Dear Reviewers and Editorial Review Team,
We are deeply appreciative of your time and thoughtful feedback on the manuscript. We are confident these changes have greatly improved this study of the long-term growth variability in *Polylepis pepei* from a tropical Andes-Amazon treeline. To briefly highlight the major updates in the March 2026 version of *egusphere 2025-2032 Oelkers et al.* :

i.) The *Appendix* figures are now included in the main text after conclusions, per the request from the Editorial Review Team. Originally these figures were uploaded as a separate PDF file November 2025.

ii.) Changepoint analyses has been improved and generated for both the standard and raw tree-ring width chronologies (**see response #14** to reviewer 3).

iii.) We calculated residual correlations between ring-width and detrended monthly and seasonal climate data. The new figures were placed in the Appendix (**see response #15**).

iv.) The figure of the 1960-2015 climate trends for precipitation, and mean, minimum, and maximum temperature at this site was moved from the appendix to Main Figure 4. (**see response #45**)

v.) we added a new Results Section 3.4 entitled *Long-term changes in diurnal climate conditions at the Keara treeline*. The relevant text and appendix figures are included at the **end of this document after response #53**.

Specific point-by-point responses are included below.

On behalf of all co-authors, Thank-you for your consideration of this manuscript for the Special Issue of *Biogeosciences*: "Treeline ecotones under global change: linking spatial patterns to ecological processes". We hope we have addressed your major concerns during this revision process.
Sincerely,

Rose Oelkers
March, 2026

Reviewer requests **are numbered 1-53(**black, Sans-serif font**)**
Author response is indicated in blue
Specific text from the manuscript is included in italics (dark grey font)

Reviewer #2

1.) Despite stating in the point-by-point response that acronyms were removed from the abstract, I still find RW used throughout. Please remove this acronym at least from the abstract; if you wish to keep it in the main text, it should be defined at first use.

We apologize for this. We have now removed all RW acronyms in the abstract. We have opted to use the acronym in the main text and defined it at first use in the Introduction.

2.) Additionally, please check whether terms such as mean temperature (Tavg) and precipitation (Pre) are defined before their first use. In general, reducing the use of acronyms would improve readability.

These terms are introduced in Methods Section 2.1 'Climate Data'. Thanks to this suggestion proposed by both reviewers. The use of climate acronyms is now limited to the methods sections (2.1, 2.6), figures, and figure captions.

3.) Line 380: Repetition of "sea surface temperature"; please correct.
4.) Lines 383–384: Please delete the repetition in "ENSO-related anomalies SST anomalies…".
5.) Line 386: Please write "Polylepis tarapacana".
6.) Lines 387–389: Please correct typos related to missing spaces and missing full stops.
7.) Line 598: Please correct "number".
8.) Lines 603–604: Please delete "extremely" before "cold temperatures".
9.) Line 861: Please clarify what is meant by (radial).

Thank-you we have made the changes requested in #3-9.

10.) Line 977: Please write "51 core samples from 31 trees".

Since there are cross-section samples in addition to cores, we have opted to edit the sentence in the following way (section 2.4):

*Tree rings from **31 trees (51 radii)** were dated visually using standard dendrochronological techniques (Stokes and Smiley, 1968).*

11.) Line 982: Please place the table caption before the table.

This change has been made.

12.) Moreover, do you refer to Rbar as the mean RW correlation?

Rbar ($\overline{r}$) in Table 1 (results 3.1) is defined as the mean intercorrelation among RW series. The updated table and caption are included below.

Table 1. Summary of P. pepei tree-ring sample locations, age, sample size, and mean correlation among RW timeseries. The RW chronologies are composed of the entire collection of cross-dated P. pepei samples from Keara obtained in both 2012 and 2019.

Site	**Location (elevation)**	***n* trees (*n* samples)**	**Mean age [yrs]**	**Timespan**	**Mean Correlation [$\overline{r}$]**
Open-canopy forest (south-facing)	14°40'S 69°06'W (3795-4100 m.a.s.l.)	16 living 2 dead (33)	89	1850-2018	0.53
Closed-canopy forest (west-facing)	14°43'S 69°04W (4000-4400 m.a.s.l.)	12 living 1 dead tree (18)	101	1871-2018	0.44
Full network (mean Raw, standard, residual chronologies)	-	31 (51)	93	1850-2018	0.50

13.) I previously suggested adding DBH; however, considering the low number of trees for which DBH was measured, I suggest reporting this information in the text rather than in the table.

Thanks for your input. We have removed the DBH column, but the information remains in the text for section 3.1 after Table 1.

Reviewer #3

General comments

14.) One of the main concerns is about the application of the change point detection analyses to the raw data (L225) and the fact that there was no clear presentation of the results of this analysis in the proper section. Trends and breakpoints should be analyzed primarily on the detrended chronology in a way that biological growth signals are removed. A 60 years cubic spline was correctly applied to effectively remove individual growth trends, therefore the analysis should focus on the low frequency trend that can still be observed after 1960, especially in the standard chronology. This could be further supported by the climatic information showed in the supplementary. When looking at the climatic variables showed in Fig. A5, time series are clearly reporting a change in the trend after 1960. For these reasons, the narrative of the manuscript revolving around 1997 should be better explained and supported by clear results, and the discussion about the change in 1960 integrated.

We really appreciate this comment. To summarize, we have now done both, included Sen's slope and Mann-Kendall trend analyses on Figure 1, and improved the description in Methods and Results accordingly.

In *Figures P1-P3 below*, we demonstrate why it is beneficial to conduct changepoint analyses on *both* detrended and non-detrended RW. Changepoint detection in the (1) Raw chronology can be used to identify (step) changes in absolute growth related to microsite disturbances while (2) changepoint tests in the Standard chronology may provide insight on a shift in mean variance after low-frequency variability is removed (e.g. macro-site /climate response).

First, to provide some context, original changepoint analyses for the raw chronology were conducted between 1900-2018 when the Sub-sample signal strength (SSS) was >0.85 (see Figure P1 below for SSS visualization).

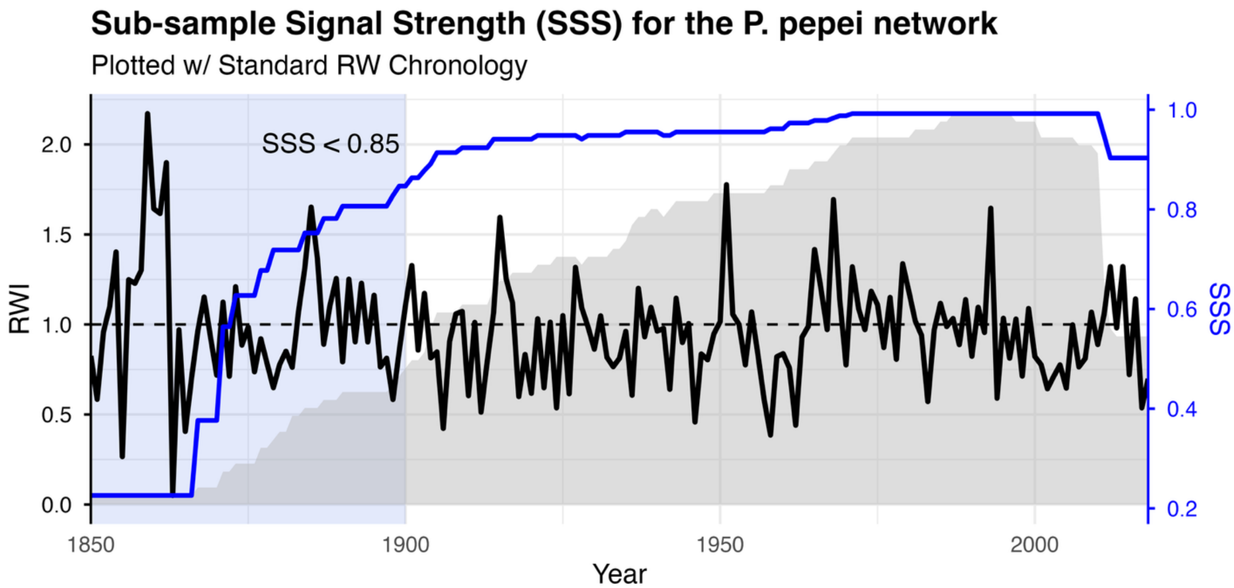

Figure P1. *The sub-sample signal strength index (blue line) was generated using individual RW timeseries, but here it is visualized with the standard chronology (black line).*

Associated text in Methods section 2.4:

The subsample signal strength (SSS) statistic was used to determine how well the available tree-ring samples represent the common growth signal of the P. pepei population (i.e. site)(Cook and Pederson, 2011)[1]. SSS quantifies the strength of the shared variance through time by incorporating the number of cores per tree, the number of individual trees, and the mean interseries correlation among RW series. An SSS threshold of 0.85 (or better) is commonly used in dendrochronology and signifies the years when sample replication is adequate and the chronology is considered robust (see discussions in Buras et al., (2017) and Wigley et al. (1984) for more details). An annual SSS Index was generated using the 'dplr' package in R (Bunn, 2008).

Second, changepoint analyses in the Raw chronology (original analyses) are important for evaluating growth shifts prior to removing the low frequency growth signal. The removed signal could be age-related (biological), but it may also signify an environmental, or microclimate related effect.

In Figure P2 we show an example of how a 60yr age-dependent spline (ADS) behaves for a single RW series with a timespan of 1935-2018 (the average age of the trees in this network is 93 years).Because ADS becomes progressively stiffer with cambial age, it can remove any low-frequency signal (biological, or otherwise; see also **response to # 36** in this document).

