

Response to Anonymous Referee #1

We thank the reviewer for their detailed comments and suggested considerations to improve our manuscript. We have addressed each individual comment below and will edit the manuscript accordingly. Reviewer comments are in italics and our responses are in normal text.

Summary:

Lindberg et al. investigate patterns in leaf wax (n-alkane and n-alkanoic acid) distribution in vegetation from the Arctic. The work provides a foundation for interpreting paleoclimate records based on leaf wax molecular proxies in sediment cores. Their assessment of the environmental parameters (meteorological/environmental effects, and vital effects of different species) is thorough, in that it combines their large dataset from the Eastern Canadian Arctic with a pan-Arctic synthesis. Ultimately, they provide a practical tool for paleoclimatologists working in the Arctic.

The manuscript is very clearly written, includes a solid statistically-based discussion, includes pertinent citations, and is essentially ready for publication, although I have two considerations for the authors, as well as a few very minor comments.

Considerations:

The first consideration is that latitude is not tested as an environmental parameter. We don't typically think of latitude as a driving factor, but in the case of Arctic leaf waxes, there has been discussion on if day-length impacts leaf wax hydrogen isotopes. Perhaps their study sites don't span a substantial gradient in day-length, or the length of the 24-hour daylight season (latitude is a proxy for this), but I think it would be worth at least acknowledging this point. That is, a previous study from Baffin Island by Shanahan et al. (2013) had anomalously small fractionation values between precipitation and leaf wax D/H – how does that previous. In fact, this is one paper that seems like it should be cited, or explained why it is not included in the synthesis.

We agree with the reviewer that latitude should be included in our statistical analyses of environmental parameters and plant wax indices. We will include text in the Materials and Methods, Results, and Discussion sections which incorporate the explanation of latitude as a proxy for the length of the 24-hour daylight season (Shanahan et al., 2013; Yang et al., 2009, 2011) and how this mechanism compares to correlations between latitude and plant wax indices. We will also adjust Figures 6-9 to include the results of these correlations.

In response to the second part of this consideration, we do not include plant waxes from Shanahan et al. (2013) in our pan-Arctic data synthesis because their data was extracted from lake sediments, not modern plants. We will adjust the wording as follows in our description of the data compilation methods in this study (Section 2.1) to better emphasize that we only compiled plant wax data extracted from terrestrial plants:

“To expand the sample size and range of environmental conditions, we compiled published plant wax data from terrestrial plants from sampling sites across the entire Arctic; within the latitude range spanned by the ECA transect (Fig. 1a).”

The second consideration is that among all the environmental parameters tested, they did not include Vapor Pressure Deficit. I wonder, if they combine the air temperature, relative humidity, and added in the modeled leaf temperature, would they find strong gradients in VPD across their sites, and how would this relate to the epsilon value. It has been untested, to my knowledge, but could be potentially revealing as an important environmental control.

We thank the reviewer for their suggestion to consider Vapor Pressure Deficit (VPD) in our analyses of Arctic environmental parameters. However, after testing VPD in our correlation matrices, we have decided not to include it in our revisions because VPD was strongly negatively correlated ($r \leq -0.92$) with relative humidity in all plant wax data subsets shown in Figures 6-9. This resulted in all Pearson r-values between VPD and plant wax indices having nearly the same magnitude with the opposite sign compared to correlations with relative humidity, so showing tests with one parameter reliably predicts the results of the other. Below, we have shown the derivation of VPD and its inverse relationship with relative humidity based on Equation 1 from our manuscript (Alduchov and Eskridge, 1996), which calculates relative humidity based on temperature (T) and dew point temperature (Dp):

Saturation Vapor Pressure: $E_s = e^{[(17.625 * T)/(243.04 + T)]}$ (Alduchov and Eskridge, 1996)

Actual Vapor Pressure: $E_a = e^{[(17.625 * Dp)/(243.04 + Dp)]}$ (Alduchov and Eskridge, 1996)

Relative Humidity = $(E_a/E_s) * 100$

Vapor Pressure Deficit: $VPD = E_s - E_a$

$VPD = E_s - (RH * E_s/100)$

Additionally, incorporating modeled leaf temperature into our statistical analyses is beyond the scope of this study. This process would require implementing a separate model which would need to be run for each plant sample. Commonly used leaf models, such as Tealeaves (Muir, 2019) and NicheMapR (Kearney and Porter, 2020), are also not currently suited for modeling non-vascular plants, which represent a significant portion of our total samples.

Minor Comments:

Paragraph at line 244, which refers to Figure S2: Specify again in this paragraph that this includes data points from all plant types. Also, you mention that the pan-Arctic dataset has an n=386. But it does not look like Figure S2 has 386 data points. Can you clarify what is included in this figure?

We will clarify in this sentence and in the Figure S2 caption as follows that these Pearson correlations were performed using data from all plant growth forms in the pan-Arctic dataset. We also agree that our description of sample sizes in this manuscript needs clarification.

While we used data from a total of 386 plant samples between the samples we analyzed and compiled from other publications, not every data type was available for each sample or compound class. To illustrate this better, we will add two new tables to the supplement (to be Table S1 and Table S2) that show the number of data points for each data type in each compound class. Table S1 shows the raw sample counts and Table S2 shows the sample counts where plants of the same species collected at the same time from the same site are averaged together (see Section 2.4):

Section 3.3: “In the pan-Arctic dataset using all plant growth forms, we found that *n*-alkanoic acid $\delta^2\text{H}$ had a weak, positive correlation ($r = 0.25$; $p = 0.02$) with MAF precipitation $\delta^2\text{H}$ (Fig. S2a), while *n*-alkane $\delta^2\text{H}$ had a moderate, positive correlation ($r = 0.64$; $p < 0.01$) with MAF precipitation $\delta^2\text{H}$ (Fig. S2b).”

Figure S2 caption: “Pearson correlations and linear regressions in each panel were performed on the pan-Arctic dataset using all plant growth forms (see Table S2 for sample sizes).”

Figure 7 caption: specify if this is the pan-Arctic dataset or the ECA dataset. (It's stated in the text, but would help clarify the figure caption.)

All of the correlation matrices in Figures 6-9 were produced using the pan-Arctic dataset. We will add this clarification to each of those figure's captions.

References:

Alduchov, O. A. and Eskridge, R. E.: Improved Magnus Form Approximation of Saturation Vapor Pressure, *J. Appl. Meteorol.*, 35, 601–609, [https://doi.org/10.1175/1520-0450\(1996\)035%253C0601:IMFAOS%253E2.0.CO;2](https://doi.org/10.1175/1520-0450(1996)035%253C0601:IMFAOS%253E2.0.CO;2), 1996.

Kearney, M. R. and Porter, W. P.: NicheMapR – an R package for biophysical modelling: the ectotherm and Dynamic Energy Budget models, *Ecography*, 43, 85–96, <https://doi.org/10.1111/ecog.04680>, 2020.

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Yang, H., Liu, W., Leng, Q., Hren, M. T., and Pagani, M.: Variation in *n*-alkane δD values from terrestrial plants at high latitude: Implications for paleoclimate reconstruction, *Org. Geochem.*, 42, 283–288, <https://doi.org/10.1016/j.orggeochem.2011.01.006>, 2011.