Anonymous referee #1

R: We thank the anonymous referee #1 for the time and effort in reviewing our manuscript (cp-2020-39). The comments, suggestions and feedback raised in the review are highly appreciated as they help us to clarify our statements and to improve the quality of our manuscript. Below you will find a point by point response (*reviewer*, response).

By analysing a European network of 26 tree-ring sites with δ18O measurements, the authors aim at extracting regional climate signal imprinted in the records to investigate the dominant modes of variability of the European climate and their relationships with the large-scale atmospheric circulation, in particular ENSO. Their findings suggest that climate variability in Europe is strongly modulated by ENSO teleconnections at least over the past 130 years, but that some differences arises between the northern and southern regions.

Although the results are promising, I do not think the manuscript is ready for publication yet. A restructuration and reorganisation of the paper is strongly needed. While the introduction is relatively well written and easy to follow, many confusions arise from the Material and Methods section and some clarifications are required to allow the readers to easily understand why and how the proposed analyses were made. The division of the 'Results and Discussion' section into two separate sections should improve the readability of the manuscript. It seems that the authors have not carefully re-read their manuscript to check for typos and ensure that the text is fully understandable before submitting it. The authors also should make an effort to properly, clearly and thoroughly discuss their results and their implications for the understanding of the atmospheric teleconnections. So far only in the Summary and Conclusion section are the results clearly highlighted and interpreted.

R: We are glad that the results are promising, and we agree with the reviewer that structural changes are necessary. We agree that the "Material and Methods" section has potential for improvement. Therefore, the "Material and Methods" section will be extended by a more detailed description of the isotope measurements (e.g. the used measurement technique, sample site). Furthermore, we will extend our description of the used climate data including the used ENSO indices and the SST dataset, and we add more argumentation why we used the specific datasets (e.g. the usage of the ensemble mean of NOAA-CIRES Twentieth Century Reanalysis (V2c) (Compo et al., 2011)). Moreover, the uncertainties were highlighted more prominently in the method section as well as in the discussion. We agree that we should

extend our discussion and separated it from the results chapter. The interpretation of the results will be worked out in more detail.

Some additional comments and suggestions:
L20: 'may not be stable. . .'

R: We will add the missing word.

L42-43: Actually, it is the other way around: δ18Ocel depends on δ18OSW but δ18OSW itself does not depend on δ18Ocel. Please rewrite.

R: Thank you for the comment! We will change it in the revised version of the manuscript.

L55-56: You could also cite more papers showing the potential of δ18Ocel for reconstructing large-scale patterns of climate variability (since it is one aim of your study), e.g.: Brienen, R. J. W., Helle, G., Pons, T. L., Guyot, J.-L., Gloor, M., Oxygen isotopes in tree rings are a good proxy for Amazon precipitation and El Niño-Southern Oscillation variability, PNAS, (42) 16957-16962; DOI: 10.1073/pnas.1205977109, 2012 Lavergne, A., Daux, V., Villalba, R., Pierre, M., Stievenard, M., Srur, A. M., Vimeux, F., Are the δ18O of F. cupressoides and N. pumilio promising proxies for climate reconstructions in northern Patagonia?, J. Geophys. Res.-Biogeo., 121, 767–776, https://doi.org/10.1002/2015JG003260, 2016.

R: We will integrate the suggested references and further references, which are using $\delta^{18}O_{cel}$ for the reconstruction of large-scale climate patterns, in the revised version of the manuscript.

L76-77: I am not sure what is the meaning of this sentence. Please rewrite. L75-80: I would suggest clearly rewriting this part as it is difficult to read. You should get right to the point: how are you going to achieve your goals? What are the main analyses you are going to perform to reach those goals?

R: We will rewrite the last paragraph of the introduction according to the suggestions of the reviewer. Especially, we will shortly mention the analysis technique which is used to achieve the mentioned goals.

L94-96: Please comment on the implication of only using latewood for oak but both early- and late- woods for the coniferous species. Are you suggesting that earlywood in the coniferous species is only derived from carbohydrates formed during the current year? Please rewrite the sentence accordingly.

