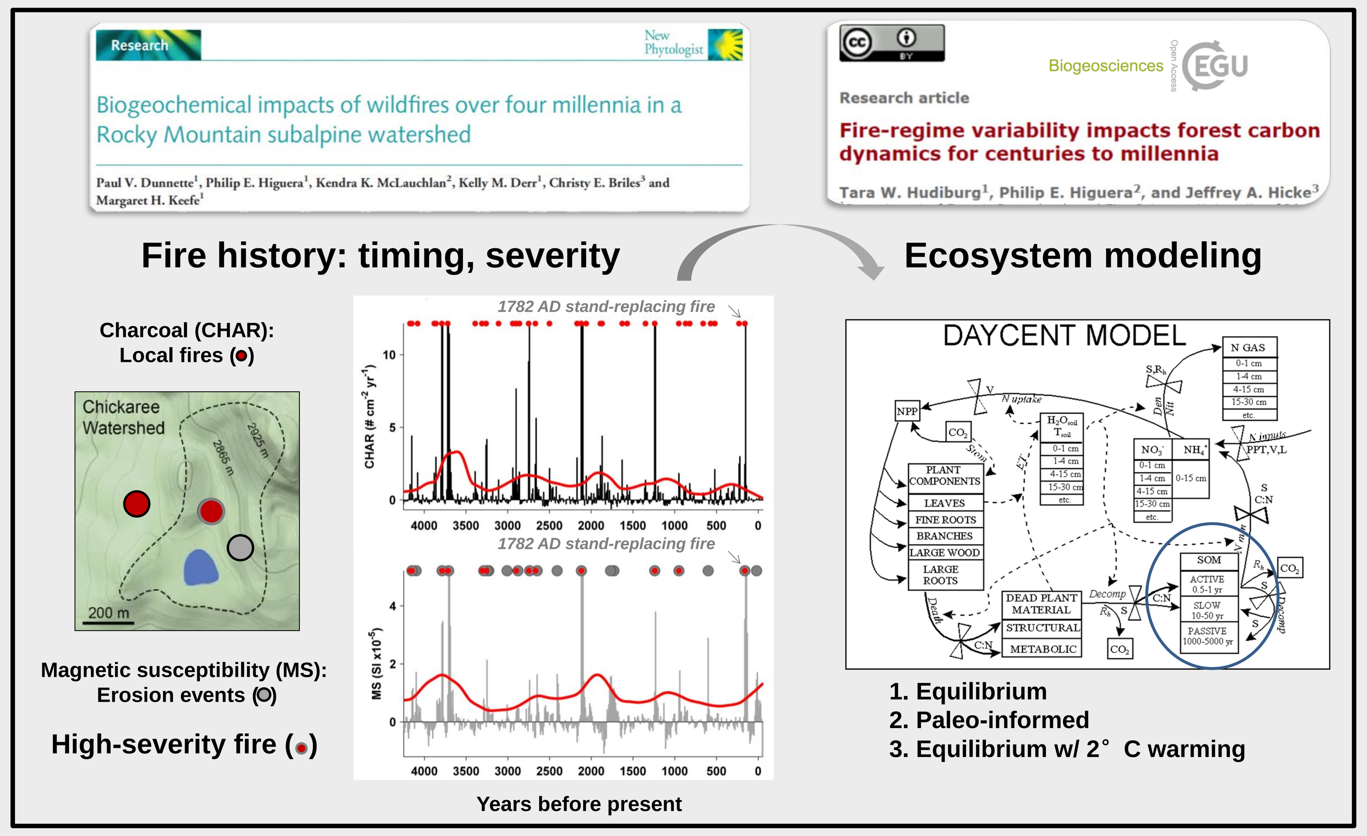


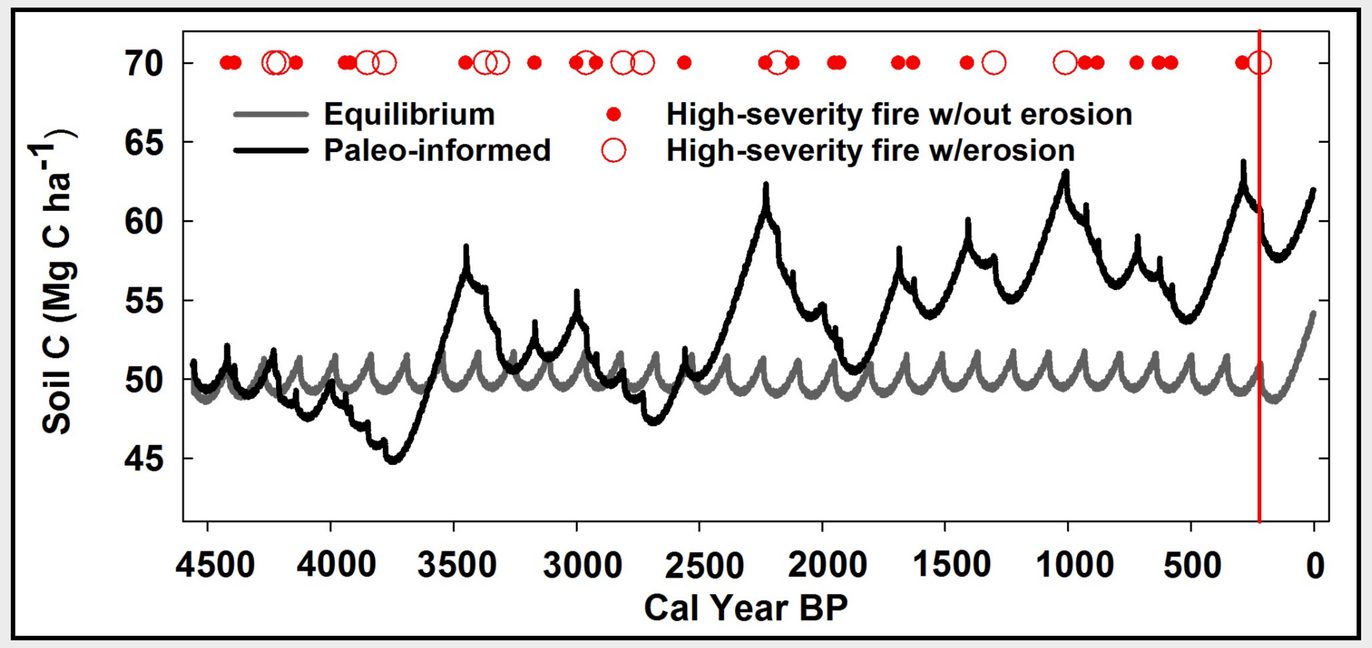
4. Biogeochemical impacts of fire-regime variability

The consequences of repeated fires or temporal variability in a fire regime (e.g., the characteristic timing or severity of fire) are largely unknown, yet theory suggests that such variability could strongly influence forest C trajectories (i.e., future states or dynamics) for millennia. In a proof-of-concept study, we combined a 4500-year paleoecological record of fire activity [3] with ecosystem modeling to investigate how fire-regime variability impacts soil C and net ecosystem C balance [5].

We found that C trajectories in a paleo-informed scenario differed significantly from an equilibrium scenario (with a constant fire return interval), largely due to variability