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[1] Sometimes dendrochronologists use the SSS to designate a truncation point of the chronology prior to detrending. Since this is the first RW record of *P. pepei* in this area, we have opted to show the entire 1850-2018 timespan.

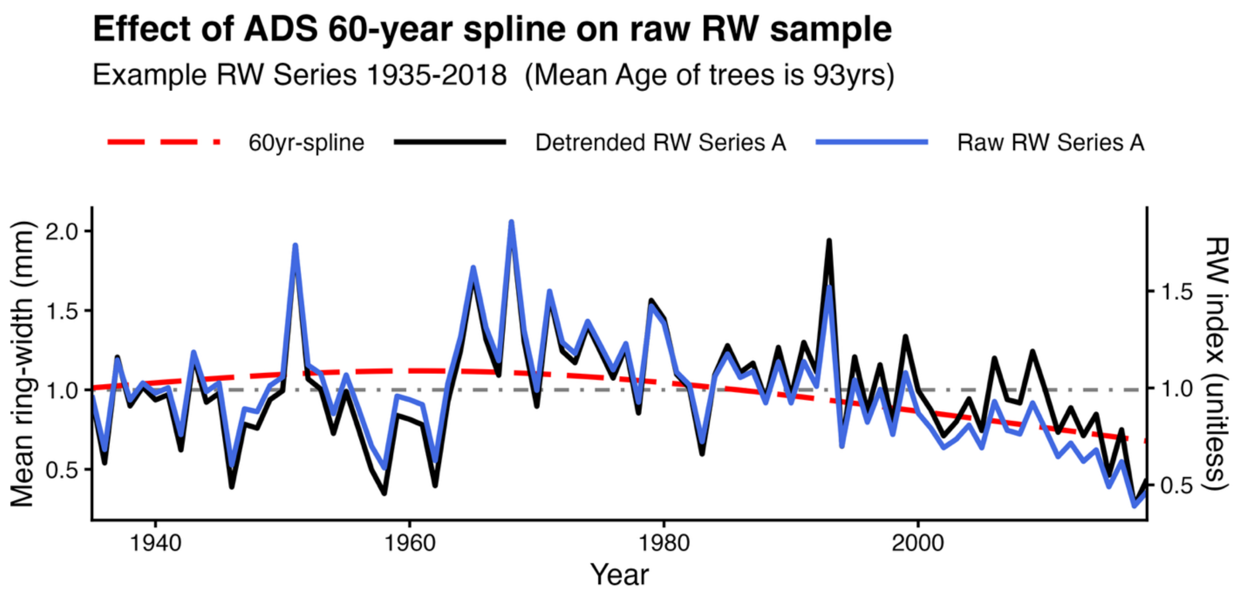

Figure P2. *The fitted ADS curve (red) represents the low-frequency component removed during standardization for this sample. As a result, the declining growth in the late 1990s (blue raw series) is minimized (black, detrended series).*

Third, as described in methods (now new section 2.5) we applied the Pettit's changepoint test using the *trend* package *R* for the period in the chronology when SSS >0.85 (1900-2015). The function evaluates all possible breakpoints and returns **a single year** that maximizes the rank-based difference between observations before and after the breakpoint (lowest p-value).

Changepoint analyses on the raw chronology resulted in a significant changepoint in the 1993/1994[2] growth year and a subsequent negative growth trend beginning in the 1994/1995 growth year. Since analyses was conducted during a period when sample replication was adequate and (SSS), and because both open and closed-canopy populations had the same abrupt shift in raw RW we believe this to be a meaningful result that highlights site-level changes in absolute growth (Raw chronology, **Figure. P3 A below**). This decline in raw growth happens to coincide with an 8.2 magnitude earthquake event in 1994 that was recorded ~150 km east of our site.

Following your suggestion, we have now also conducted changepoint analyses on the standard chronology. Although there was marginal evidence of a step change in 1962 (p=0.06), the long-term negative trend after this year was significant (p<0.001). In summary, *P. pepei* RW significantly declined after 1960 at this treeline at the same time warming and drying trends in the study region were observed. **As a relevant update we have moved the 1960-2015 seasonal climate trends to Main Figure 4 (previously included in the appendix; see the responses to #15 and #45 below).**

[2] In the first version of the manuscript, we did not apply the Schulman convention for RW dates; thus the changepoint dates were written as t+1. The 1997 trend is now correctly written as 1996 throughout the manuscript for consistency.

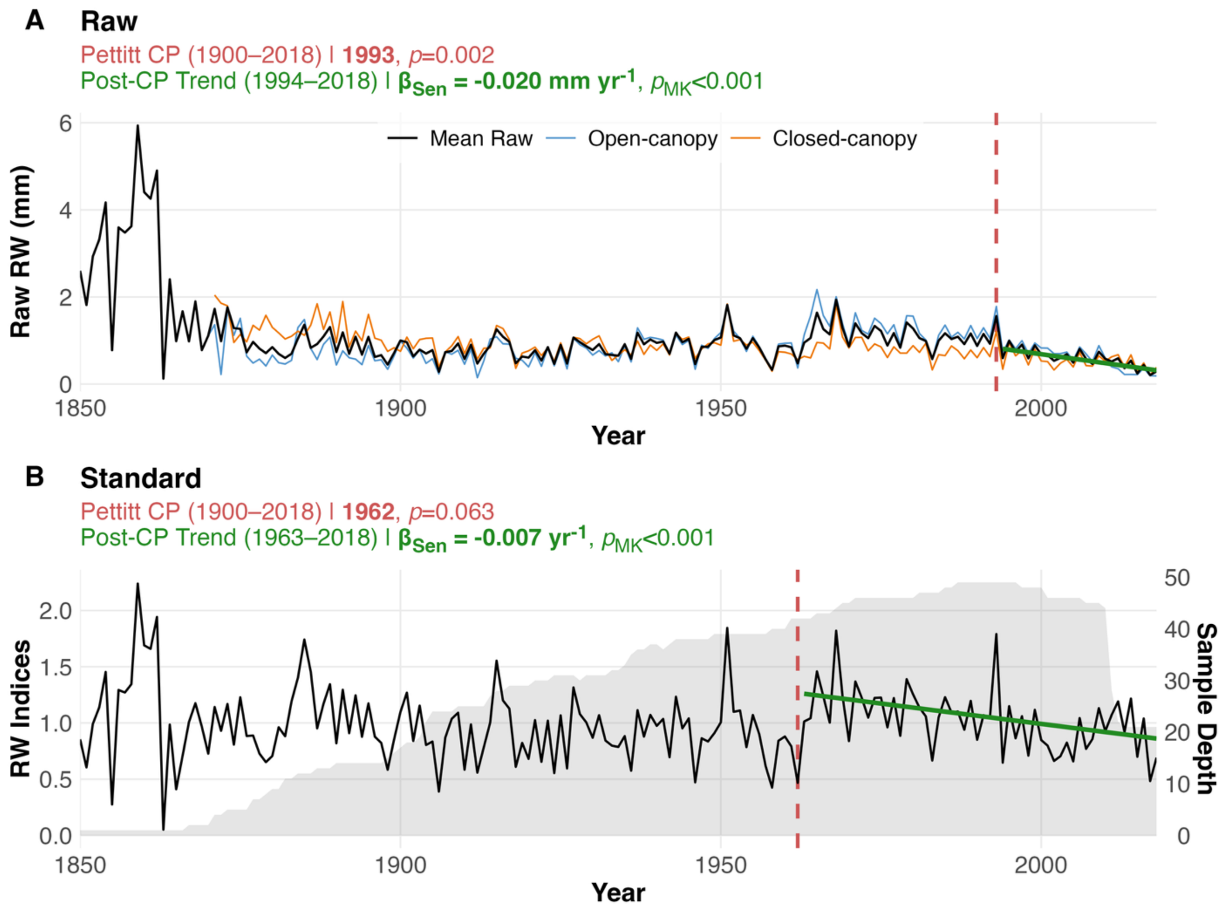

Figure P3. *The raw and Standard RW chronologies from main Figure 2A and 2C. The changepoint is represented by dashed red lines while the Sens slope trend line is solid green. The associated statistics are included as subtitles in the same color.*

15.) In addition, in view of the negative trend after the '60s, CGC correlation should be performed with detrended climate data and detrended RW chronology, to remove the possibilities of spurious correlations.

Residual RW vs. Residual monthly climate correlations are now included in the Appendix (Fig A4) and confirmed the main findings shown by Figure 3 in the main document. While we agree that residual correlations are useful for showing relationships between RW and high-frequency climate variability (Fig A3 below), we also kept standard correlations because they are also necessary to evaluate the long-term influence of mean climate variability on RW. Therefore, the **(1)** standard RW/mean climate (Main Figure 3) and **(2)** residual/detrended climate data (Appendix Fig. A3), are now both included in this investigation.

