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Climate of the Past Discussions

Interactive comment on "Reconstruction of multi-millennial summer climate variations in central Japan by integrating tree-ring cellulose oxygen and hydrogen isotope ratios" *by* Takeshi Nakatsuka et al.

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We will present our responses to the referee#2's comments (RC2) one by one in the following order. (1) comments from Referees, (2) author's response, (3) author's changes in manuscript.

(1) SYNOPTIC COMMENT The authors use of d2H and d18O tree-ring series for reconstruction of central Japan hydroclimate. Combining composite data set constitutes a serious technical challenge. The authors selected stem segments mostly of

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Japanese cypress from living trees, excavated archeological wood, architectural wood and naturally buried logs. They propose an iterative calculation method to merge 67 series from the various types of wood samples, including the buried archeological and construction wood pieces, and a tentatively quantitative method (factors A and B) to calculate past climate based on d2H and d18O values, using a suite of equations derived from Roden's et al (2000). (2) Thank you very much for taking a lot of times to review this manuscript and give us valuable comments. (3) We will revise our manuscript considering your valuable comments below.

(1) However, they did not nitrate their samples prior to analysing the d2H values of tree-ring cellulose, so that the exchangeable H is included in their analyses. The simple determination of d2H values on cellulose can generate artefacts. (2) In fact, we did not nitrate our cellulose samples, but there were two reasons. First, it was impossible to nitrate more than 10,000 samples of very small tree-ring cellulose in this study, because nitration of cellulose is very time-consuming and it usually needs more than 10 times larger amount of cellulose compared to the direct isotopic analyses of cellulose. Second, it was desirable to measure d18O and d2H simultaneously for the same cellulose samples in order to integrate d18O and d2H data in this study, but nitration of cellulose makes it impossible to measure the d18O. Indeed, measurement of the OH-hydrogen together with C-H hydrogen in cellulose may reduce the analytical precision of cellulose d2H to a certain degree, but it does not change the temporal pattern of d2H variations, to be compared with those of d18O, because all OH-hydrogen of cellulose in a wood segment must be exchanged with the same water in a test tube during the cellulose extraction process in this study. Moreover, we think that the negative influence of lower precision in d2H measurement was minimized in this study by focusing only on low-frequency component in d2H data, which can smooth analytical uncertainties in the individual tree-ring cellulose d2H measurements. (3) We will explain carefully the reason why we didn't nitrate samples in Section 2.

(1) Additionally, the number of trees studied for d2H results are significantly lower than

for the d18O determination, and the expressed population signals obtained for the composite d2H series are too low (Fig. 3, b, d). The fact that the d2H and d18O series do not derive from the same populations of trees may generate artefacts. (2) This is obviously a misunderstanding of the referee. The samples for d2H measurement in this study were completely same as those for d18O measurement. The low EPS for d2H series is owing to the low R-bar for d2H series. The core idea in this study is to measure both d18O and d2H simultaneously for all tree-ring cellulose samples and integrate them. (3) In order to avoid misunderstandings, we will emphasize that we measure d18O and d2H simultaneously for all tree-ring cellulose samples in Section 2.

(1) Another point is that the authors did not evaluate the reliability of the isotopic signals for the buried pieces of wood, but alteration of cellulose can occur due to microbial activities during long periods of burial. (2) Thank you for your comments. Indeed, tree-ring isotope ratios in buried wood are sometimes influenced by microbial activities in soil. However, we selected only well-reserved conifer woods from buried samples in this study. Moreover, we had confirmed that our method of cellulose extraction makes it possible to recover past cellulose isotopic ratios precisely even in the case of highly degraded hardwood samples by comparison of cellulose isotope ratios between degraded and non-degraded parts within a wood segment. (3) We will add this information in Section 2.