in the timing and severity of past fires. Paleo-informed scenarios contained multi-century periods of + and - net ecosystem C balance, with magnitudes significantly larger than observed under the equilibrium scenario. This variability created legacies in soil C trajectories that lasted for millennia, and was of a greater magnitude than simulated under an equilibrium, climate-warming scenario (i.e., 2°C growing season warming).

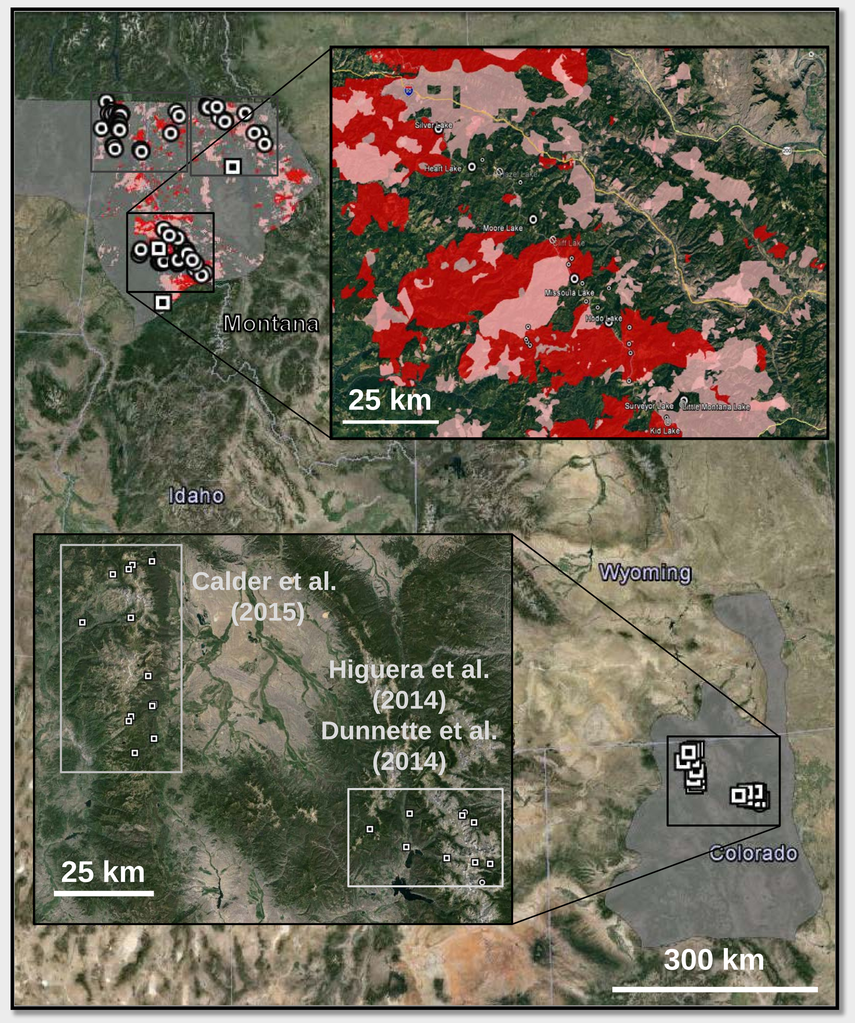
Our results imply that fire-regime variability is a major driver of C trajectories in stand-replacing fire regimes. Predicting carbon balance in these systems, therefore, will depend strongly on the ability of ecosystem models to represent a realistic range of fire-regime variability over the past several centuries to millennia.