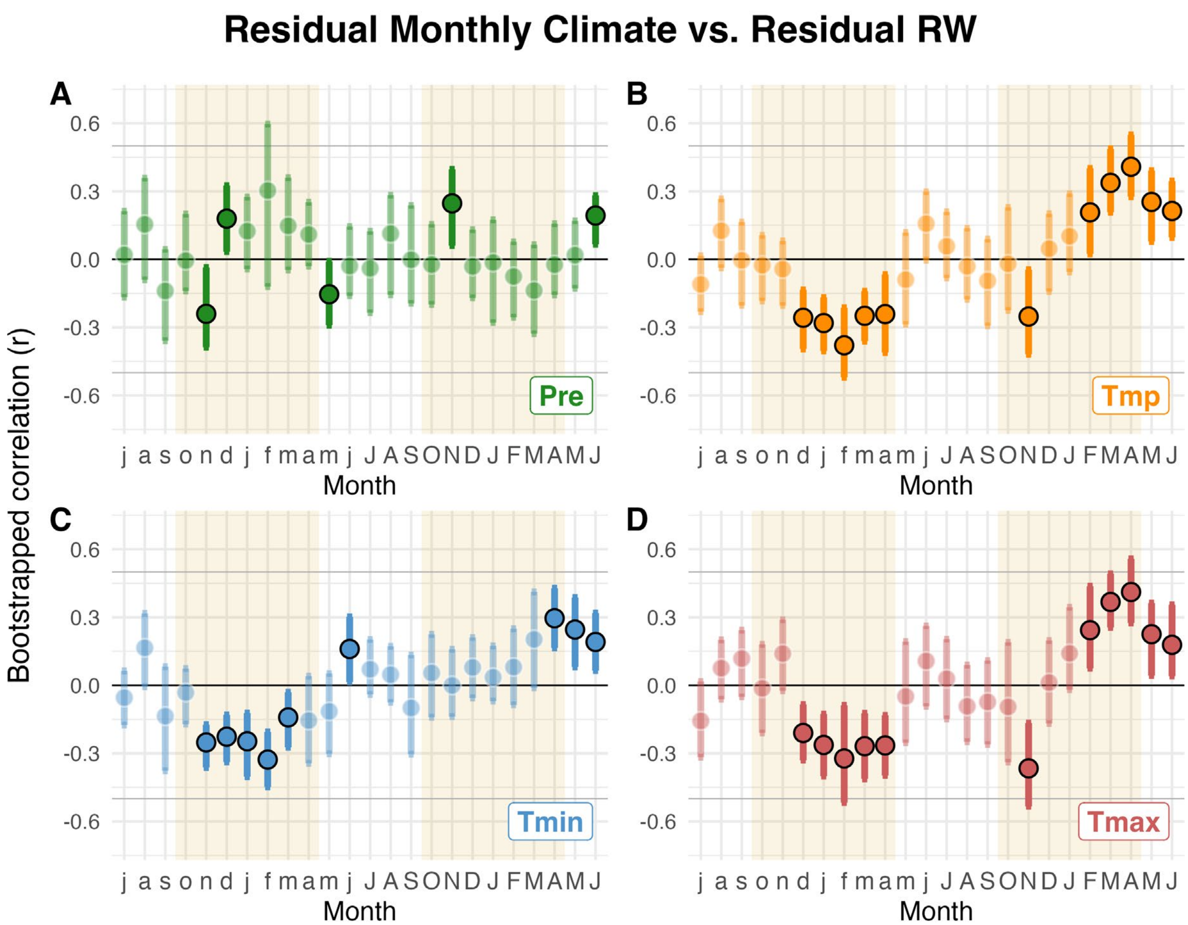

Figure A3. Residual P. pepei RW correlations with Residual monthly climate data 1960-2015. The residuals from a linear regression were applied to the local monthly precipitation (A), and mean, minimum, and maximum temperature series for the site (B-D) to evaluate the interannual relationships between annual RW and monthly climate variables. Lowercase letters on the x-axis represent prior-year climate (lag=1). Correlations are reported as the median r estimated using stationary bootstrapping. Significance was defined from 95% bootstrapped confidence intervals and are denoted in solid-colored circles outlined in black. Tan-shading represents the estimated 'wet-season' for the treeline site which extends between October-April for this period.

An interesting result from the residual climate correlations is that monthly temperature variability dominates the high frequency signal (Fig A3 C-D), whereas correlations with residual precipitation were less significant. However, because RW is likely more sensitive to seasonally-integrated climate rather than individual months, we now include seasonal climate correlations using both standard and residual timeseries (Figure A4 below).

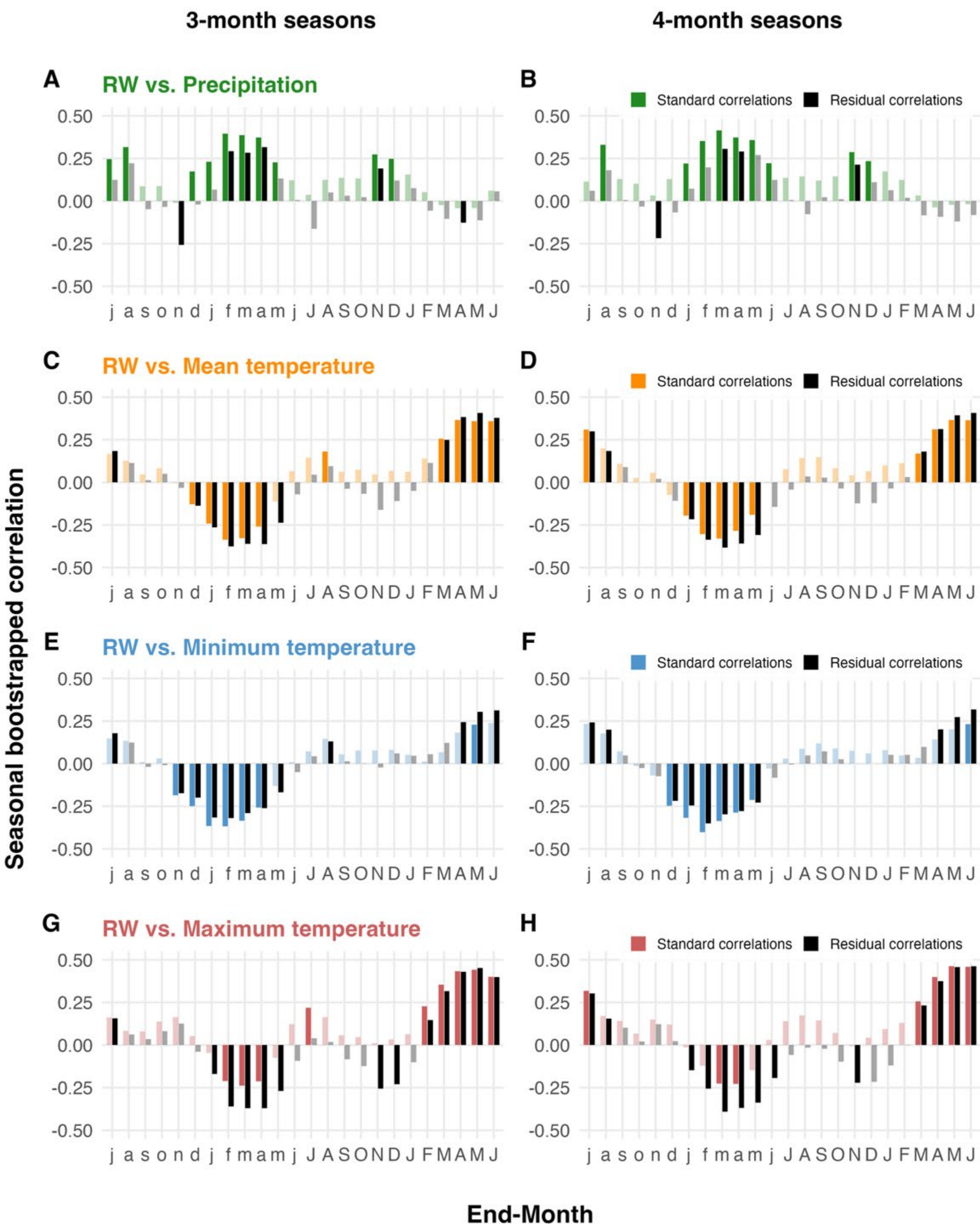

Figure A4. *Running seasonal climate correlations with P. pepei RW for 3-month (left column) and 4-month (right column) seasonal averages using local temperature and precipitation data (1960-2015). 'Residual correlations' are represented as black bars (i.e. detrended climate vs. Residual RW), while colored bars represent 'standard correlations' (i.e. mean climate vs. Standard RW). The x-axis represents the 'end-month' of the season, for example, lowercase 'f' in panel (A) represents correlations between RW and prior-year December-February precipitation (lag=1). Significance was inferred from 95% bootstrapped confidence intervals. Non-significant seasonal correlations are faded, while significant correlations are solid-colored bars.*

Also, on the topic of avoiding spurious RW-climate correlations due to trends, we would like to emphasize that although spatial correlations were between RW and mean climate data, we conducted binomial field significance tests for the gridded results (see related figure and caption in **response #48**)

16.) The manuscript should be improved with some more classic style publication-level wordings, avoiding informal language or personal interpretation. English proofreading is strongly suggested. Readability could improve also by removing unnecessary abbreviations and repetitions of concepts explained with parenthesis throughout the manuscript. If the information is considered important then it can be included as subscript (e.g., Tmin1960-2015).

We agree with this sentiment shared by both reviewers. We have now (1) removed phrases such as 'our study site' and 'Fig X shows' and (2) limited climate-variable acronyms to methods and figure captions only.

Specific Line-by-line comments:

ABSTRACT

17.) L. 21 Presenting the results without explaining methods and aims reads strange. Please reformulate.

The referenced text corresponds to the beginning of the abstract included below in italics text. We have edited the text and highlight it here in **bold (black color)**:

The impact of rising temperatures on tropical treeline ecosystems remains understudied. Here we report on ***the growth history and climate response of Polylepis pepei trees growing in Madidi National Park, a tropical forest setting at elevational treeline*** *in the Andes-Amazon ecotone of Bolivia.*

18.) L. 33 A better formulation of the closing sentence is advised. For example, you could state which severe implications you are expecting.

Edited text is in **bold (black color)**.