(1) Overall, the article is lengthy for what it brings, but generally clearly written. The discussion of the low-frequency trends (long-periodicity variations) is confusing. The authors interpret them unguardedly as age trends, without presenting supporting arguments, and then they bring up the option of these trends possibly relating to changes in growth rates (lines 149-150; 160-165). This potential interpretation implies that environmental conditions may have generated these trends, at least partly. Moreover, the use of ring width for specifically deducing the cause of inverse d2H and d18O trends is risky because in many cases, the isotopic and ring width series do not respond to the same environmental factors. (2) Thank you for your comments. In this study, we

demonstrated that changes in “the rate of post-photosynthesis isotope exchange with xylem water” (f-value in this study) underlie low-frequency trends of tree-ring cellulose d18O by comparison of long-term variations in cellulose d18O and d2H based on the theory of Roden et al (2000), and suggested that changes in the growth rate may cause the changes in “f-value” by comparison of long-term variations in d18O and dD with those in tree-ring width. As you suggest, it is impossible to remove “growth rate-related signals” from tree-ring cellulose d18O using tree-ring width data, because controlling factors are completely different between tree-ring width and tree-ring cellulose d18O. Instead, we use the data of tree-ring width here only for discussing the reason why low-frequency isotopic signals sometimes become opposite between d18O and d2H, and we don’t use the data of tree-ring width for any kinds of quantitative calculation, so that the tree-ring width does not influence the long-term climate reconstruction in this study at all. (3) We will write about the role of tree-ring width in this study carefully to avoid any kind of misunderstandings.

(1) Another important point is that some of the sampled populations of trees belong to forests exposed to human perturbations; such sites are not suitable for producing isotopic series to be used for climatic reconstruction. (2) So far, dendroclimatologists have been thinking that trees exposed to human perturbation are not suitable for climate reconstruction. However, there are only few regions in the world where millennial length of non-human perturbed wood samples can be collected, such as Arctic region, mountainous regions in America and Eurasia etc. In most of other areas like Mediterranean and East Asian regions including Japan, where climatic influences to human history should be investigated using high-resolution paleoclimatological records over last several millennia, purely natural forests had already disappeared more than a few millennia ago owing to the intense logging activities by human beings. For the tree ring study in those areas and periods, most of wood samples are buried wooden artefacts excavated from archaeological remains, where human activities inevitably influenced the wood formation. Therefore, we believe that it is very important to establish a new sophisticated method for reconstruction of past climate variations using woods exposed

to human perturbations in order to develop paleoclimatology in the world. The method proposed in this study is exactly to contribute to that purpose. Hence, we cannot accept this referee's comment at all, because this comment does not fit the real purpose of this study and prevents us from contributing to development of paleoclimatology in Japan and many other regions in the world. (3) In Section 1, we will emphasize that in this study, we develop a dendroclimatological method to utilize woods exposed to human perturbations effectively.

(1) Concluding that (1) d2H analyses would be more reliable if performed on nitrated cellulose, and (2) memory effects occur when performing online pyrolysis, are not new findings and do not bring constructive information in this field of research. Furthermore, as mentioned above, it underlines the fact that 50% of the data used for evaluating paleoclimate is faulty, and weakens the basis for the final reconstruction. Overall, given the purpose of the article and the unfortunate non-rigorous sample selection and treatment, CP should not accept this article. (2) We agree that the precision of d2H measurement in this study is not the best one in the viewpoint of analytical chemistry and it is obvious that the report of memory effect is not the purpose of this study. However, it is also obvious that we cannot finish this study within a practical research period such as several years if we apply "nitration of cellulose to remove OH-hydrogen" and "triplicate measurements for individual samples to prevent memory effect", recommended by the referee, for the analyses of more than 10,000 tree-ring samples in this study, because those procedures request us to spend more than 10 times of analytical periods and sample amounts. In this study, we utilize the d2H data only for their low-frequency components smoothing of individual d2H data, so that we think that influence of possible lower precision in the individual d2H measurement must be minimized in the final result of this study. Of course, we agree that it is very important to develop "more sophisticated, practical and precise analytical method" of cellulose d2H. In order to promote development of the new analytical technology in the isotopic dendrochronology, we believe that it is very effective to publish this study utilizing d2H together with d18O for reconstructing of low-frequency climate variations explicitly, be-

cause recently the d2H is not often measured compared to the d18O in the field of isotopic dendrochronology. (3) We will revise our manuscript according to many constructive comments below.

SPECIFIC POINTS

(1) Line 30 – replace However by In addition. (2) Thank you for your suggestion. (3) We will replace the word according to your suggestion.

(1) Line 75 – Please provide a minimum of details about the direct cellulose extraction of 1-mm thick wood samples so the reader does not have to read two other articles to find out. Do you mean that all stem segments were dissected into suite 1 mm-thick samples regardless of ring width and age? (2) Yes. We sliced all stem segments into 1mm-thick wood plates regardless of ring width and age in order to keep the condition of cellulose extraction constant. (3) We will move this sentence to Section 2 and expand the description on analytical procedure, especially that related to Kagawa et al (2015).