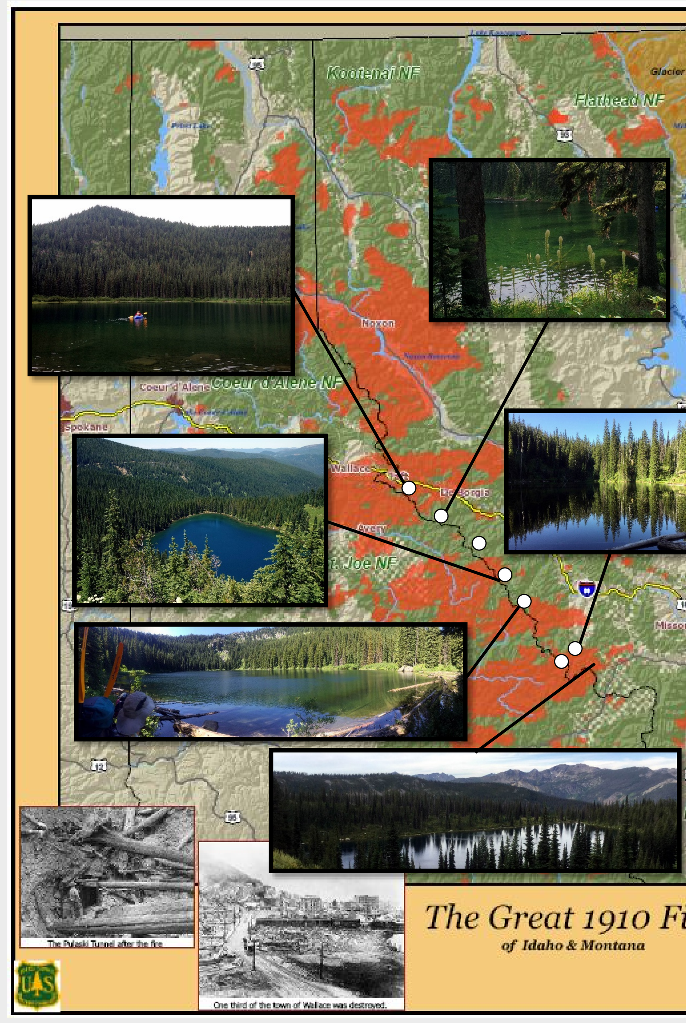
Simulated soil C dynamics under equilibrium and paleo-informed scenarios. Variability in fire timing and severity creates multi-century periods of + and – net C balance. The warming scenario did not differ from the equilibrium scenario.

5. “Big Burns” study regions



Southern Rockies ecoprovince:
Ecosystem modeling will start using existing high-resolution records of fire (n = 21), vegetation (n = 2), and biogeochemical change (n = 2) from two landscapes to study the patterns and drivers of fire regimes [1-4, 7]. We are developing additional biogeochemical proxies in two existing records for a total of four focal sites in the region.

Northern Rockies ecoprovince:
We are developing 12 high-resolution fire-history records, and four high-resolution records of vegetation and biogeochemical change within a ≈ 1000 km^2 landscape centered on the Great Fire of 1910. Site density (0.01 lakes/km^2) should capture enough area to detect changes in fire regimes, if present, as in recent studies highlighting fire-regime change during the Medieval Climate Anomaly [1,6].



References: contact Philip.Higuera@umontana.edu or visit www.cfc.umt.edu/research/paleoecologylab for reprints

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