R: Basically, trees form their annual ring from current assimilates and reserves (starch and fats). The used carbohydrates come from a pool which, depending on the season and the rate of assimilation during the vegetation period, is in part clearly dominated by reserves from the previous year(s). Since the conifers of the isotope network are evergreen, the proportion of the reserves used for wood accumulation decreases rapidly at the beginning of the earlywood formation and is usually not as high at the beginning as in the case of the deciduous oak trees utilized here. Therefore, we don't suggest that earlywood is only derived from carbohydrates formed during the current year for coniferous. However, oak is a ring-porous tree species known for having its earlywood growth almost completing before the leaves are fully green and net photosynthesis is positive. Hence, for this species it makes sense to skip earlywood as it is rather easy to distinguish from latewood. On the other hand, it is difficult to identify a clear boundary between the early- and latewood of conifers without technical means of quantitative wood anatomy. We will rewrite the sentence and add the mentioned short explanation.

L100-101: "Here" is repeated twice in the sentence. Furthermore, the sentence is not grammatically correct. Please be more careful!

R: Thank you for the comment. We will correct it in the revised version of the manuscript.

L108-109: what is the COBE-SST2 dataset? Please describe it here. Also, which index of ENSO are you using to define El Niño/La Niña years?

R: The COBE-SST2 dataset was created by Hirahara et al. (2014) and it is based on in situ sea surface temperature (SST) and sea ice concentration (SIC) observations. The monthly SST fields are provided by NOAA/OAR/ESRL PSL, Boulder, Colorado, USA and can be downloaded from https://psl.noaa.gov/data/gridded/data.cobe2.html. For detailed information about the used methods and the uncertainties, we refer to the publication of Hirahara et al. (2014). Furthermore, we used the anomaly (1981-2010 mean removed) of the December Nino 3.4 index (HadISST1; Rayner et al., 2003). The index represents the averaged SST from 5°S-5°N and 170°-120°W and can be downloaded from https://psl.noaa.gov/gcos_wgsp/Timeseries/Nino34/.

We agree with the reviewer that the used SST dataset should be explained more in detail and also the ENSO index shall be presented in this subchapter. These points will be changed in the revised version of the manuscript.

L114-116: What is a 'nudge model scenarios/simulation'? It is not clear why you choose this title for the section. I would recommend combining sections 2.2 and 2.3 instead. How using both

δ18OP and δ18OSW will inform you about 'fractionation/ photosynthesis processes'? You will never get insights into the fractionation processes occurring during photosynthesis using only those two timeseries! Please clarify.

R: We agree with the reviewer that more information is required to understand why we used the simulations. In general, the name of the chapter is given based on the method which produces $\delta^{18}O_P$ and $\delta^{18}O_{SW}$ (in our case the nudged model simulations from Butzin et al. (2014)). Our goal with the model output is to test the correlation between $\delta^{18}O_{cel}$ and modelled $\delta^{18}O_P$/$\delta^{18}O_{SW}$ to identify if the water, which is used within the photosynthesis processes, has a multi-seasonal isotopic signature. If yes (as shown in our plots), it is an explanation how $\delta^{18}O_{cel}$ is able to capture the ENSO signal. Our results are of interest to the community because a significant ENSO influence of the European climate have been identified for winter (Fraedrich and Müller, 1992; Fraedrich, 1994; Pozo-Vazquez et al., 2005; Brönnimann et al., 2004; Brönnimann et al., 2007) and spring (Brönnimann et al., 2007; Lloyd-Hughes and Saunders, 2002; Helama et al., 2009). Since the captured climate information of the $\delta^{18}O_{cel}$ network mainly reflects the summer season, our correlation analysis suggests that $\delta^{18}O_{cel}$ is able to capture multi-seasonal climate signals through hydrological processes (soil moisture and soil water content) and therefore, can also contain a winter/spring climate signal.

L123-131: What is the difference between EOF and PCA? From my understanding of those analyses, EOF and PCA are really similar. Are you suggesting that EOF provides information about spatial patterns, while PCA gives information about temporal patterns? The whole paragraph is confusing (especially the filtering actually done to fulfil the North et al. (1982) rule), please rewrite.