(1) Line 76 – Please explain what are 'level offsets'. (2) Here, we use the "level offsets" to explain phenomenon that averaged tree-ring isotope ratios are significantly different between different individual trees during a same period. (3) We will explain about it at the first appearance of the words in the manuscript.

(1) Line 80 – Simultaneous (?) measurements of d2H and d18O values? How possible with good precision? Using more than one standards is required for a good calibration (two end members with distant isotopic values defining a range broader than the measured isotopic ranges, and a third standard as an intermediate checkpoint), but the described analytical procedure does not mention this required approach. (2) We understand that the methods you recommend are effective to determine absolute d2H and d18O values of individual tree-ring cellulose precisely. However, according to the following 4 reasons, we decided to measure d2H and d18O "simultaneously (by peak jumping method)" using "only one standard material". 1) We must finish all d2H and d18O measurements of more than 10,000 tree-ring cellulose samples within practical

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research period of several years. 2) In order to integrate d2H and d18O data using the method in this study, it is highly desirable to obtain those data from completely same samples for individual tree rings, so that the simultaneous measurement of d2H and d18O for the same cellulose is the best way. 3) Large memory effects inevitably occur when multiple cellulose standards with distant d2H values are inserted in the sample measurements. 4) In this study, we discuss only the relative variations in d2H and d18O without considering their absolute values, so that the absolute precisions of measurements do not influence the main research result. (3) We will add those explanations in the Section 2.

(1) Lines 86-87 – Please modify text: : : for reconstructing climate over the past 2,600 yr: : : (2) Thank you for your suggestion. (3) We will modify our manuscript according to your comment.

(1) Lines 91-96 what are the average, minimum and maximum ring widths of the studied samples; this information will help follow the wood slicing procedure of next section. (2) Thank you for your suggestion. (3) We will add the description about them in the Section 2.

(1) Lines 96-97 – Please briefly explain how the new tree-ring d18O time series were used for dating rings. Usage of a statistically strong constructed and multiply verified d18O suite as dating method? How widely is this applicable? For which geographical area was the dating series constructed? What is the operating time resolution on which the comparison is used? (2) Thank you for your comments. As you can see in Fig.3a, R-bar of tree-ring cellulose d18O is around 0.6-0.7 within the studied region in Fig.1, meaning that the cellulose d18O can be used not only to date all tree rings in this study precisely by the standard cross-dating method, but also to date any tree rings of any tree species collected in this region by comparison with the combined d18O chronology in Fig. 8 or 12. In fact, those data are now being applied to date many tree rings not only in central Japan but also in northeast Japan and south Korea because there are significant correlation (0.2-0.4) even between those distant areas. (3) Although the

application of tree-ring d18O chronology to dating is not the main purpose of this study, we will explain briefly about its present situation in Japan in Section 2.

(1) Lines 102-107 – Scientists have recognized for a long time that the production of tree ring d2H series to be coherent requires nitrating cellulose, so that only the C-bond hydrogen is analysed (Epstein et al., 1976; a reference they use and list). Otherwise, exchangeable H may blur true environmental effects. It seems here that the authors have chosen to save time by analysing simultaneously d2H and d18O in non-nitrated cellulose. No surprise that they conclude they need to improve their analytical procedure (lines 485-487). However, this information has been available to scientists since 1976, with a methods proposed for improving the throughput and reducing the amount of material required back in 2006 and 2009 (Filot et al., 2006; Sauer, 2009; rapid comm. mass spectrom.). (2) Thank you for your comments. As we mentioned above, there were two reasons why we did not nitrate cellulose ("saving of time and sample amount" and "necessity of simultaneous measurement of d2H and d18O"). Besides, we also understand that, under the two conditions, the method of Filot et al (2006) may be a good solution to obtain absolute d2H values of C-H hydrogen. However, we decided not to use the method of Filot et al (2006) according to the following two reasons. 1) We had already modified our auto-sampler system of TCEA to make it possible to measure about 200 cellulose samples per a day continuously, but the system of Filot et al (2006) could not be set to our system. 2) In this study, we do not need absolute d2H data, but only focus on relative variation in d2H for each individual stem segment, which can be obtained easily by our direct cellulose extraction method from a wood lath. (3) We will explain those reasons briefly in Section 2.