If temperature continue to rise at current rates, one of the highest-elevation tree species on the globe, P. pepei, may continue to decline ***leading to forest mortality and jeopardizing the survival of treeline ecosystems.***

INTRODUCTION

19.) L. 57-60 Despite the topic is still about climate influence on tropical mountain species, it refers to a different aspect of the species ecology than TRW. This second part of information could be introduced with a connecting sentence.

Thank you for this, the introduction has been re-written and this sentence has been removed. The first paragraph now begins with a broad definition of Andean treelines, current ecological observations of treeline dynamics, and the knowledge gap for the such forests in the tropical Andes.

20.) L. 62 you may write populated by or characterized by instead of "site of" you may write growing "at" These kind of corrections can be avoided when the article is proofread by a native speaker.

The sentence has been updated to:

Here we describe a new tree-ring record of Polylepis pepei from a treeline site in Bolivia's Madidi National Park (MNP), a hotspot for biodiversity in the southwestern Andes-Amazon region in Bolivia (BB.Simpson)(Simpson, 1979).

21.) L. 79 I suggest joining paragraph 4 5 and 6, in a way that the description of the species and the reasons why this is the species of interest are joined together.

We have now combined and reorganized these paragraphs. The general description of the tree species and study region is in paragraph 4, and the need for tree-ring research in this region is in paragraph 5.

22.) L. 85 The reasons why this is the case are not clarified. Also consider adding link to the next sentence

The following sentence has been updated with a citation, and is now located in paragraph 3 of the introduction that highlights the value and spatial extent of the Polylepis genus:

"The name Polylepis is derived from the Greek word 'many layers' which refers to the multiple sheets of thin, compressed bark useful for thermal insulation and frost tolerance at high elevations (Rada et al. 2001; Rodriguez-et al. 2021).

23.) L. 86 Reporting the references at the end of the sentence would improve readability avoiding mid-sentence brackets.

We have moderately reduced the use of in-sentence parentheses to improve readability overall.

24.) L. 87 Either soil temperature is reported as "soil temperature above 5 cm " or >5 can be omitted. These kind of stylistic adjustments where reported only the first time the issue appeared. However, they should be corrected throughout the whole manuscript.

Thank you for noticing this. This has been corrected during revisions.

25.) L. 92" Southwest of our P. pepei site" is an example of colloquial tone. You may write "Southwest of the study area in object" or "In areas located southwest of the study area"

Although this sentence has been reworded and moved elsewhere, we applied this advice throughout the manuscript.

26.) L. 111-117 This part should be joined with the third paragraph where the study site is described. Description can also be shortened as the materials and method section can be used for such precise description.

The description of tree-ring records in the Madidi National Park (MNP) was merged with sentences describing current climate and forest observations for the area (paragraph 5). The following text was edited and moved to methods 2.2:

'..the vegetation is characterized as an Alto-Andino Yungueño (Upper Andean Yungas) forest (Navarro et al., 2010).'

METHODS

27.) L. 125-128 The sampling strategy should indicate the number of samples taken for both living and dead trees as you correctly did in paragraph 2.3. I suggest moving these information and sample processing to paragraph 2.3 as 2.1 correspond to site description and climate. Section 2.3 should contain also other info: How were the cross section treated? From how mani radii were RW extracted? From which direction were the cores taken? In the species description, it is mentioned that this species can also have a shrub phenology, how many stems where included? What was the tree selection criteria? These information are crucial to establish the effectiveness of the sampling strategy.

Thank-you for this helpful suggestion. The original text in 2.1 describing the sampling methods is now located in the beginning of section 2.3 and included below. The updated information is in **black, bolded font**.

2.3 ***Wood processing and anatomical analyses***

Tree-ring samples from ***at least 30*** *living P. pepei were collected using a 2-threaded* ***16-inch*** *increment borer (5mm in diameter) in October 2012 and July 2019. Two to four cores were extracted f***rom varying directions within each stem (north, south, east, and/or west radii) in an effort to adequately represent radial growth. Cores were taken from a single stem at breast height (1.2 meters), or near the base of the largest stem for multi-stemmed trees (~30 cm, less than 5 samples).** *During the 2019 campaign, tree-diameter was measured at the height core samples were sampled (1.2 meters on average).* ***Tree-ring cross sections*** *from 3 recently dead trees were obtained using a gas-powered chainsaw or a standard saw-tooth blade.*

28.) L.134-136 This sentence would help reformulation in a scientific tone and further explanations. You should consider checking a botanical description of the species and a possible comparison with your observation to the description.

Thank-you for pointing this out. After reorganizing section 2.1 (now new 2.2) and 2.3 per your suggestion, we felt these descriptions are better suited with Appendix Fig A2 (below, next page). The revised sentences are **included in bold** within the figure caption. please note we also moved the old L191 referenced in **response #34** here as well (second sentence that **is bolded**).

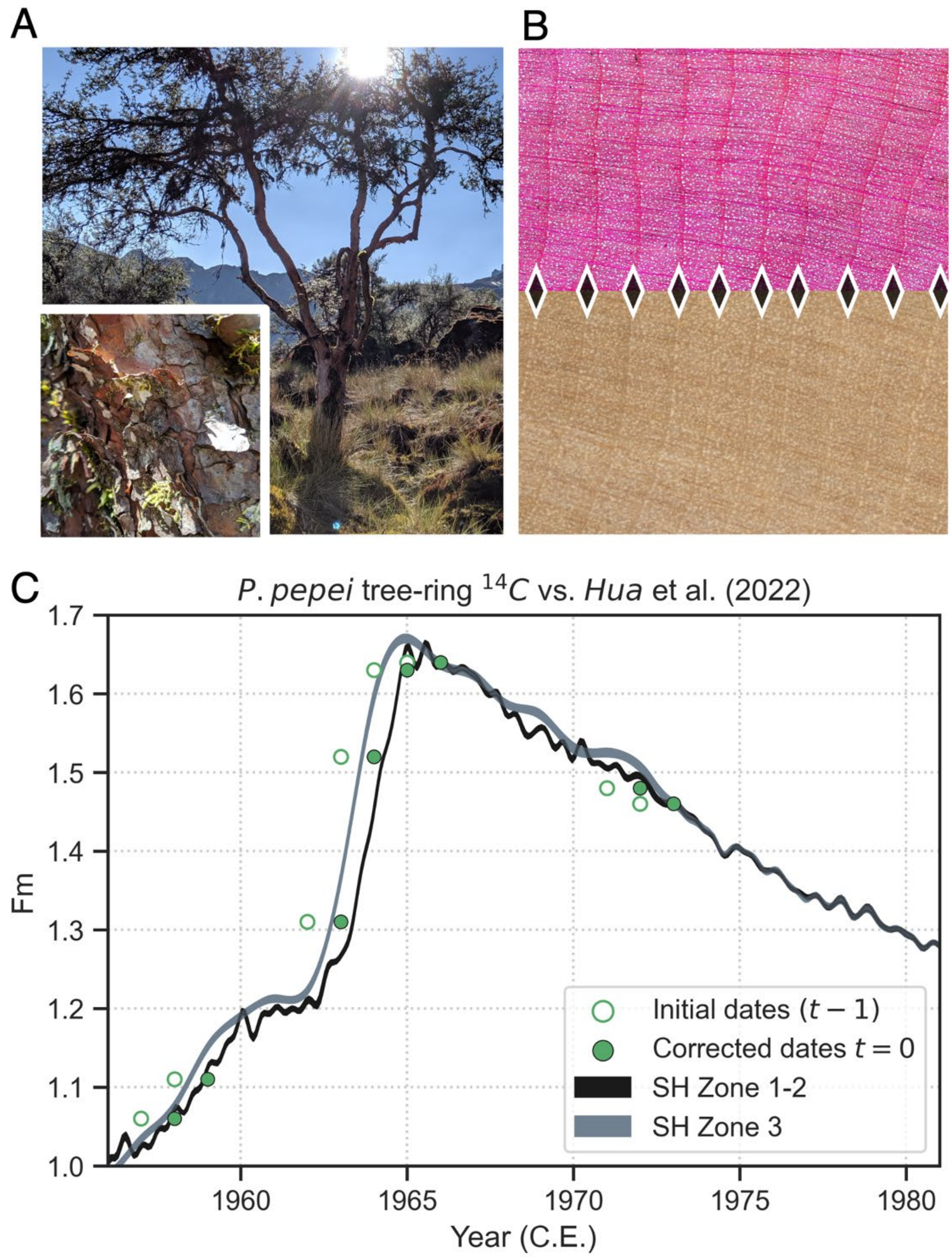

Figure A2. (A) Photo of a P. pepei tree in Keara ***during the dry season in July 2019****.* ***The trees have evergreen foliage, and can appear shrublike, with twisted, and at times multiple, stems. The bark consists of thick layers of compressed flakes that are red and brown in color****. (B)* ***P. pepei* wood anatomy for a histological slice (40X magnification Echo microscope camera) and scanned image of a tree-core (3200 dpi).** *The direction of radial growth is from left to right (pith to bark) while diamond shapes indicate the latewood/earlywood boundary between annua tree-rings.* ***P. pepei tree rings feature large, uniformly distributed vessels in the earlywood while the latewood includes both solitary vessels and thicker, fiber-like tracheid cells. The vessel lumen area in the latewood appears to taper tangentially in size before each subsequent growth-ring boundary.*** *(C) Radiocarbon measurements (green circles) from the alpha-cellulose of selected rings in a cross-section is plotted with the [a]Hua et al. (2022) reference curves SH Zone 1-2 and SH Zone 3***.**

29.) L. 138-146 Consider removing the brackets and explicitly state the ranges and the abbreviations. Correlations results seem something that should belong to the results section or, possibly, the next section where climatic data collected are described in depth. Site description should include a sole description of the site with no interpretation.

