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Climate of the Past
Discussions

CPD
11, C372–C380, 2015

Interactive Comment

# *Interactive comment on* "A millennial summer temperature reconstruction for northeastern Canada using oxygen isotopes in subfossil trees" *by* M. Naulier et al.

**M. Naulier et al.**

maud.naulier@hotmail.fr

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[1.1] In particular, I noted that the authors do not provide comparisons with the D'Arrigo et al (1996, 2003). Tree ring record from northern Labrador which provides somewhat different results;

We are well aware of the series produced by d'Arrigo et al. (1996, 2003). These authors have reconstructed mean summer temperature over the last four centuries. This series and many others in the literature are of interest but do not cover the last millennium. The reader has to keep in mind that our discussion compares our 1000 years-long reconstruction, i-STREC with six other millennial series. That way our discussion



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is not too long; a long discussion being unnecessary (see review by H. Linderholm).

[1.2] Many of the interpretations provided in the text and some of the information would benefit by comparison with the results of Way and Viau (in press) which characterizes the regional drivers of climate variability in Labrador over the past century. This work is relatively recent and has only been online since August of 2014 but it certainly would reinforce and help with the interpretation of results;

The Way and Viau paper (2014) appears as an interesting discussion helping to understand forcings that controlled air temperature of the last century in Labrador, with a rapid increase during the last 17 years. Such suggestions could apply in part for the warming observed in northeastern Canada. Therefore, we have added this reference and we now allude to this possibility for the warming observed in the study region during the last three decades (lines 360-370): "Nevertheless, the causes that triggered these periods are likely different (i.e., Landrum et al., 2013; Way and Viau, 2014). Indeed, if the MWA is only controlled by natural processes, it seems that the warming of the modern period results from a combination of natural and anthropogenic causes (i.e, Mann et al., 2009). By using empirical statistical modeling and global climate models, Way and Viau (2014) have shown that the variance of annual air temperature over the period 1881-2011 in Labrador was explained at 65% if anthropogenic forcing was also included in the model. Even if summer temperature has increased at a lower rate compared to annual air temperature in Labrador, the observed warming (+1.9°C) between 1970 and 2000 is one of the fastest over the last millennium in the region of L20. In the next decades, if warming continues at this rate, temperature will reach a record for the last millennium."

[1.3] An additional point of discussion is the authors provide information of the role that multidecadal variability plays in the region relative to their results and particularly with respect to whether it is detectable in the air temperature reconstruction provided - I believe noting this type of variability would add to the discussion - does the reconstruction agree well with AMO reconstructions for instance?





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We have examined the links between i-STREC and AMO series for various months (see Figure I below), and the correlations obtained over the recent 143 years are not stable over time (vary from positive to negative, and from significant to non-significant). Consequently, the control of the AMO on temperature in northeastern Canada is not suggested by our reconstruction, and AMO does not appear as relevant for the discussion of potential main forcings.

[1.4] The authors state that they do not train on the period of 1900-1929 due to the lack of weather stations within 300 km of their study area during that time. Was there a particular reason to choose 300 km and 1930 as the specific thresholds? Many authors have noted that temperature anomalies are correlated at distances exceeding 1000 km (Hansen and Lebedeff, 1987; Rohde et al., 2013; Cowtan and Way, 2014) therefore interpolation methods such as those employed in the CRU TS dataset should perform reasonably well in the absence of local station data.

A strong climate spatial variability was observed in the Labrador-Québec Peninsula in relation with contrasted atmospheric teleconnection influence (Nicault et al., 2014). This variability seems to be even more important in the past. Moreover, as stated in the submitted paper, we obtained correlations between the regional series resulting from the data normalized for the three closest stations to our site (Schefferville, Wabush, Nitchequon; 1943-2010) and data from several remote stations that covered a period preceding 1943-2010. Data from many remote stations showed no significant correlations with the regional data. This observation allowed us to determine that any CRU data preceding 1930 should not be considered in the calibration period (1930-2010).

[1.5.1] The authors exclude the post-2000 data from calibration because of a divergence which they attribute to a change in growing season that affected the relationship between temperature and the S18 values. Would this change in growing season and the resultant non-linearity not be a concern for other decades of rapid warming throughout the record?



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The comment suggesting the possibility of changes in growing season can have occurred in previous phases of the millennial record is valid. Inevitably, this sort of consideration referring to past changes in climatic regimes is always pertinent when discussing reconstructions of climatic parameters based on statistical models. This limitation is inherent to the calibration method which assumes that present conditions are warrant of the climatic past. The validity of the assumption could eventually be assessed by combining ecophysiological approaches with isotopic reconstruction.

[1.5.2] Similarly could there not be additional causes for the divergence which could be considered viable?

We are open to suggestions to explain the divergence after 2000 between tree-ring $\delta$18O values and JJA max T. Please note that we have evaluated the possible influence on $\delta$18O values of el Niño, snow cover changes, humidity changes, and hydric stress using available data. The only cause that coincided in time with the period of divergence and had the potential of explaining the isotopic departure in mechanistic terms was the observed change in the duration of the growing season.