R: Overall the PCA and EOF technique are related, but differences exist and both abbreviations are often mixed up. Yes, the PCA provides information about the temporal pattern and the EOF gives information about the spatial pattern. After this paragraph we will add a simple explanation about PCA and EOF analysis. In the revised version of the manuscript, we will rewrite the entire section and clarify the differences of the two techniques. Additionally, we will mathematically describe the North et al. (1982) rule.

The concept of the Principal Component Analysis (PCA) was firstly described by Pearson (1902) and Hotteling (1935) and used for the first time by Lorenz (1959) for climatological research (Storch & Zwiers, 1999). The general aim of the PCA is to find a new set of axes which explains the most of the variability within the dataset. This is done by rotating the initial data onto axes which are orthogonal to each other (Schönwiese, 2013). For this purpose, a vector is necessary which indicates the direction of the new coordinate axis which is called

eigenvector. This type of vector doesn't change its direction by a rotation. Therefore, the eigenvectors are used as a transformation matrix for the input high dimensional datasets onto the new axis. To indicate if a rotation maximizes the explained variance, every eigenvector has a corresponding eigenvalue. The corresponding eigenvalue is a kind of stretch factor for the eigenvectors. A huge eigenvalue indicates that the eigenvector has to be strongly stretched to map high variabilities within the dataset which can be explained with the new set of axes. Therefore, the eigenvalue (λ) is equal to the variance of the time series ($\vec{X}$) from matrix M which got rotated by the corresponding eigenvector ($\vec{e}$) (Equation 1).

$$Var\left(\langle \vec{X}, \vec{e} \rangle\right) = \lambda \quad (1)$$

To find a first set of eigenvalues and eigenvectors, the data is rotated until an axis can be defined which explains the highest variance. Storch & Zwiers (1999) described this with the effort of minimizing ϵ_1 respectively to maximize $Var(\langle \vec{X}, \vec{e}^1 \rangle)$(Equation 2).

$$\epsilon_1 = Var\left(\vec{X}\right) - Var(\langle \vec{X}, \vec{e}^1 \rangle) \quad (2)$$

Finally, the rotated data forms the first component. Like in a traditional coordinate system, it is possible to calculate a new axis which is orthogonal to the first one. Therefore, the second component is formed by an orthogonal rotation around the axis of the first component. The total number of components is given by the absolute number of time series. To compute the time series for the first component, the e.g. first value of all input time series is multiplied with the individual eigenvector and afterwards, summed up over all time series for each year. This process forms the time series of a principle component which has the same temporal coverage as the input time series.

Especially a separate analysis of the eigenvectors of $\overrightarrow{X}$ is commonly used. This analysis is known as Empirical Orthogonal Functions (EOF) and the goal of it is to identify spatially coherent climate patterns which explain a significant part of the variance for a specific region (this is shown and used for example in Ionita et al. (2008)). Therefore, the largest part of the variance can be explained by the pattern of the leading EOF.

L132-133: Why are you mentioning this here? It should be already stated in Section 2.1.

R: It is mentioned here again to explain why we used the filling algorithm of Josse and Husson (2016).

L133-140: How can you be sure that by using the gap fill method, you will not influence your results? Also, why would you need to fill in the gaps for 400 years knowing that your climate data only goes up to 1851?

R: Since the used climate data is only available from 1851, the advantage of using the presented tree ring network is to go beyond this time scale and to introduce a new perspective on the observed relationship between $\delta^{18}O_{cel}$ and ENSO activity back in the past. If we want to go back in the past the filling algorithm is necessary because the temporal coverage of the $\delta^{18}O_{cel}$ records are different as described in the "Material and Method" section.

