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Biogeosciences Discussions

Interactive comment on "Fire-regime variability impacts forest carbon dynamics for centuries to millennia" *by* Tara W. Hudiburg et al.

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Response to Rev 2

Also, aside from discussing the biogeochemical elements, it could be interesting to also compare some of the ecological attributes like age distribution of forest stands between the paleoinformed and equilibrium approaches. Clearly the distribution of ages will be quite different, which could have implications if eventually model simulations become a tool for forest management guidelines aiming at sustainability of ecological services.

Response: We agree examining other ecological attributes would be interesting. The reviewer has hit on a frustrating problem in the ecosystem modeling world, especially as it pertains to providing useful tools for management. Unfortunately, DayCent (and most BGC models) do not model age distributions or forest structural changes, as

there are no 'trees' explicitly modeled. To model individual trees, one needs to use forest landscape/succession models, which either lack the biogeochemistry or operate a spatial scales much too large for this project (like LPJ as suggested below). We also believe the soil model in released/validated versions of LPJ is insufficient for this project.

Specific comments Introduction: L87-93 Would this rather illustrate that many models that perform a spin-up period lack a validation of their simulated biochemical cycle?

Response: We disagree. Spin-up is a necessary step given the need to reach steady state. Spin-up does not need to be validated, other than it should reflect realistic 'steady states'. The period after spin-up (what we refer to as equilibrium in this study) is validated against current ecosystem states, given information available. For DayCent, validation of the biogeochemical cycling has been performed in 100s of studies for 1000s of data points, originally published as the CENTURY model (Parton et al. 1983) with many publications in all types of terrestrial ecosystems since then.

Materials and Methods: L165 What exactly is the size of the simulated area? Are fires spatially-explicit? Or just based on random selection of cells? Perhaps a few word on this.

Response: This was a 'point' simulation (size is not explicitly modeled) for a single study site. The simulation represents the watershed (c. 30 hectares) that would be affected in a high-severity fire with erosion. The fire is spatially-explicit to the single point, as there are no other points/grids. We have clarified that this is a point simulation in the text.

L176 So climate and radiation are constant. This may be problematic because in the eventuality that climate was different during the late-Holocene, as compared to the Anthropocene, likely the simulation will be misleading the productivity levels. So I guess this is another argument for doing the +2C and -2C simulation experiments (L217-224). Not using paleoclimatic simulation is an important weakness of this study and I would

recommend that authors put more emphasis on the importance of this temperature sensitivity analysis. However, they should note that temperature is not the only driver of NPP; radiation and precipitation are also important.

Response: As pointed out by Rev. 1, climate impacts are not (and should not be) a main focus of the study. We agree that using paleo and/or future climate scenarios would be very interesting and useful. However, in this paper we are purposefully isolating the potential impacts of fire-regime variability. Our intent is not to replicate the exact dynamics that occurred at Chickaree Lake; rather, we are using DayCent as a tool to test alternative hypotheses and using the fire history of Chickaree Lake as an example of realistic variability in fire activity. In DayCent, we thus prescribe when fire events occur, which automatically decouples the fire events from climate from a modeling point of view. Even if we had a perfect paleoclimate data, few (if any) models would be capable of replicating the Chickaree Lake record, which would turn the paper into a model development project.

In terms of the temperature sensitivity, we show that net C balance is not sensitive to temperature relative to the impacts of disturbance, and this was really just a check on what we already know about climate vs. disturbance impacts (as pointed out by Rev. 3). In terms of other abiotic influences (precipitation and radiation), we agree they are important but again, we do not and cannot easily acquire paleoclimate data for this watershed, making these impacts beyond the capability of the current study.

L182-185 More details are needed in regard to the validation dataset. What kind of datasets are these observations? How were they derived? Why select these over others? What do you mean by 'similar-aged'?

Response: There are very few observations (carbon, nitrogen pools, NPP, etc) for old (200+ yr) stands of lodgepole pine in the Rocky Mountains. The studies were chosen given that they had reported variables the most similar to our model output, were for the same species or taxa, and were in similar environmental/climate conditions.

'Similar-aged' means the same forest age. We do not consider these comparisons with reported observations a robust validation dataset; rather, this is the only means of validating some of the model output. We have clarified this in the manuscript.

Results and Discussion: L241 What are the plus and minus signs for? Standard deviation or confidence intervals? What is the sample size? Area under analysis? Seems that crucial details are missing.

Response: The plus/minus signs are the standard deviation for the range of bulk density and soil organic matter percent reported for the dominant soil type that occurs in the Chickaree watershed. Soil carbon can be calculated from STATSGO data using bulk density, depth, and organic matter percent, assuming a %C of the organic matter (we use 58%). This has also been clarified in the manuscript.

L274-278 This statement about disturbance free or intensified disturbance periods is partly false, because DGVMs now have the capacity to run fire dynamics using paleoclimate simulations that feed into a dynamic fire behaviour and growth model (e.g., LPJ-LMfire). This removes the necessity to do the paleo-informed, but nevertheless paleodata comparison is necessary as a validation step.

Response: Yes, there are models (and not just DGVMs) with prognostic fire, so yes there could be predictions of disturbance-free periods (and more intense ones). However, there are few models that actually duplicate known records of ignitions, burn area, and most importantly for this study, carbon combustion; we are unaware of any models with reasonable accuracy at the point scale. We chose DayCent because of its proven ability to predict above and belowground C dynamics at daily to millennial scales. We are also unaware of downscaled paleoclimate simulations that are 'readily available' at high spatial resolutions for this region.

L294-298 This is not really new and has been known for decades. The impact of fire versus vegetation is quite obvious considering that fire has the potential to exclude treed vegetation from landscapes despite generally improving growth conditions with

warming and CO2

Response: Yes, we agree and have changed the wording to reflect that our results confirm what has been known about the impacts of individual fire events, for decades. The 'new' information has more to do with the impacts of the varying timing/sequence and severity of events over centuries to millennia. Certainly, any given fire will outweigh climate impacts in early post-fire recovery. Here, we show that the timing and severity of events over centennial and millennial scales strongly influences the state and trajectory of biogeochemical properties, outweighing at least the impacts of a simple 2°C warmer climate.

L343 "the lack of paleoclimate data" : this is an important weakness of this study. A few sentences about this is needed here to help readers unfamiliar with this issue to understand what is meant by 'paleoclimate data'.

Response: We agree that not using paleoclimate data is an important limitation of our study, and our intention in this portion of the text is to clearly frame our results in this context. Although paleoclimate proxies exist for other regions in Colorado, for example in the form of lake-level reconstructions and oxygen isotope records, these records are far from the detailed climate information needed to drive DayCent. Thus, utilizing paleoclimate proxies to develop climate drivers for DayCent is a project in itself. For example, it involves developing methodologies to downscale paleoclimate proxies in space (to the elevation and location of Chickaree Lake), in time (to daily value), and to the specific metrics required by DayCent (e.g., from a relative moisture proxy to daily precipitation). We will add text to further clarify this limitation and why this was not done in this study.

Figures: Figure 4 This figure is not obvious to read. Perhaps put on separate panels.

Response: Thank you for the comment. We have separated the panels. âĂČ

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