Thank-you this was a useful suggestion. The sentence referencing the covariance between precipitation was moved to Results 3.4 that discusses climate-growth correlations.

30.) L. 147 The authors showed a lot of effort in collecting and managing such an amount of data. This complex dataset deserves a clear explanation and structure. It is advisable to add an introductory sentence where it is clarified which data are local and which are gridded and the reason why so many different climate data were collected.

The climate data section has been moved to methods 2.1 and improved for clarity. As mentioned in response #38 below, the lack of long-term, in situ, and reliable climate records is a major problem in South America and thus (most) analyses were limited by the temporal extent of the precipitation record (1960-2015).

31.) L. 178 Panel B includes a legend with four indexes but the figure shows only two.

The statistics in the previous Figure 1B are now removed but remain in the text for site description and climatology (Section 2.2).

32.) L. 191 It would be more precise to refer to vessel distribution.

The following sentence has been updated. However, this text was better placed in the figure caption of Appendix A2 instead of the methods.

P. pepei tree rings feature large, uniformly distributed vessels in the earlywood. The latewood includes both solitary vessels and thicker, fiber-like tracheid cells. The vessel lumen area in the latewood appears to taper tangentially in size before subsequent growth-ring boundary.

33.) Also, as for diffuse porous, ring porous does not need quotation mark, it is considered common nomenclature of the anatomical structures.

Thank-you the quotations have been removed

34.) L. 198-200 Between the sample processing and the chronology development step, the image acquisition process should also be described. Especially considering the different samples analyzed. What was the acquisition procedure for core surfaces and thin sections? Which resolution was obtained?

Section 2.3. and 2.4 have been updated to include the scanning resolution and image acquisition for the thin section. Edited text below in black /bold.

2.3 Wood anatomical processing: *"P. pepei is an angiosperm with diffuse porous wood anatomy, which is typically more difficult to date than ring-porous wood, due to less distinct boundaries between the latewood of the prior year and the earlywood of the current year (Fig. A2). To aid in identifying ring-boundaries in the wood, histological (micro) cuts were performed on a single cross-section following the techniques described in von Arx et al. (2016) using a WSL Core microtome (https://www.wsl.ch/en/services-produkte/microtomes/).* **High-resolution images of the thin sections were captured using an Echo Revolve R-4 microscope camera, with a magnification of 40X.** *Further information regarding the wood anatomy of this species is included in the Appendix (Fig. A2).*

Updates for Section 2.4 (Tree-ring chronology development) :

> *Tree rings from 31 trees (51 radii) were dated visually using standard dendrochronological techniques (Stokes and Smiley, 1968).* ***Each wood sample was scanned using an Epson Expression 11000XL scanner at 3200 dpi resolution.***

35.)L. 208-218 and throughout the whole manuscript It is important to state the function used for each analysis and the working environment.

We have now included that RW chronologies were detrended using the dplR package in *R* (section 2.4) and have updated the citation for the 'boot' package used in part for climate-growth analyses (section 2.6).

36.)L. 210 What does "initial" stand for?

Here is the sentence in section 2.4 (chronology development):

> *Individual RW time series were detrended conservatively with age-dependent cubic splines (initial spline stiffness of 60 yrs) (Cook and Peters, 1981; Melvin, 2004).*

We apologize for the confusion. Age-dependent spline stiffness represents the behavior of the smoothing parameter as a function of cambial age. For this study, 60 years is the initial stiffness of the cubic spline that is applied to the rings formed during the juvenile phase (near the pith). When trees are young and grow quickly (i.e. larger RW), the flexible spline minimizes low-frequency and preserves the year-to-year (high frequency) variability of growth. Theoretically, as the trees age and radial growth becomes more stable, the spline becomes progressively stiffer to retain medium-low frequency variability in the 'mature' phase of growth.

Age-dependent spline detrending has broad applications in dendrochronology, and initial spline stiffness is commonly reported. Most studies use this approach to account for trees with different age classes (Melvin et al., 2007) or for trees sampled in varying micro-climates or ecologies (e.g. open vs. closed canopy, (see Druckenbrod et al., 2024).

Cook and Peters, 1981 were the first to introduce the frequency-dependent cut-off for a cubic smoothing spline detrending technique, while Melvin 2004 was the first to describe the term 'age-dependent smoothing spline' and thus were cited in the text above. We hope this clarifies any confusion!

37.)L. 225 Refer to the initial comment. Moreover, further explanation on the aims of this analysis should be added, along with some context.

Changepoint analyses methods are now in a new designated section in 2.5.

38.)L. 229 As reported before, many different climate data were collected, with different time-span and resolutions. However, there does not seem to be an explanation on why the climate growth correlation was performed only for the period from 1960 to 2019. Either this should be clarified, even considering that the amount of work for this manuscript is already reasonable, or it would be interesting to perform a moving climate correlation and observe what effect does the shift have on the TRW correlation. In any case, as it was previously specified, the noticeable trend in the climate data should be removed to exclude spurious correlations.

Please note we have moved the climate data section to 2.1 and have improved the details. The 1960-2015 analyses period for the 'local' climate timeseries is based on data availability of the station-based precipitation data. While moving correlations would be interesting, there is limited availability of continuous, in situ stations that extend before this date. However, since temperature data is less spatially variable than precipitation in the Andes, we included the long-term diurnal temperature trends (1901-2015) in Appendix A5, which are referenced in the new results section 3.4 and discussion 4.2 (**see updates at the end of this document after #53).** We include some of the updated text from Methods 2.1 below.

> *"..Local precipitation data and gridded temperature products were used to generate monthly climate indices for the site between 1960-2015. This period was selected for the site climatology and climate-growth analyses due to the limited availability of continuous precipitation data for this region of Bolivia. Daily precipitation from the Italaque station in Bolivia (15.48°S, 69.03°W, 3500 m.a.s.l.) was gap filled with nearby station data to generate a continuous monthly timeseries using the 'redprecc' package in R (Huerta et al. 2025). Nearest neighbor interpolation was constrained to sites above 3000 m.a.s.l. Raw (daily) precipitation data for Italaque (1978-2005) and nearby stations (~1945-2015, non-continuous) can be obtained from the DECADE dataset which were originally sourced from the National Meteorology and Hydrology Service of Boliva (Hunziker et al. 2018; SENAMHI; https://senamhi.gob.bo/index.php)..."*

RESULTS

39.) Results should be written using the same tense, past simple usually.

Present tense was used for sentences that describe what the data and figures show, while past tense refers to analyses that was performed. We have edited sentences accordingly where appropriate.

40.) L. 278 Results for the Petitt analysis on the change point detection do not seem to be shown, nor in the manuscript nor in the supplementary material. Results could be displayed as a table in case multiple years are detected, and at least listed here.

We apologies that this was not clearly stated originally. As stated previously, our changepoint analyses using the 'trend' package in R returns **a single year** that maximizes the rank-based difference between observations before and after the breakpoint. We realize it may be beneficial in the future to use different tests that can return multiple changepoints in the future. Please refer to our **responses in #14**.

41.) L. 289 Information on the sampling strategies are missing. See comment on paragraph 2.1 and 2.3. If some side of the stem showed visible ring while others did not, it might also mean that reaction wood (commonly forming larger rings) was measured, partially invalidating the results. Better specification on the samples and especially image acquisition would clarify this aspect, especially in view of the difficult material examined (i. e., diffuse porous, shrub form). Why were thin sections not useful? on how many samples were they performed?

Line 289 here refers to text in the Results (section 3.1):

> *Due to extreme suppression in radial growth (Fig. 2B), only one or two cores per tree (out of three total) were able to be cross-dated and used for the final RW datasets.*

Please see response to **#27** and **#34** for updates regarding field sampling and anatomical analyses.

As described methods 2.3., an anatomical cut of a *single-sample* was conducted to identify the ring boundaries of this species prior to cross-dating (e.g. what denotes the earlywood/latewood boundary between annual rings?). We would have loved to generate thin-sections for all samples but unfortunately quantitative anatomical analysis was beyond the scope of this paper.

Although it is entirely possible that some radii could have had reaction wood (anatomical cuts would independently verify this), we found the appearance of growth ring structure to be mostly consistent across cores. The cross-section samples (dead trees) were particularly useful to review for this visually across a complete stem.

To validate tree-ring dates for the samples that *were* included in the final chronology, we measured and analyzed the(1) 'annual' growth patterns between cores of the same tree, and different trees using a microscope (internal vs. external cross-dating; 'List Method', see: Yamaguchi, 1991 in the reference section for this document), (2) statistical correlations among the ring-width timeseries (3) and radiocarbon measurements from a dated core sample. Based on the results described in section 3.1 the dating for the samples *that were included* in the final chronology is robust.

42.) L. 291-293 Trends should be analyzed primarily on the standard chronology in a way that common biological growth signals are removed.

We have now analyzed changepoints and trends in both the standard and raw chronologies (see **response #14** for updated **Figure 2A and C**). We do agree that the raw changepoint is secondary to the negative trend in the standard chronology (after a non-significant in 1962). We are open to placing the changepoint results for Raw RW in the Appendix upon further review.

43.) L. 299-300 It is unclear how one point in time measure can provide information on how fast trees trees are growing.

We include the following sentences here from section 3.1:

> *The average age of the trees was 93 years and the* ***average growth rate between 1850-2018 was ~ 1.0 mm yr^{-1}****. DBH measurements in 2019 confirmed these trees were slow-growing with stem diameters ranging from 10 cm to 54 cm (mean DBH 30 cm).*

Average ring-width was calculated per year across all samples, and 1.00 mm represents the average tree-ring size per tree per year. Although these trees are 93 years old on average, the mean diameter was only 30 cm.