(1) Line 105 – Strict rigor would require indicating the true significant numbers for precisions (reproducibility), i.e., 0.1 or 0.2‰ and 1 or 2‰ for d18O and d2H values, respectively. In the light of the moderate correspondence between nitrated cellulose and cellulose, and of the analytical protocol (only one standard, memory effects not dealt with, peak jumping), it seems hardly conceivable that the d2H precision and accuracy would

be of 1‰ it is likely no better than 3‰Ėven with limited effects from OH-exchangeable fraction, the analytical precisions are rarely better than 2‰ (Filot et al., 2006; Sauer, 2009). (2) We agree to your comments in the sense of absolute accuracy. But, in this study, we only discuss about relative variations in d18O and d2H, and the measured cellulose d2H values in this study is affected by unknown OH-hydrogen d2H values which are constantly exchanged with experimental water during the cellulose extraction process, so that we do not discuss about the absolute accuracy but describe only the reproducibility of measurements here. (3) In order to avoid the misunderstandings on the VSMOW values of d2H, we explain this strategy briefly in Section 2.

(1) Equations 1 and 2 – The ‰ sign should be on the left of the equations, near the delta notation. Otherwise, ‰ x 1000 implies no change in the reported values. (2) Thank you for your comments. (3) We will modify those equations according to your comment.

(1) Lines 112-113 - Why all the cellulose samples could not be nitrated? Not enough material extracted from wood? The authors decided to follow an alternative approach, not clearly defined (temperature, time of equilibration), but apparently different than the Filot approach, so that their cellulose and nitrated cellulose only show correlations (r) between 0.74 and 0.77, which is significantly lower than the correspondence obtained using the rigorous protocol of Filot et al (0.94). This compromise is not ideal when producing d2H series destined to climatic reconstruction. (2) As we mentioned above, we did not nitrate cellulose samples in order to same time and sample amounts and measure their d2H and d18O simultaneously. If we nitrated more than 10,000 samples in this study, we could not finish their measurements within a practical research period. In fact, the correlations between nitrocellulose d2H and cellulose d2H in this study were lower than that by Filot et al (2006). However, those correlation coefficients (0.77, 0.77) mean that we can infer d2H variations to a certain degree even using our method, and the fact that there are significant correlations between d18O and d2H in Fig.4c, 5c and Fig.9 suggests that we can obtain climatologically significant signals even using our

method. (3) As we mentioned above, we will explain carefully about our strategy of d2H measurement in Section 2.

(1) Lines 118-119 – The authors should revisit this statement and write with more nuance, because they sacrifice on the reliability of the d2H series by analysing cellulose instead of nitrated cellulose, or by apparently using an alternative protocol that unfortunately does not perform as well as previous equilibration protocols documented in the literature (Filot et al., 2006; Sauer, 2009). (2) Thank you for your comments. (3) As you point out, we will mention here more carefully about the possibility that the lower accuracy of d2H measurement in this study influence the data analyses.

(1) Lines 119-121 – The memory effects are well known when dealing with online pyrolysis systems, and there are several ways to avoid analytical artefacts due to them. Possibilities include placing a blank (empty capsule) between each samples in the carousels, or analyzing samples in triplicates, or a combination of the two approaches, etc. The appropriate analytical protocol with the instrument should be decided upfront, prior to producing the results. Unfortunately, again, the authors underline the issue after conducting all analyses, but truly this issue could have been easily dealt with prior to producing the isotopic series. (2) We understand several methods to reduce the memory effect as you recommend. However, if we apply triplicate measurements for individual tree-ring cellulose and insert empty capsule between different samples, the total period necessary to finish more than 10,000 tree-ring measurements becomes 3-4 times longer. It seemed obviously unrealistic. In this study, the main research target is d18O, and the d2H is just used to remove long-term physiological effects in the d18O variations, so that we set the analytical conditions of tree-ring cellulose isotope ratios to maximize the efficiency of d18O measurements. (3) In Section 2, We will explain why we could not use methods to minimize the d2H memory effect briefly.