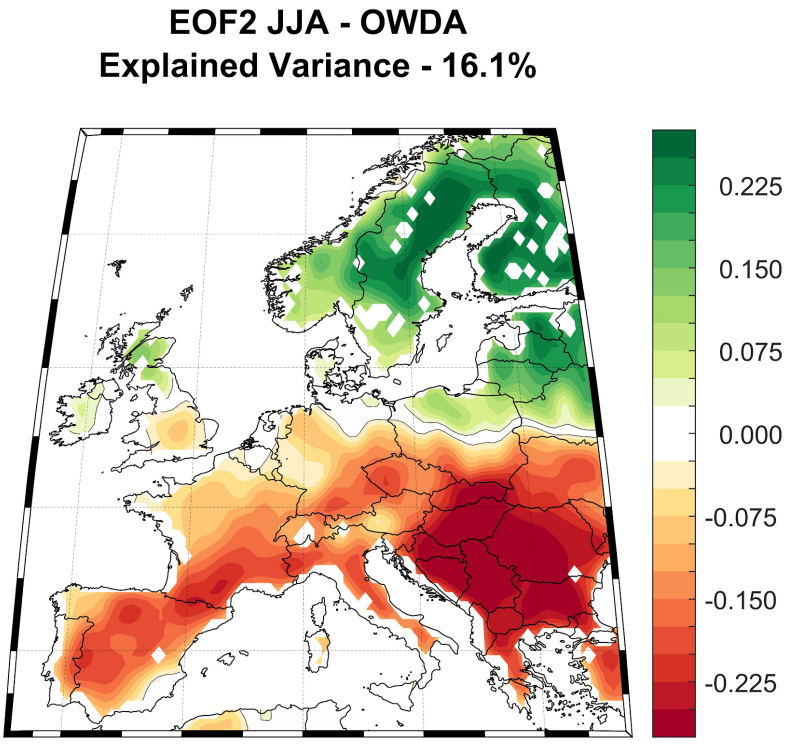

Figure 1: The EOF for the second component of the OWDA (Cook et al., 2015) for JJA which explains 16.1% of the variance.

To test if our results are influenced by the gap filling method, we tested the correlation with the reconstruction with summer wetness and dryness reconstruction from the Old World Drought Atlas (OWDA) which was developed by Cook et al. (2015). At first, we investigated the correlation between the first 4 PCs for JJA with the PC1 of the isotope network for the period 1850 to 2005, where we have closely the highest sample density. The highest correlation is detected with the PC2 (EOF plot below) of Cook et al. (2015). The component is explaining 16.1% of the variance (very similar to the explained variance of the first component of the isotope network) and the correlation is characterized by Pearson's R=0.43 and p-value=3.1e^-08. If we test the correlation for the entire period 1600 to 2005, it would be expected that the correlation is strongly changing in the case that the filling algorithm is influencing the representation of climate signals. In our study, the correlation is only slightly changing to Pearson's R=0.39 (p-value=4.2e^-16) which indicates that the influence of the filling algorithm on the results is not so strong, because climate signals are presented in a

similar manner as in comparison for the period with a high sample coverage. Nevertheless, we have to consider the uncertainties based on the used gap filling method, especially for the first decades where the sample density is low. Therefore, the interpretation of the first decades have to be handled with care and is not pronounced in our manuscript.