44.) L. 302-304 Extreme years and events identification could be shown in the current figure but should be stated in the appropriate section.

This is in reference to the 5th/95th percentiles observed in the residual RW chronology in Figure 2D. We have now moved the associated text that wsa in section 3.1 originally to the SEA results '**Section 3.5 Growth response of treeline *P. pepei* to extreme climate events'**.

45.) L. 323 It's unusual to directly refer to the image, results should be rather reported and the figure reference should go in brackets.

For context, this is referencing examples such as old line 323 included here:

> ***Fig. A4A shows*** *December-March (DJFM) precipitation significantly decreased over the 1960-2015 period at a rate of ~6 mm per decade at the same time there was an observed decline in P. pepei RW (Fig. 2A).*

We agree with the reviewer here and have limited instances of "Fig ___ shows" throughout the results section.

As a related note, we decided to move this figure to the main text (Figure 4. 1960-2015 seasonal climate trends). we feel strongly this result belongs in the main text instead of the appendix, because it advanced further analyses for this study (e.g. Figs. 5, A4-A6) and the interpretation of the recent trends in growth.

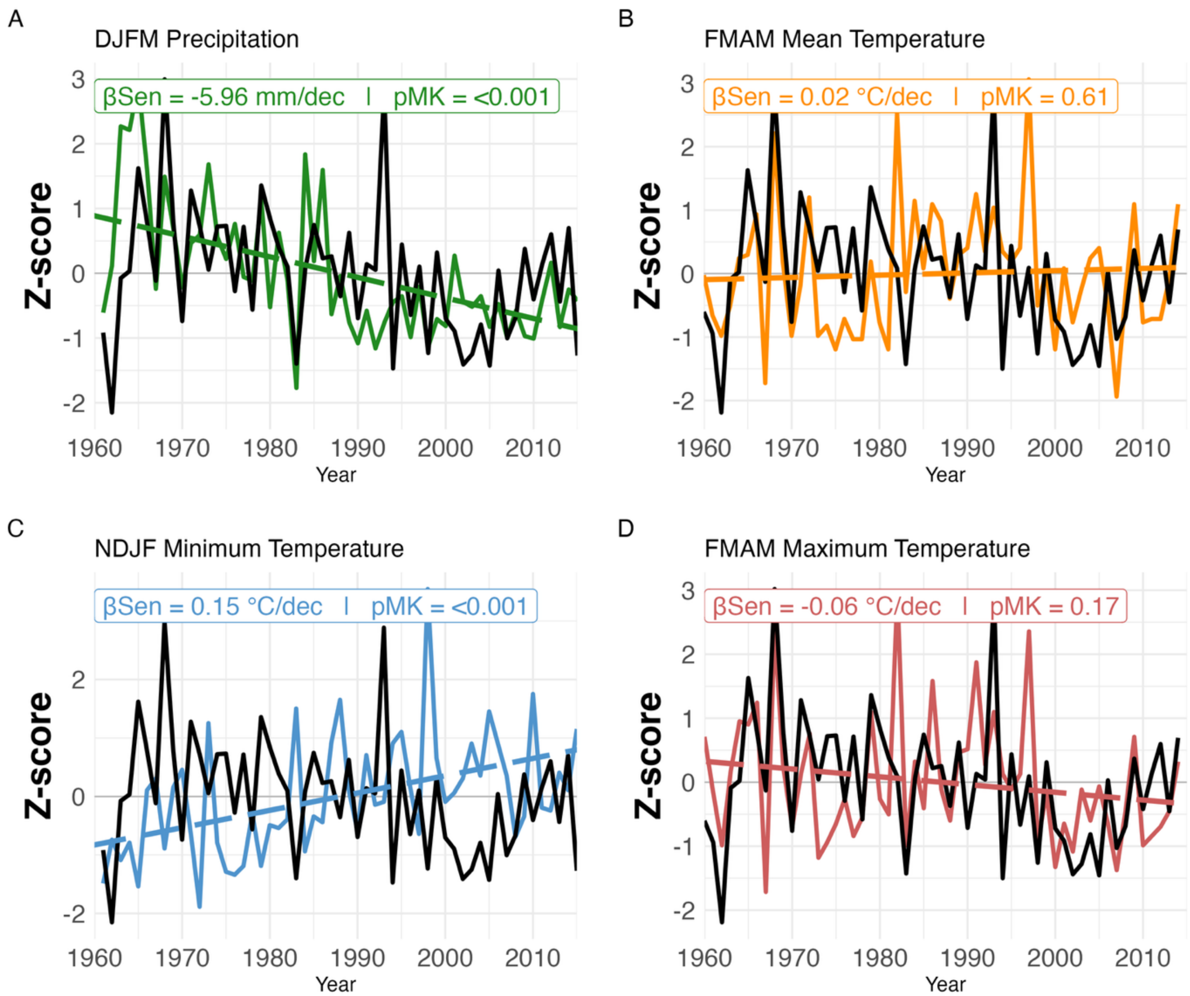

Figure 4. Z-scored P. pepei RW (black lines) and seasonal climate variables (colored solid lines) between 1960-2015. The selected seasons were based on the highest and most significant correlations between local climate and RW for this period (standard and residual, p<0.05). Lagged DJFM Precipitation is in green (A, lag=1), FMAM mean temperature is orange (B, lag=0), lagged NDJF minimum temperature is blue (C, lag=1) and FMAM maximum temperature is in red (D, lag=0). Averaged seasonal trends are reported in units of climate per decade (β, colored dashed lines). Mann-Kendall tests were used to estimate the two-tailed significance of the linear trend (pMK). Precipitation data is reconstructed from nearby station records and temperature data is sourced from the nearest CRU TS 4.08 grid point.

46.) L. 328 It should refer to figure 3D.
Thank-you, this has been fixed.

47.) L. 349 Complete information should be reported. It is not clear which chronology was used here.
In the previous version of the manuscript, we stated that the standard chronology was used for climate-growth analyses. However, with the updated appendix figures, the captions and Methods sections 2.4 and 2.6 have been updated accordingly.

48.) L. 369 In the image, it seems more meaningful to indicate the parameters rather than the source. "vs Prec y-1" could be a better way to explain what is represented in the first panel for example. All the other info can be reported in the caption.

The titles for the spatial correlation figure (old figure 4, current figure 5) have been updated and the temporal resolution of the datasets remain in the caption (included on the following page).

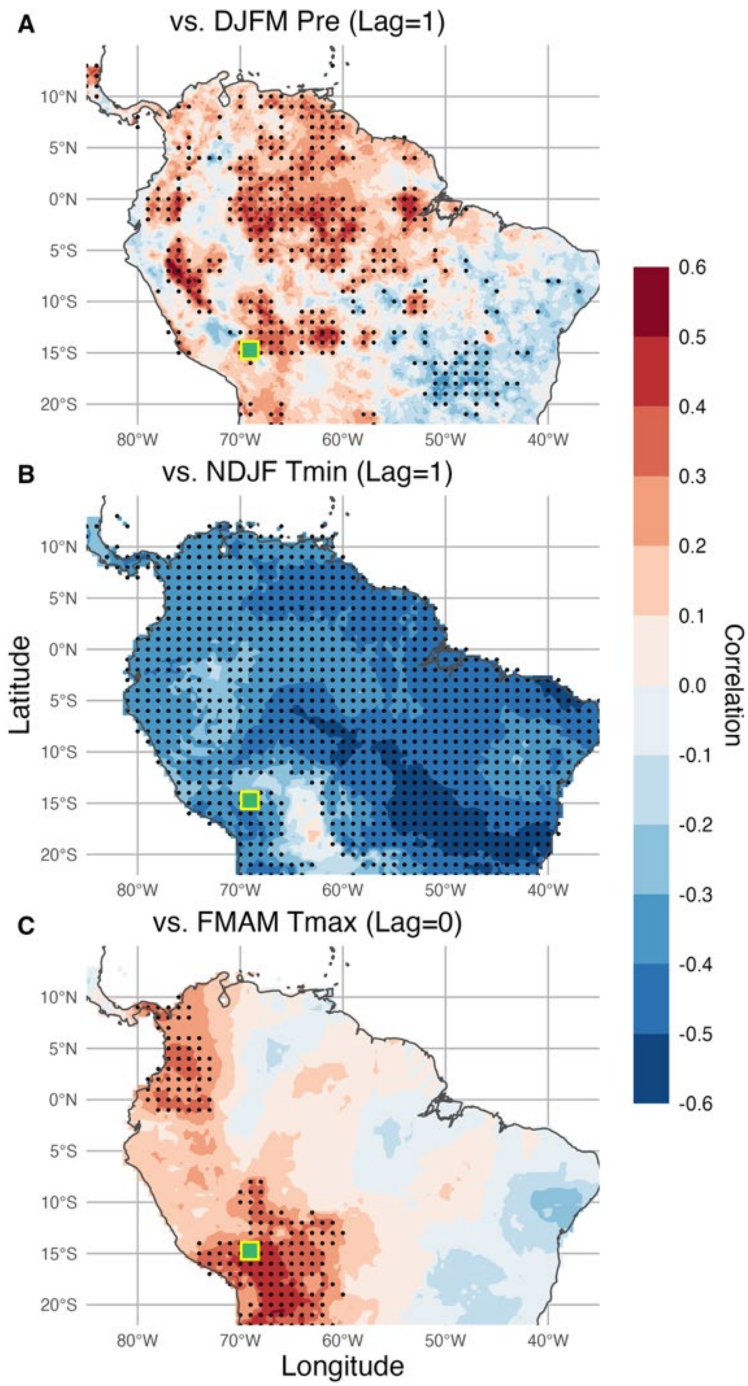

Figure 5 (note than in previous submission was Fig. 4). *Spatial correlations between P. pepei RW and (A) DJFM precipitation (lag=1), (B) NDJF minimum temperatures (lag=1), and (C) FMAM maximum temperatures (lag=0) in tropical South America. Black dots represent the significant grid points (p<0.05). Gridded* *precipitation analysis was limited to 1981-2015 due to the availability of CHIRPS data (A) while RW-temperature correlations covered the 1960-2015 period (B-C, CRU data). Binomial field tests indicated that were more significant cells than expected by chance for all spatiotemporal relationships (a=0.05, p<0.001)*

49.) L. 387 Quality and resolution of figure 5 should be improved. The two numbers in panel A overlap, are they outliers? if so they should be mentioned in the caption.