(1) Lines 125-129 – This text and Figure 3 do not inform the reader about the distribution of the wood types. Which isotopic series derive from buried pieces of wood? Departures from real values are reported to occur for altered cellulose/wood (Yapp,

2001; Mancini et al., 2003; Savard et al., 2012). Mancini, S.A., Ulrich, A.C., Lacrampe-Couloume, G., Sleep, B., Edwards, E.A., Lollar, B.S., 2003. Carbon and hydrogen isotopic fractionation during anaerobic biodegradation of benzene. Applied and Environmental Microbiology 69, 191–198. Yapp, C., 2001. Rusty relics of earth history: iron(III) oxides, isotopes, and surficial environments. Annual Review of Earth and Planetary Sciences 29, 165–199. Savard, M. M., Bégin, C., Marion, J., Arseneault, D., and Bégin, Y., 2012. Evaluating the integrity of C and O isotopes in sub-fossil wood from boreal lakes, Palaeogeogr. Palaeoclim. Palaeoecol., 348–349, 21– 31. (2) Thank you very much for introducing many papers on the effect of microbial wood degradation to their isotope ratios. You can see the "wood types" of all analyzed wood segments in Table 1. As for the description in Fig.3, all data before 5th century AD are owing to buried woods so that we don't think that it is meaningful to use different colors depending on wood types in Fig. 3. All woods analyzed in this study are conifer woods those are not affected by microbial degradation, and moreover, we have confirm that our method of cellulose extraction can provide us of original cellulose isotope ratio even in the case of seriously degraded hardwood samples by comparison of isotope ratios of extracted cellulose between degraded part and undegraded part in a wood segment, so that we think that our data are not influenced by microbial alteration of wood isotope ratios. (3) In Section 2, we will explain that our samples and methods can provide us of cellulose isotope ratios unaffected by microbial activities by referring related papers.

(1) Lines 129 – What are the indications that these are age trends? Are trends visible on all Individual tree segments prior to combining them? Or are they visible after combining them? In the later case, the authors should consider discussing the possibility of an artefact to the treatment of the data. (2) In this paper, we use the words "age trend" just to indicate apparent long-term trend in the tree-ring isotope ratios, showing that the d18O gradually decreases with ages in most trees (Fig.3a). In fact, the long-term decrease in d18O is corresponding to that in the tree growth rate (tree-ring width), and the d18O sometimes increases suddenly even in old trees if the growth rate increases suddenly due to some environmental disturbances as shown in Fig. 4 and 5. And

of course, if a long-term climate signal such as gradual drying overlaps the long-term d18O trend, we cannot see the apparent d18O decrease in that case. Therefore, both of your two questions are not right. All individual tree segments do not necessarily have the age trend, but most of them have the apparent age trends, and after combing all data, there remain the long-term age trends. Of course, it is not an artefact. (3) At the first appearance of the words "age trend" in the manuscript, we will define the meaning in this paper exactly.

(1) Lines 136-139 – The authors clearly state here why their d2H series are not reliable or suitable for climatic reconstruction. Ideally, they should not be used in the following parts of the article (or in the article). (2) We think that there are two possible reasons why R-bar in d2H is lower than that in d18O. One is the possible lower accuracy of d2H measurements in this study that we mentioned here. The other is the more complex mechanism in the post-photosynthesis isotope exchanges with xylem water for hydrogen than for oxygen as Roden et al (2000) described. Given that most of samples in this study are randomly affected by human perturbations, the complex nature of post-photosynthesis d2H alterations may lower the R-bar among tree segments in this study. (3) We will add the second reason in the revised manuscript.

(1) Section 3.2 – The entire discussion about the supposed 'age trends' is misleading. What are the arguments supporting this interpretation? If growth rates correlate with d2H and d18O, inversely and directly, what are the most logical environmental reasons for that? Why do d2H and d18O trends inversely correlate (assuming that the d2H trends reflect something real)? Any possible mechanisms in teleconnection that could explain coeval long-term changes in the three proxies (growth, d2H and d18O)? (2) The "age trends" in this paper is corresponding to the apparent long-term gradual decreases in d18O, which have been frequently discussed in Esper et al. (2010) etc. However, we think that "apparent age trend" is not "real age trend" but caused by a physiological mechanism that the rate of post-photosynthesis isotope exchange with xylem water (f-value in this paper) gradually increase with age in some conifer trees.