[1.6] The authors state that the i-STREC values are representative of the natural variability of the region based on the relatively good correlation (r2=0.64) with the CRU TS series; however, the authors also note that both series were smoothed at 9-year intervals therefore it is expected that the strength of this relation may be somewhat overstated

As shown in Naulier et al. (2014), the correlations obtained between tree-ring $\delta$18O values of living trees (sampled with an annual resolution) and standardized JJA maximal temperature are highly significant (r2=0.25) even when using 4 trees (instead of 5 as in i-STREC) and including the divergent period. In other words if one were to use data not smoothed, the correlation would still allow to reconstruct Tmax. The r2 obtained for the cohort series in the submitted paper is indeed excellent. One should consider that the methodological smoothing produced by the cohort strategy may increase the statistical



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link existing between Tmax and $\delta$18O values, but it does not create an artificial or false linkage.

[1.7] The authors state that a warm phase of the AMO could cause the warm period observed during the MWP but they also state that there was an overall decline in temperatures consistent with orbital cooling (reduced summer insolation). It would seem that there is little need in speculating as to the relationship with the AMO during that time period as there is not a clear understanding of the AMO state during the MWP. Sicre et al (2014) have argued that during the MWP there was enhanced Labrador Current activity which would seemingly argue against North Atlantic SSTs being the major driver of regional warming at that period.

It is a good point. We have now extended the text that was already referring to AMO in the discussion (lines 328-336): "In contrast, the AMO influences spring and summer temperatures (Fortin and Lamoureux, 2009) and is partly responsible for the recent sea surface temperature warming of northeastern Canada (Ding et al., 2014). However, the state of the AMO at the beginning of the millennium being unknown, it is difficult to assess its influence on climate during the MWA. Recently, Sicre et al. (2014) have demonstrated that during the MWA, the strong Northern Annular Mode (NAM) was concomitant with a strong ice-loaded Labrador Current (LC). This combination could be responsible for a decrease of fresh air from Arctic to eastern Canada and consequently, for an increased temperature along the continent during a part of the medieval period."

[1.8] The authors note the difference between reconstructed MWP summer temperatures in their reconstruction and prior works which have found unprecedented warmth in recent decades relative to that period at the hemispheric scale. Here it is worth noting that this is not necessarily contradictory in that the reconstructions have different target seasons (annual versus summer). As anthropogenic warming at high latitudes has a strong winter signal relative to summer, it would not be unexpected that summer air temperature reconstructions may give different results than an annual average. According to Way and Viau (2014), winter air temperatures in the region have increased at a much faster rate than summer air temperatures therefore this point should be considered.

According to CRU TS 3.1 data for the studied region, Tmax of summer months has increased with an average of 1.2°C between 1940 and 2010 whereas winter temperature has not increased but shown the strongest variability in the studied region (Figure II). In other words, the winter trend discussed by Way and Viau is not recognized in our region. Additionally, knowing that the correlation between June to August Tmax and annual Tmax is strong ($r^2$=0.64), we can argue that our reconstructed summer Tmax can be representative of an annual Tmax.

[1.9] In discussing the tree ring response to volcanic events it is worth discussing Tingley et al (2014) - particularly given the high latitude study area in question.

We now discuss this publication in the text addressing the record of solar radiations by trees in lines 398-401: "In addition, Tingley et al. (2014) have demonstrated, by analyzing the ring density in trees growing at high latitude, that the trees recorded not only volcanic eruptions but also variations in light intensity. This finding indicates that both isotopes and density of trees can record changes in solar radiations."

[1.10] Brown et al (2012) should also be mentioned in the text given that it also examines climate in this region.

We are convinced that this paper is of great interest for discussing climate of Nunavik and Nunatsiavut. However it is not so relevant for a discussion addressing northeastern Canada climate. Moreover, the study by Brown et al. covered only a part of the last century whereas we focused on a millennial reconstruction which permitted to identify the decadal and centennial climatic variability.

Please also note the supplement to this comment:
http://www.clim-past-discuss.net/11/C372/2015/cpd-11-C372-2015-supplement.pdf



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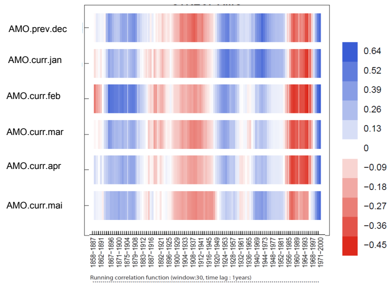


**Fig. 1.** Figure I. Correlation coefficient between i-STREC and the AMO index (Enfield et al., 2001). The positive correlations are in blue, the negative, in red. Prev = previous year, curr = current year



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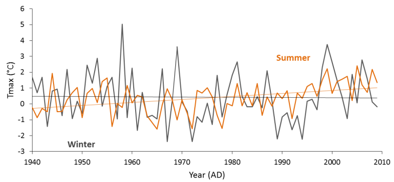


**Fig. 2.** Figure II. Maximal temperature for summer (June to August; orange curve) and winter (December to February; grey curve) months and their linear regressions.



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