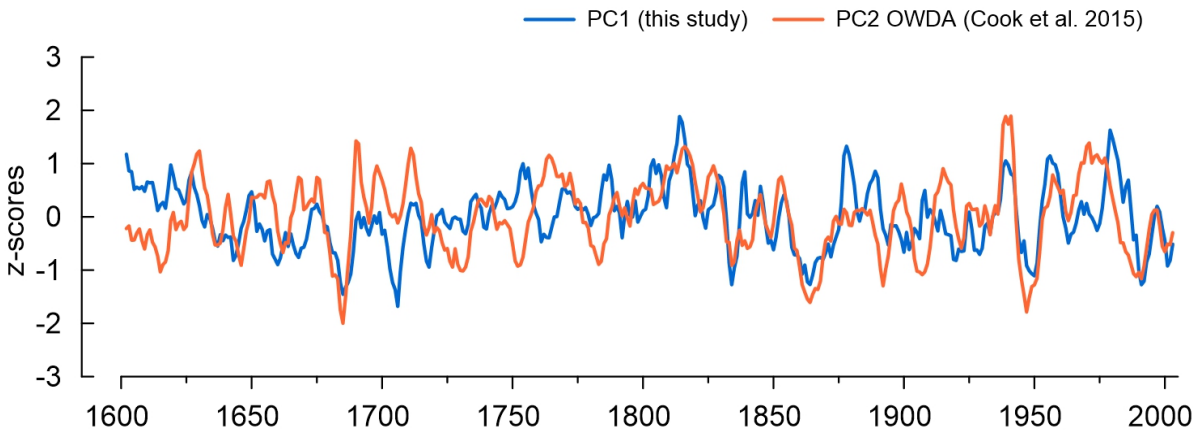

Figure 2: Comparison of the time series of the first component of our study and the second component of the OWDA (Cook et al., 2015) for JJA.

L141-146: What do you mean? The whole paragraph is pretty confusing and after reading it several times, I still do not get what you are really doing here.

R: We will try to explain the technique behind the composite maps. In the next version of the manuscript, we will rewrite the explanation of composite maps for a better understanding. This will also make it easier to investigate the presented results of the composite maps for readers.

What kind of information is providing the geopotential height 500mb (Z500) for the analysis?

R: The geopotential height is a standard variable in atmospheric sciences which is often represented in contour maps with isohyets. They connect places at the same altitude at which a certain air pressure (here 500 hPa which is on average 5500 meters high) prevails. This height is called geopotential in meteorology. With the differences in the geopotential height maps, it is possible to identify low- and high-pressure systems based on the different pressure patterns as for example shown in Figure 4. From the Z500 maps, the wind direction can be determined which is helpful for the understanding and the investigation of large-scale flows in the atmosphere. A big advantage of this variable is that the influence of friction at the surface and the influence of dynamic disruptive factors of the upper layers of the atmosphere, e.g. the Jetstream, are relatively minor.

L151: 'Nino 3.4 index' this should come earlier in section 2.2 when you are presenting the environmental data used in the analyses.

R: We agree with the reviewer and we will add more information about it in the "Material and Method" section (see above).

L158-160: The first sentence does not provide any clear information. Please remove.

R: We will follow the suggestion of the reviewer and remove the sentence from the manuscript.

Figure 1: Could you add more information in the figure A related to the latitude of each site? The names and characteristics of the sites are not presented anywhere in the manuscript. Even though the data have already been published, a Table with sites information should be included. In figures B and C, how is it possible that R2 and p-value are exactly the same for the relationships between δ18Ocel and altitude and between δ18Ocel and latitude? I suspect that there is a mistake here.

R: We agree with the reviewer that more information about the sample sites would be helpful. Therefore, we will add a table with the coordinates, tree type and altitude for each site in the revised version of the manuscript. Furthermore, the reviewer is right that there is a mistake within the textbox of Figure 1B (should be R^2=0.417 and p-value=2.17e^-04). We will correct it in the new version of the manuscript.

L160-161 and L172-173: Since no information about the exact location of the site presented in Figure 1A is provided, it is difficult to follow this statement.

R: We agree with it. It will be easier when the table with the site characteristics are included.

L162: I would remove 'This might be determined genetically,' from the sentence as it is not completely accurate (different species of Quercus also have different genetic information).

R: We thank the reviewer for that suggestion, and we will remove that part.

L165: You could also cite more updated papers describing differences between an giosperms and gymnosperms, e.g.: Carnicer J., Barbeta A., Sperlich D., Coll M., Penuelas J., Contrasting trait syndromes in angiosperms and conifers are associated with different responses of tree growth to temperature on a large scale, Front. Plant Sci., 4, 409, https://doi.org/10.3389/fpls.2013.00409, 2013

R: We will integrate the mentioned reference and further references in the revised version of the manuscript.

L177: 'which could influence the relation by a latitudinal effect.' please rewrite as 'thus the latitudinal and altitudinal gradients may have confounding effects on δ18Ocel' or something similar

R: Thank you for the comment. We will rewrite this sentence to make it clearer.