We also suppose that the increase in f-value is caused by the decrease in growth rate with age. This is a new hypothesis, but we think that it is sufficiently reasonable due to the following two reasons. 1) There are often opposite long-term trends between d18O and d2H variations, as shown in Fig. 3, 4 and 5, which can be explained systematically only by the change in f-value as shown in Roden et al (2000). 2) In most cases when d18O and d2H suddenly changes to opposite directions in old trees, the tree-ring width also drastically changes, suggesting that the drastic changes in tree physiological conditions occur and cause the change in f-value through some biochemical mechanisms such as change in the utilization rate of stored carbohydrate for cellulose synthesis. Although this phenomenon has not been discussed in the tree-ring studies, we have already published a paper on tree physiology to demonstrate the existence of this mechanism by comparison of intra-ring variations in cellulose d18O and d2H (Nabeshima et al., 2018). (3) We have already described the mechanism in detail in Section 3.2, but the understanding of this mechanism is definitely the essence of this paper. Therefore, we will expand the explanation more carefully in Section 3.2.

(1) Lines 214-215 – It seems that the sites selected for this research are not suited for climatic reconstruction. (2) We cannot accept this comment as mentioned above. Because this is the most important characteristic of this paper, we will answer to this comment again. So far, dendroclimatologists have been thinking that trees exposed to human perturbation are not suitable for climate reconstruction. However, there are only few regions in the world where millennial length of non-human perturbed wood samples can be collected, such as Arctic region, mountainous regions in America and Eurasia etc. In most of other areas like Mediterranean and East Asian regions including Japan, where climatic influences to human history should be investigated using high-resolution paleoclimatological records over last several millennia, purely natural forests had already disappeared more than a few millennia ago owing to the intense logging activities by human beings. For the tree ring study in those areas and periods, most of wood samples are buried wooden artefacts excavated from archaeological remains, where human activities inevitably influenced the wood formation. Therefore, we

believe that it is very important to establish a new sophisticated method for reconstruction of past climate variations using woods exposed to human perturbations in order to develop paleoclimatology in the world. The method proposed in this study is exactly to contribute to that purpose. Hence, we cannot accept this referee's comment at all, because this comment does not fit the real purpose of this study and prevents us from contributing to the development of paleoclimatology in Japan and many other regions in the world. (3) In Section 1, we emphasize that in this study, we develop a dendroclimatological method to utilize woods exposed to human perturbations effectively.

(1) Lines 251-252 & Eq 18 – The physiological effects does not always generate a negative relationship between d2H and d18O series. Is it not right? (2) Thank you for your comments. Of course, as you point out, all of physiological mechanisms do not necessarily change the d2H and d18O to opposite directions. The physiological effect defined in this study is related only to the changes in the rate of post-photosynthesis isotope exchange with xylem water before cellulose synthesis (f-value). Other biological mechanisms related to "age effect" such as "root deepening" are not considered in Eq.18, so that they are unfortunately added to the climatological component in Eq. 17, if such mechanism actually exists. Here, we propose the method to remove the physiological component from d18O variations based on the assumption that physiological effects other than "change in f-vale" are negligible. (3) In order to avoid misunderstandings, we will clearly explain that we focus only on the changes in the post-photosynthesis isotope exchange with xylem water (f-value) as the cause of physiological influence to the tree-ring d18O and d2H variations.

(1) Lines 258 & 267 – Using constant A and B values implies multiple big assumptions. (2) We deeply agree to your comments. In fact, adequate A and B values may be different for different individual trees, and it may become possible to propose different A and B values for individual trees by some sophisticated methods in near future. However, in this paper, we decided to fix A and B values constant according to the flowing reasons in addition to the convenience in calculation procedure already described in the text. 1)

The method integrating d18O and d2H to extract climatological components proposed in this paper is a totally new one and very complicated even in the present condition. If we add the procedure to set different A and B values for individual trees in this paper, the paper become lengthier and cannot be understood easily. 2) We think that it is meaningful to investigate the resultant long-term variation in climatological component of d18O extracted using constant A and B values as their simplest cases at first in order to develop this method further. In fact, as we demonstrate in Section 3.11, the resultant long-term variation in climatological component of d18O are well corresponding to those in other lower-resolutions of paleoclimate proxies, suggesting that the assumption of constant A and B values has proven realistic to a certain degree. We anticipate that it promotes the participation of many other researchers to the study of the d2H and d18O relationships. (3) We will explain more in detail about the reason why we set A and B constant here.

