

# ***Interactive comment on “Drought and vegetation change in the central Rocky Mountains: Potential climatic mechanisms associated with the mega drought at 4200 cal yr BP” by Vachel A. Carter and Jacqueline Shinker***

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Dear Reviewer #2. Thank you for your input and suggestions. We believe your suggestions will greatly improve the manuscript.

1. Incomplete discussion of the regional extent of a so-called ‘150 year long’ ‘4200 Cal BP mega drought’ and implications for the utility of seasonal synoptic analogues. More close attention to precisely what regions this study is meant to be useful for is needed. The Long Lake record, within the Medicine Bow Range, is described here as

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reflecting the Rocky Mountain region, according to another recently published paper by this author; Carter et al. (2017). However, the citation for the 4.2 ka 'mega' drought is Booth et al. (2005), who focus on the Northern Great Plains. It is not mentioned here that Booth et al.'s hypothesis was not further verified by additional high resolution multi-proxy data (e.g., Grimm et al., 2011). The other records mentioned in support of the drought are Wyoming dune activity and speleothem isotopes from northeastern Utah. However, the dune data is not well-enough dated (OSL and  $^{14}\text{C}$ ) and conflicting interpretations are possible for the carbon and oxygen speleothem isotopes from Minnetonka Cave.

Therefore, it is puzzling why the synoptic analyses are focused on the central Rocky mountain region of Wyoming (rather than the Northern Great Plains), and that there is no mention of other paleohydroclimatic data from Wyoming and northern Colorado that are numerous and nearby. Perhaps these regional selections were discussed and justified by Carter et al. (2017) but then this would need to be explained in more detail here. As it is, readers of this study cannot actually evaluate the spatial regional patterns of the modern analogues in relation to any proxy data because it is not shown on the maps. Unfortunately, there are nearby records that do not indicate a 4.2 ka 'mega' drought and which are not mentioned in this study. Through this omission, the study overlooks important implications that likely limit the utility of the modern analogue approach.

Response to comment #1: Thank you for your suggestion. We agree there are a variety of published records within the region (central Rocky Mountains and northern Great Plains) that document conflicting accounts of paleohydroclimate between 5,000 and 3,500 cal yr BP. However, the published paleo-proxy climate reconstructions rarely, if at all, provide insight into synoptic processes and mechanistic conceptual models such as those we are presenting in our study. We propose adding a section in the discussion that addresses paleohydroclimate in the central Rocky Mountains and northern Great Plains region in the context of modern climate analogues.

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2. Incomplete discussion of the temporal uncertainty of drought timing and length and how to understand the relationship between seasonal analogues and lower frequency climate mean states (i.e., multi-decadal to century time-scales). There is currently no helpful discussion of time-scales in the paper. The range of uncertainty associated with timing of the so called ‘\_150 year’ ‘mega drought at 4200 Cal BP’ is necessary to know in order to contemplate how seasonal anomalies could be translated by radiocarbon dated proxy records. At the very least some discussion of the age control, and uncertainties, for the timing of the quaking aspen rise at Long Lake is needed. The analogues provide seasonal-scale drought mechanisms but discussion about how seasonal synoptic scale mechanisms inform our understanding of drought mechanisms on century time-scales is not here.

Response to comment #2: We propose to include a sentence in the Methods section that clearly answers the point regarding the timing of the quaking aspen period at Long Lake identified by Carter et al. (2017). As for the discussion pertaining to how seasonal synoptic scale mechanisms inform our understanding of drought mechanisms on century time-scales, we point out that our aim is not to reconstruct climate during the drought period identified by Carter et al. (2017). Rather, the point of our paper is to investigate plausible mechanisms that could be used to explain the ecological changes from the central Rocky Mountains. Similar to Shinker et al. (2006), we selected modern climate analogues to investigate whether the analogues can be used to infer processes that were likely important in controlling moisture anomalies in the past. Using the principle of uniformitarianism, we believe that the mechanisms that cause droughts at present (on seasonal, annual, and decadal time-scales) can be used to explain paleo droughts. Further, our composite-anomaly analyses use statistically significant dry years which represent persistent dry conditions as analogues for climate mechanisms and processes associated with drought conditions in the past.

3. Incomplete discussion of changing boundary conditions across the 5000 to 4000 Cal BP time window and the potential role of the North American Monsoon (NAM) and El

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Nino Southern Oscillation (ENSO) that could have potentially affected this study region during that time.

There is no discussion of previous studies based on nearby proxy records that indicate potentially significant changes in the mean state of the NAM and ENSO before and after 4 to 3 ka (see Reference list below). Modern day ENSO effects are discounted based on an argument that the region is currently unaffected. The same assumption for the mid-Holocene is likely incorrect. Even if a thorough evaluation of Holocene changes in mean state of NAM and ENSO is beyond the scope of this study, a discussion explaining their potential significance still needs to be acknowledged. Changing boundary conditions present major challenges for understanding how to apply modern analogues and should be acknowledged.

Response to comment #3: Thank you for your suggestion. We propose to add additional information based on the suggested references, as well as additional ones in the discussion section with regards to changing boundary conditions across 5,000 and 4,000 cal yr BP. We will discuss the role of the North American Monsoon and ENSO on the region at that time to strengthen this work.

4. Sampling of missing relevant references, and references therein: (in no particular order and by no means complete)

Response to comment #4: Thank you for the suggested references. We will include the suggested references, and references therein in our newly proposed discussion sections.

Technical Corrections (typing errors, grammar etc.) -As previous reviewer suggested, avoid emotive language and delete “Unfortunately” on lines 5 and 13. -p.5 Line 24, spelling of “analyse” -p.9 Line 24, “of flow of cold”?

Response to technical corrections: Thank you for pointing out these typing errors. We will avoid emotive language, delete “Unfortunately” on lines 5 and 13, and we will delete

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'of' on p.9 l24.

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