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Climate of the Past
Discussions

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

Vachel A. Carter and Jacqueline Shinker

vachel.carter@gmail.com

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Dear Reviewer #1. Thank you for your input and suggestions. We believe your suggestions have improved the manuscript.

1. The composites are based on only five events. But there is no attempt anywhere in the paper to address the statistical significance or the robustness of the results. The features of the maps may easily in many cases be just results of chance. This should be investigated by calculating and showing the statistical significance. Also, it should

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be tested if the results are robust and if they depend on one or a few of the five events. It should also be tested if results depend on the threshold (-1.5 standard deviations).

Response to comment #1: To justify our selection of analogue years, we used a two-tailed Student's t-test with an alpha of 0.05 to quantify significance at each grid point in the data set comparing the precipitation that fell during our five composite years to that during the 30-year climate normal (1981-2010). Because climate composites are calculated using an arithmetic mean (30-year climate normal) as the measure of central tendency, we feel a two-tailed Student's t-test was the best statistical test to validate the significance of our case years. Our results are then presented in a map depicting the spatial distribution of significant p-values ($p < 0.05$) across our study region. We propose to include this new map as Figure 2b (see proposed Fig. 2b below). Precedent for using a t-test to calculate statistical significance of composite anomalies in climatological analyses is well established in the existing literature (see Cayan 1996; Shabbar and Khandekar 1996; Taschetto and England 2009). Spatially, if we look at the most statistically significant case years ($p < 0.05$) from the modern record (e.g. the shared common period between the precipitation data and NARR data between 1979 – present), the significance values are representative of persistent conditions which we use as modern climate analogues in our analyses.

2. The duration of the modern analogues are around a year, while the duration of the mega drought is more than 100 years. Is there any reason at all to believe that events on such different time-scales have the same or related mechanisms? Long lasting events tend, in general, to also be more spatially extended. See e.g. DOI: 10.1002/2016RG000521 for a review of how the number of spatial degrees of freedom depends on the temporal scale considered. The validity of the method of modern analogues should be investigated and discussed in detail.

There is a lot of available model experiments (e.g. CMIP5) where this could be investigated.

Response to comment #2: While the duration of the individual case years used in our analyses represent one year, the composite-anomaly approach takes into consideration the overall processes occurring within the selected group of case years as representative of persistent conditions, providing an analogue to the long-term drought identified in the paleoecological record. Your statement ‘Long lasting events tend, in general, to also be more spatially extended’ is illustrated in the results of the Student’s t-test described above, demonstrating that that our case years were not only anomalously dry in our study region of south-eastern Wyoming, but our case years were anomalously (and statistically significant) dry across the region (see proposed Fig. 2b below). Thank you for suggesting the Christiansen and Ljungqvist (2017) reference. While we agree the degrees of freedom should be considered in temperature reconstructions, our paper is not attempting to reconstruct temperature – rather the goal of the modern climate analogue approach is to understand atmospheric processes involved with prolonged drought that then potentially can be used to explain ecological responses to persistent drought conditions. We propose adding a paragraph to the Introduction which provides additional literature discussing previous studies that have used the modern climate analogue technique. We feel that the addition of this new paragraph will address the reviewer’s comments, and provide the reader with the proper background and citations that justifies the use of modern climate analogues as a potential way to explain past atmospheric processes and conditions. Our analysis is a first-step approach to understanding the relationship between vegetation change and drought-related disturbance at a local and regional scale. Since the NARR data are initiated with climate station data, our study can be used for data-model comparisons utilizing climate models (e.g. CMIP5), as well as sensitivity tests of the described processes in future analyses.

Minor comments: p6, l13: Why are these years "suitable analogues". Are other conditions than the drought index used?

Response for comment p6, l13: We apologize if this text was vague. What we meant by 'suitable analogues' is that the five case years identified represent the driest years (-1 standard deviation or below from the mean) in the modern record. However, using the results from the Student's t-test, we are able to say that our case years are statically robust analogues, rather than just stating they are 'suitable.' We will update the sentence on p6, l13 to say, 'Five case years (2012, 2002, 2001, 1988, and 1994) that were -1 standard deviations below the long-term average were chosen because they were found to be the most statistically significant ($p < 0.05$) analogues for dry conditions in the North Platte River Basin.'

Figure 2: What is the value of the standard deviation?

Response for Figure 2: One standard deviation is equivalent to 58.89 mm. We would like to point out that the Y axis on Figure 2 was previously mislabeled. The Y axis on the figure presented in the attachment is now correct. We also would like to point out another error that was in the manuscript. We previously described analogues as being suitable if they were -1.5 standard deviations from the mean. However, the correct number should be -1 standard deviations from the mean. We apologize for these errors.

Additional References related to our analysis of statistical significance:

Cayan, D. R. (1996). Interannual climate variability and snowpack in the western United States. Journal of Climate, 9(5), 928-948.

Shabbar, A., & Khandekar, M. (1996). The impact of el NinoâĂŘSouthern oscillation on the temperature field over Canada: Research note. Atmosphere-Ocean, 34(2), 401-416.

Taschetto, A. S., & England, M. H. (2009). El Niño Modoki impacts on Australian rainfall. Journal of Climate, 22(11), 3167-3174.

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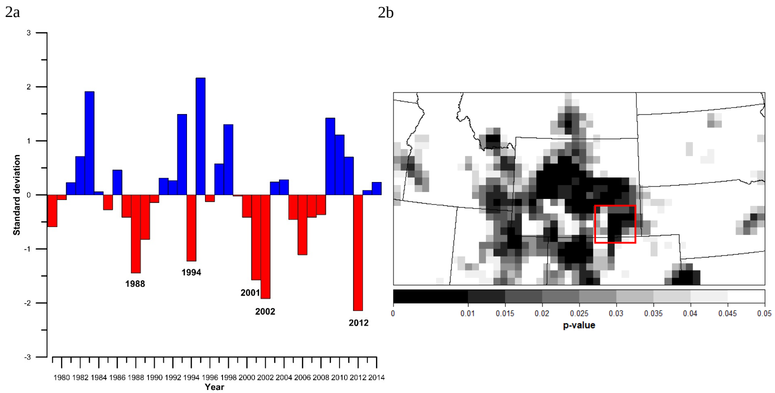

Figure 2. Precipitation anomalies and the spatial distribution of significant p-values across the study region of south-eastern Wyoming. A) A time series of annual precipitation anomalies for 1979-2014 compared to the long-term average (1981-2010) from Wyoming climate division 10, Upper Platte River Basin. The first five years with -1 or more standard deviations below the long-term average include 2012, 2002, 2001, 1998, and 1994. One standard deviation equates to 58.89 mm. Climate division data were collected from http://www.esrl.noaa.gov/psd/cgi-bin/timeseries/timeseries1.pl. B) A map showing the spatial distribution of significant p-values ($p < 0.05$) across the study region (outlined in red box) identified during the five driest years. P-values were evaluated using a two-tailed Student's t-test with an alpha of 0.05.

Fig. 1.

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