Yes, the two numbers in panel A are the outliers. We have reduced the overlap between the numbers, added their description in the caption, and updated the figure quality. The updated figure and caption is included here:

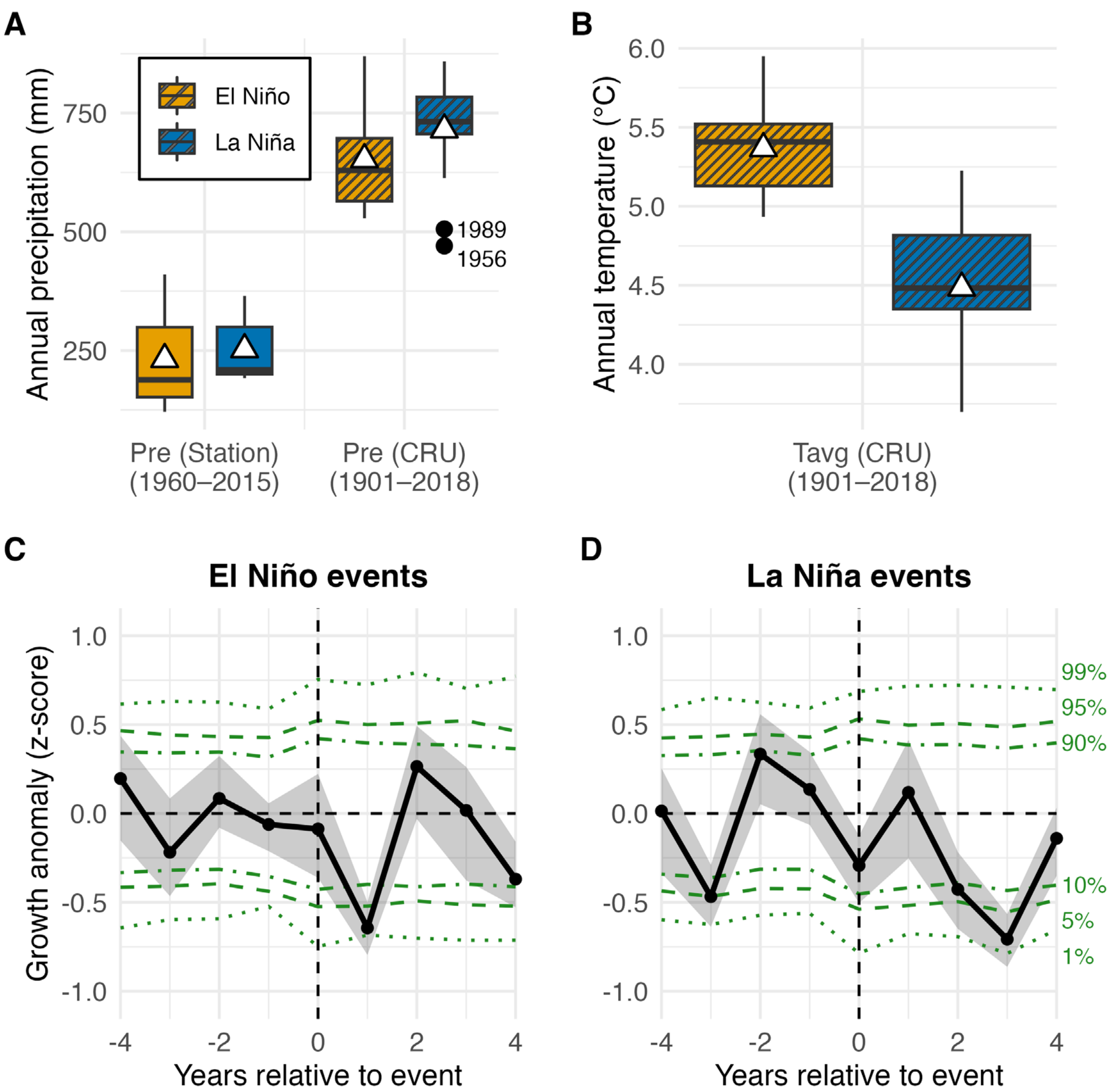

Figure 6 (note that in previous submission was Fig. 5). *Boxplots of annual (A) precipitation and (B) temperature for the 26 years of extreme DJF-ENSO events, using both station and CRU data. Outlier years in the CRU precipitation data* ***are represented as black dots (A; 1956, 1989)****. Annual mean climate during El Nino-DJF is represented as orange colors, while La Niña is shown in blue (n = 13 years per event).*

*Superposed epoch analysis of the residual RW response 4 years before and 4 years after the DJF-ENSO events (C, D; black line). The uncertainty of the growth response is depicted as grey shading. Horizontal green-lines represent the two-tailed significance thresholds: (10-90%, 5-95% 1-99%) derived from stationary bootstrapping***.**

Discussion

50.) Especially within the discussion, connections between different points should be better explained to improve fluency.

This is a good point. We made an effort to enhance the transitions between paragraphs. As mentioned below, the first section of 4.1 has been improved overall to answer the main research objectives and highlight the new findings from this study.

51.) L. 404-405 After this sentence, the reader would expect a list of factors that influence tree growth, ordered by what is a recent discover from this study, towards what is already known in literature. For how it is written now, the ranking is not clear, nor is clear what new results have been discovered.

We have now largely re-written the discussion. The first paragraph begins in the following way:

Here we have generated the first P. pepei tree-ring chronology from the MNP treeline in Bolivia and the longest annual growth record for this species in South America spanning from 1850 to 2018 CE (3795-4400 m a.sl; 14.75°S).

This section answers our original objectives, summarizes main findings, and compares the climate-correlation results to other Polylepis RW studies.

52.) L. 417- 421 Please refer to all the comments previously done. Discussions should be adjusted accordingly.

Old lines 417-421 referred to the changepoint analyses which has now been expanded in the second paragraph of section 4.1.

53.) L. 521 "Moving forward" does not sound like scientific language

This phrase has been removed from the conclusion section.

Additional updates related to discussion section 4.2, and Results (new section 3.4):

While reviewing the manuscript we realized that a section was necessary in the results to report the results regarding the long-term changes observed in diurnal temperature range (DTR), minimum and maximum temperatures. Accordingly, we added a results section named "***3.4. Long-term changes in diurnal climate conditions at the Keara treeline"***. Aside from assessing the significance of the trends in DTR, minimum and maximum temperatures, this section also describes the results in relation to temperature and relative humidity data in situ, which confirm a significant increase in minimum temperatures but not in maximum temperatures, and a significant decrease in relative humidity. These are important results that are largely discussed in the section 4.2. of the Discussion. The associated text for Results section 3.4 reads as follows:

3.4. Long-term changes in diurnal climate conditions at the Keara treeline

To visualize the significant increase of minimum temperatures near Keara in a long-term context, annual and seasonal diurnal temperature range anomalies were calculated for the full CRU TS 4.08 calibration period 1901-2015 (Fig A5; DTR, Tmin, Tmax). There was a significant decrease in DTR and an increase in minimum temperature anomalies since the mid-20th century at this site. The largest decline in DTR was observed for the October-April season at a rate of -0.197°C decade^{-1}, though annual and July-August DTR declined at a similar rate (-0.191°C and -0.194°C decade^{-1} respectively, 1960-2015; Fig. A5).

In agreement with the decreased DTR trend observed since 1960, in situ daily temperature loggers independently confirmed that minimum temperatures for the October-April season have increased at this site (Fig. A6 A-C). Minimum temperatures for the October-April season in 2011-2014 ranged from 1.9-2.3 °C and increased to 3°C in 2021-22, which is higher than the 0°C average between 1960-2015 (Section 2.2, Tmin Fig. A1). The distribution of daily wet season minimum temperatures in 2021-2022 was significantly higher than the 2011-2014 seasons overall ($p<0.001$; Fig A6).

Interestingly, average October-April maximum temperatures recorded by the data loggers ranged 7.2°C-8.2°, which is substantially lower than the 1960-2015 average (Section 2.2, Tmax~13°C; Fig. A1). Daily maximum temperature for the 2021-2022 season was significantly lower than the 2012-13 and 2013-14 seasons ($p< 0.01$), while no significant difference was detected relative to the 2011-2012 season ($p= 0.37$).

The daily data loggers also recorded a significant reduction in relative humidity within the 2011-2022 period (October-April; Fig A6D-F). Relative humidity declined from an average of 98% in 2011-2014 to 90% in 2021-2022, while minimum daily humidity decreased from ~94% to 80% (Fig. A6D, F). Although 2011-12 corresponded to a DJF-La Niña year (Table A1), the distribution of daily relative humidity values during that season was comparable to the 2012-13 and 2013-14 years ($p>0.05$), and all 3 seasons were more humid than the 2021-22 year (Fig. A6. $p<0.001$). In fact, almost one third of daily relative humidity values for 2021-2022 (63 days) were below 90% for October-April, while less than 25 days were recorded for the same threshold in the 2011-2014 seasons.