L177-179: I would rewrite this sentence as the effects of the two gradients on δ18Ocel have already been observed and documented in many other studies, for instance: Szejner, P., W. E. Wright, F. Babst, S. Belmecheri, V. Trouet, S. W. Leavitt, J. R. Ehleringer, R. K. Monson, Latitudinal gradients in tree ring stable carbon and oxygen isotopes reveal differential climate influences of the North American Monsoon System, J. Geo- phys. Res. Biogeosci., 121, 1978–1991, doi:10.1002/2016JG003460. 2016

R: We will rewrite the sentence and highlight the findings of previous studies in this field.

L181-186: Here again comes the confusion between EOF and PCA. You should clarify from the beginning (see previous comment) what is the difference between the two especially given that EOF1 and PC1 both seem to explain 16.2% of the variance in the records.

R: We see the point that the differences between EOF and PCA is not well explained and can be confusing. With the explanation above, it will be easier to understand the differences. As mentioned above, we will extend the explanation of the EOF and PCA techniques.

Figure 4: In the legend, you are describing the columns not the rows.

R: Thank you for the comment. We will change it.

L216 Is the distribution of PC1 for El Niño (or La Niña) years significantly different from that during normal years (i.e. when excluding El Niño/La Niña years)?

R: Yes. This is shown in the first figure of the supplement and written from L214 to L216. To make it easier to understand, we will rewrite these sentences in the revised version of the manuscript.

L222-224: Please rewrite the sentence. As it reads now, it looks like you are saying that Europe is characterized by higher precipitation and lower air surface temperatures in summer! And it is not clear what the parentheses apply for.

R: We will rewrite and hopefully improve this part and we will give a short general introduction how to read and analyze composite maps. The changes will make it easier to understand Figure 4 and the argumentation.

L230-231: 'because we to take into account. . .' Why would SPEI3 index accounting for the climate conditions prevailing over the previous season? So far, nothing has been said about this dataset.

L227-233: this part mostly belongs to the Material and Methods section and could be improved for readability.

R: Good point! We will write more details about the SPEI3 dataset within the "Material and Method" section. Furthermore, we will highlight our motivation why we used that drought index.

L235: 'the used reconstruction': which one?

R: We will add another subchapter to the "Material & Method" section to describe the used reconstruction for the comparison within our study.

L240: 'to capture a multi-seasonal signal' what do you mean?

R: We agree with the reviewer that this part is not easy to understand. We will rewrite this paragraph and add further information about the goal and method of nudged model simulations which are listed in our response to the reviewer's comment L114-116.

L243-244: where is it shown?

R: This is shown in Figure 6.

L244-245: so why then δ18Ocel is not more strongly related to δ18Osw? Your argument is contradictory with what is actually described.

R: Thank you for the comment! The referred sentence is difficult to understand and we will re-rewrite and improve it.

L239-248: And so what? What are you really trying to say here? Also, I do not think the results are properly discussed and compared to the literature.

R: As mentioned above, we will extend the description of the performed analysis and rewrite and specify the goals which we want to achieve. Based on that, we will add further information that the main findings are better represented. We agree with the reviewer that

the results should be compared to literature and discussed more thoroughly. In the revised version of the manuscript, we will address and change these points.

Figure 6: You mean the upper row Why description of Figure 6 comes before Figure 5?

R: Thank you for the suggestion. Yes, we do mean the upper row; we will rewrite this caption in the revised version of the manuscript. Also, we will change the order of the figures so that the order is determined by the explanation with the text.

L168-169 and L276: Please rewrite sentences

R: We will rewrite the mentioned sentences.

L236-237: The instability of the relationship between climate variables and ENSO has also been documented by other tree-ring studies in southern South America, e.g: Álvarez, C., Veblen, T.T., Christie, D.A., González-Reyes, Á., Relationships between climate variability and radial growth of Nothofagus pumilio near altitudinal treeline in the Andes of northern Patagonia, Chile. For. Ecol. Manage. 342, 112–121, 2015

R: In the revised version of the manuscript, we will look for further literature in this field and we will integrate the mentioned reference and further references in the revised version of the manuscript.

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