(1) Line 296-298 – Another big assumption that this simple combination cancels out the inter-tree average offsets. (2) Thank you for your comments. The biggest assumption in Line 296-298 is related to the determination of B value in Fig. 10. But the inter-tree average offset itself can be cancelled out explicitly by the method described in Fig.6. (3) We will make clearer the meaning of assumptions here.

(1) Section 3.7 – How can the authors attest that this approach does not generate artefacts at the point of junction between series (e.g., Gagen et al., 2012). Gagen, M., McCarroll, D., Jalkanen, R., Loader, N. J., Robertson, I., and Young, G. H. F., 2012. A rapid method for the production of robust millennial length stable isotope tree ring series for climate reconstruction, Global Planet. Change, 82–83, 96-103. (2) Thank you for introducing a paper. As you can see in Fig.6, the iterative calculation in the averaging and offsetting method finally makes a combined time-series where its averaged d18O value during the period corresponding to an individual tree segment becomes equal to that of the offset d18O variation of the individual tree segment. If you start from the same original dataset on d18O variations of tree segments, the

pattern of relative variation in the final combined d18O time-series is mathematically unique although its absolute value has no meaning. That is, there is no room where some artefact influences resultant time-series. (3) We will add this explanation briefly in Section 3.7.

(1) Section 3.8 – It seems that there are several short cuts slid in the procedure for attempting to correct for limitations introduced by the analytical approach (lines 367-371). Since there is no true comparison with a fully rigorous approach, the assessment of the procedure is impossible. The comparisons made with reconstructions from other proxies show significant departures and do not allow assessing the proposed procedure (section 3.11). (2) As illustrated in Fig.4 and 5, the physiological effect, defined in this study, influences to the low-frequency component of d18O only, so that it is not necessary to integrate d2H and d18O in the high-frequency component for removal of the physiological signals in d18O. If the lower R-bar in d2H is caused by its low analytical precision due to non-nitration and/or memory effect, we can assume that it influences the d2H data randomly, so that smoothing of d2H data to make low-frequency d2H variation can minimize the negative effect of the lower precision of d2H measurement. That is the reason why we selected the calculation procedure in Section 3.8 (Fig. 7). Given that all low-frequency paleoclimate reconstructions referred in Section 3.11 were obtained from different spatial scales using completely different proxies, it is reasonable that there are some discrepancies from the result obtained in this study, but the overall similarities in the low-frequency components suggest that there are certain significances in the dataset and calculating procedures in this study. (3) In order to make clear the meaning of calculation procedure in Section 3.8, we will revise the sentences carefully.

(1) Line 359 – Note clear... as: : : Please rewrite. (2) Thank you for your suggestion. (3) We will rewrite the sentence carefully by adding words to make it clear.

(1) Lines 394-396 – The idea is with paying attention, but unfortunately, the basic sampling and analytical procedures selected for this research are not rigorous enough to al-

low evaluating the approach in this article. (2) As we mentioned above, one of the most important purpose of this study is to propose a method to reconstruct multi-millennial climate variations using wood segments highly affected by human perturbation. In order to analyze both d18O and d2H of more than 10,000 tree-ring cellulose samples within practical research period, we needed some compromises on the analytical procedures, but the sampling strategy of woods exposed to human perturbation was not an unnecessary fault but the essential part of this study. However, as you mention, there remain many points which should be improved for further development of this method. (3) According to your comment, we will rewrite the sentence more carefully.

(1) Table 1 and Figure 2 – It seems that the term 'sample' here refers to stem segments. (2) Thank you for your suggestion. (3) We will replace the word according to your suggestion.ãĂĆ

(1) Figure 2 – 70% line? Not clear what it is and what it means? (2) Thank you for your suggestion. Yes, it is not clear. (3) We will delete the word "70% line" in the figure and add the explanation of the line in the figure legend.

(1) The number of figures is high; perhaps some of them would find a better place in a supplement of information, for examples figures 9, 13, 14. (2) In fact, there are many figures, but we think that all of Figs 9, 13 and 14 play important roles in this paper. So, if possible, we want to leave all figures at the position near the corresponding text. (3) If the editor of CP decides that those figures should be moved to the supplement part, we will obey the instruction.

That is all. Thank you very much for your valuable comments.

Interactive comment on Clim. Past Discuss., https://doi.org/10.5194/cp-2020-6, 2020.

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Discussion paper