In summary, the long-term warming and drying trends observed in precipitation and temperature between 1960-2015 (Figs. 4, A5) are consistent with in situ measurements of higher temperature and lower relative humidity for 4 distinct October-April seasons between 2011-2022 (Fig. A6).

The related figures remain in the Appendix as Figure A5 and A6, but are included on the following page here.

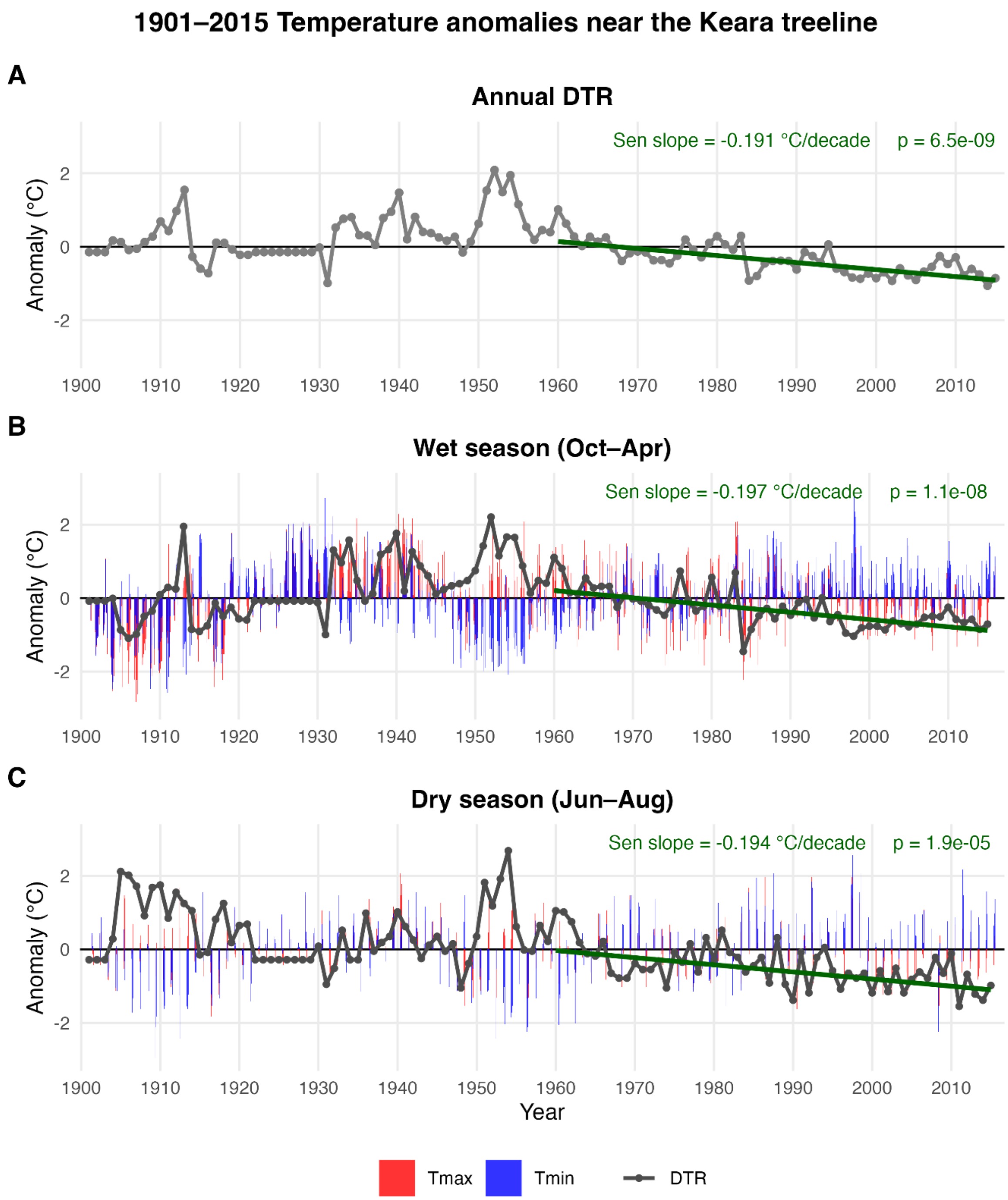

Figure A5. *Long-term temperature anomalies for the Keara site (1901-2015). The grey timeseries represents annual (A) and seasonal (B-C) diurnal temperature range for the nearest gridpoint from CRU TS 4.08. 1901 is the earliest year of available data for CRU. Linear trends in DTR anomalies were estimated using Sen's slope. The significance of the 1960-2015 trend was evaluated using a two-tailed Mann-Kendall test. The mean slope is reported as the average change in DTR per decade (°C). Seasonal anomalies for Tmax (red) and Tmin (blue) are represented as vertical bars for the 1901-2015 period (B-C).*

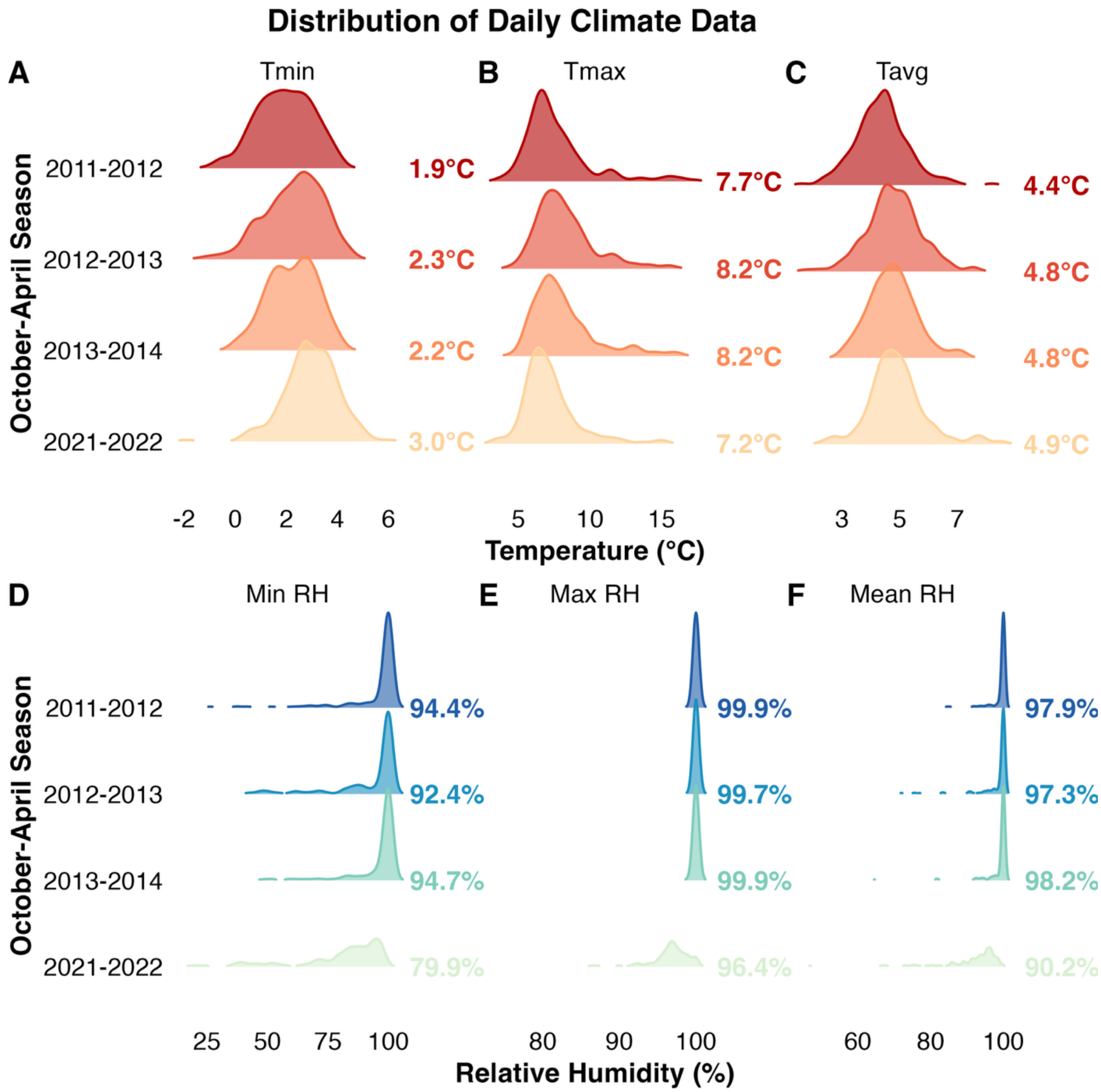

Figure A6. *Ridgeline distributions of daily temperature and relative humidity during October–April for the 2011–2012, 2012–2013, 2013–2014, and 2021–2022 seasons at the site. The top row (A-C) represents daily minimum (Tmin), maximum (Tmax), and mean (Tavg) temperature. The bottom row (D-F) displays minimum, maximum, and mean relative humidity (RH; bottom row). Colored ridges represent daily observations within each season, and bold values at the right margin indicate seasonal means for each year. This data was resampled from hourly measurements recorded in situ from dataloggers installed near the Keara open-canopy site in 2011.*

References for the Point-by-Point Response

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Melvin, T.M., Briffa, K.R., Nicolussi, K., Grabner, M., 2007. Time-varying-response smoothing. Dendrochronologia 25, 65–69. https://doi.org/10.1016/j.dendro.2007.01.004

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