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Interactive comment on "Millennial-to-centennial patterns and trends in the hydroclimate of North America over the past 2000 years" *by* Bryan N. Shuman et al.

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The reviewer raises three good points, which we would propose to address through revision.

Comparison to tree-ring reconstructions: Both reviews as well as St. George's comment highlight that the comparison is the obvious one to make. We struggled with this topic in designing the manuscript. Therefore, we propose to 1) clarify our goals for the paper, including by changing the title, and 2) include and discuss a comparison with patterns in the North American drought atlas.

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Discussion paper

In the first case, as noted in our response to review 1, we intended to evaluate the patterns that exist as recorded by data other than the excellent dendroclimatic record. We intended such an analysis to focus on patterns at multi-centennial to millennial scales, in part, as a way to place the Common Era in the context of the whole of the Holocene. We, therefore, propose changing our title to read: "Placing the Common Era in a Holocene Context: Millennial-to-centennial patterns and trends in the hydroclimate of North America over the past 2000 years."

Not all of the available data were suitable for providing a Holocene context (because of limited time depth), but the dataset was aimed at methods and archives that could capture the relevant variations. They represent the methods used to study Holocene and even Pleistocene changes – and a useful question is whether they have the sensitivity to always record climate variation within just two millennia or less as tree rings can clearly do. New methods in dendroclimatology certainly preserve many low-frequency patterns, but these methods have not been applied to all reconstructions and only cover certain regions. Including the high number of tree-ring chronologies would have also dominated the patterns in our analysis for some areas and prevented an independent perspective afforded by the other (Holocene-scale) data types.

Therefore, we aimed to be independent of this major data source (dendroclimate data), but we agree, it begs then for comparison. So, toward, the second proposed revision, we can include maps of PDSI anomalies from the North American Drought Atlas (NADA) as a point of comparison in Fig. 4. Our preliminary assessment indicates a poor correlation, but we agree even a mismatch is worthy of more discussion: why does it exist? We would propose to revise our text to discuss the potential reasons.

We would add text similar to the following as a new sub-section in the Discussion (section 4):

"Differences between the patterns in our dataset and the NADA may exist for several reasons. First, contrasts may exist between the way our dataset retains signals of

annual-to-decadal variations (clearly preserved in the dendroclimate record) and those of multi-century and longer variations. For example slow sediment dynamics or forest tree longevity may prove resilient to annual variations, but readily responsive to change over centuries. Different map patterns could arise, therefore, because NADA likely emphasizes interannual variation, even when smoothed over centuries, whereas other datasets may emphasize the effects of centennial and longer changes. The differences would represent different patterns in the averages of high-frequency variability versus the patterns in low-frequency trends.

Furthermore, our dataset may lack a consistent ability to detect either annual-decadal variability or multi-century trends in a limited 2000-yr window because of the interaction of taphonomic process (e.g., sediment mixing) and the small magnitudes of the low-frequency trends. The datasets may well be noisy relative to weak low-frequency signals. As we noted in the Introduction, the magnitudes of the trends in many records are small over even 2000 yrs (Fig. 7) when compared to many reconstruction uncertainties. The low signal-to-noise ratio may also apply to the dendroclimate data at multi-century to millennial scales, and without long observational datasets available for validation, it is difficult to assess.

A third related explanation for mismatches could be that dendroclimatic reconstructions of variables such as the Palmer Drought Severity Index (PDSI) may differ from the hydroclimate variables represented by our data (e.g., net snow accumulation in ice cores; P-ET that drives lake-level changes). We do recognize some clusters of coherent anomalies (e.g., clusters of opposite sign anomalies in the Pacific Northwest versus the U.S. Southwest in Fig. 4), which would at first pass, suggest real signal and thus, in part, require explanations that involve differences in the time scale (explanation 1) or controlling variable (explanation 3) recorded by the two different datasets. More work is needed to test the various explanations."

Overall, we agree that lessons probably lie hidden within even mismatched patterns and that we should show the comparison.

Selection of time windows: We would propose to add text to section 2.2.1 that clarifies that we used 100-yr bins as a simple approach to focusing on trends that were longer than a century. Some data do have the ability to assess finer patterns of variation, but we will clarify that our focus was on the low-frequency aspects of the records. Additionally, our focus on the last 2000 years was intended to align with the goals of PAGES 2k. Other timeframes may have been chosen to maximize the available data, but 2000 yrs was also a useful contrast with Holocene trends, which we intended as a focus of the manuscript. Similar to the suggestion about sub-setting the data, we split our data into 2ka and Holocene length groups to examine, first, the dominant patterns (if any) over the last 2 ka in these types of records and, then, how these patterns compared with those that extend through the Holocene.

Our maps contrasting the two millennia were designed with two points in mind, which we would propose to clarify. First, what were the spatial patterns of the long-term trends represented by the EOFs and PCs? Second, were differences observed when we contrast the Medieval and Little Ice Age periods a function of the long trends? However, the reviewer raises useful points and caveats.

Data Groups: The point about evaluating the data by type is a good one and we would propose to include a figure showing the mean patterns or PCAs by proxy. Breaking the data apart in this way may help elucidate the causes of different patterns in our dataset and NADA.

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