TESTING THE EFFICACY OF BLUE INTENSITY AS A TEMPERATURE PROXY IN *PICEA ENGELMANNII* FROM ITS SOUTHERN RANGE LIMIT, NORTHERN NEW MEXICO, USA

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By

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AUTHORIZATION TO SUBMIT THESIS

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ABSTRACT

Annually resolved temperature proxies are rare for the American Southwest. Recent studies involving the analysis of blue light intensity consistently show an inverse show in inverse relationship between maximum latewood density and blue intensity values. Blue intensity analysis records the amount of blue light absorbed by tracheid cells, thereby quantifying the amount of lignin present in the latewood of the annual rings. This study aims to fill the gap of historical temperature data for the southern range limit of the Sangre de Cristo Mountains of northern New Mexico using annual climate data and blue light intensity analysis of tree rings as a proxy for maximum latewood density analysis. This is done using 27 high-elevation Engelmann spruce (*Picea engelmannii* Parry ex Engelmann) samples collected from 16 trees located at Wheeler Peak, New Mexico. We also include a test of the efficacy of generating BI data with the CooRecorder density software package. Samples are also measured for minimum earlywood and latewood density, and change in blue intensity values (delta). Results of this study suggest that a statistically significant relationship exists between blue intensity values and maximum annual summer temperature. A warming trend is evident at the turn of the 21st century when observing the delta blue intensity time series data, which is also present in PRISM instrumental temperature data used. Additional research utilizing the methods described in this study can be conducted at similar sites located at high latitudes and alpine environments. Furthermore, a study comparing trends in blue intensity parameters across multiple sites would be valuable. This study contributes to the increased understanding of how blue light intensity can be used as a new and innovative tool within the field of dendroclimatology.

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CHAPTER ONE

INTRODUCTION

Anthropogenically induced climate change has resulted in a consistent warming of Earth's climate. Over the past century, Earth's surface temperatures have experienced an increase of roughly 0.6 °C, with the highest rates of increase during 1910 to 1945 and from 1976 to present day (Walther et al., 2002). This trend of increasing global temperatures has scientists searching for innovative methods to determine whether natural climate variability, or pollution onset by human activities is the cause. Because consistently recorded meteorological data is limited to the past century, in order to reconstruct historic temperatures, scientists must identify and utilize temperature-sensitive climate proxies. The use of tree rings as a proxy to reconstruct historic temperature allows scientists to develop more accurate estimations of past climate change (Eschbach et al., 1995). Few temperature-sensitive proxies currently exist across the globe, though they are much more common at high latitudes as well as alpine environments (Wilson and Luckman, 2003; Wilson et al., 2012).

Dendrochronology uses statistical analysis of tree rings to provide useful datasets to various disciplines such as climate science. Dendrochronology aims to assign calendar years to each individual annual tree ring. Because tree rings are unique to the growing conditions during the period they were created, tree rings can produce valuable dendroclimatic data that extends far past instrumental climatic records. Trees can be crossdated using the anatomy of their growth rings because individual specimens that are located in a similar area have similar growth responses to changing environmental factors, such as precipitation, temperature, and disturbances. The analysis of the annual growth rings of trees provides information for a variety of regional conditions.

Traditionally, dendrochronology consisted of analyzing the observable physical growth patterns of annual rings (Stokes and Smiley, 1968, 1996; Speer, 2010), limiting the proxies in which valuable data is provided. However, recent technological advances in classic dendrochronological methodologies have allowed for individual samples to be scanned at high resolution and analyzed for a number of new climate proxies. The use of specialized software has allowed for the expansion of dendrochronological studies to incorporate other tree ring parameters than tree ring width (TRW) and growth anomalies.

The use of tree ring proxies to reconstruct historical climate variability has been widely documented (Schweingruber and Briffa, 1996; D'Arrigo et al., 2006; Buckley et al., 2018). Though a variety of different proxies can be used to reconstruct climate variability, temperature reconstructions typically rely on expensive specialized equipment to determine the cell densities of individual tree ring samples. Until the turn of the 21st century, dendroclimatological temperature reconstructions were conducted using X-ray densitometry to measure maximum latewood density (MXD) (Eschbach et al., 1995). One of the disadvantages to X-ray densitometry is high operating costs, as it requires specific machinery, software, and trained personnel to process samples. The extensive monetary resources required for this type of analysis is exclusive, as it restricts use to affluent labs; tree ring laboratories that are underfunded may be unable to perform temperature reconstructions using X-ray densitometry (Rydval et al., 2014).

Recent temperature reconstructions have been developed for much of Europe and parts of the United States, though there are gaps in historical temperature data for much of the American Southwest (Wilson et al., 2016). Existing dendroclimatological studies spanning over the past few decades have suggested that high latitude alpine conifer chronologies of MXD have a much stronger relationship with summer temperatures than TRW-only chronologies (Wilson and Luckman, 2003; Rydval et al., 2014). As with any proxy or tree ring parameter, TRW is useful when reconstructing historic precipitation, though TRW varies based on a number of environmental variables, making it a much less reliable proxy for temperature than cell density. Recently, scientists have been performing an innovative and inexpensive method of calculating the density of tree rings. This new method of densitometry, known as blue intensity (BI) analysis, uses high-resolution scanned images of cores to quantify the blue wavelengths of light that are reflected off of lignified cell tissue.

BI analysis is conducted by measuring several values that quantify the blue wavelengths of light that are reflected and absorbed by lignified cells that make up tree growth rings. The BI parameters utilized in this study are inverted maximum latewood BI and the difference between earlywood BI and latewood BI, also known as delta-blue. Recent studies have suggested that the calculation of delta-blue in statistical testing results in a high positive correlation with the TRW series itself (Bjorklund et al., 2014; Buckley et al., 2018).

Unlike X-ray densitometry, BI analysis is much more affordable, therefore making it much more widely accessible. To process samples using BI analysis, woodworking equipment, a high-resolution scanner, and inexpensive tree ring density software are the only supplies that are needed. By producing similar results to studies utilizing X-ray densitometry, BI temperature reconstructions can be developed globally in small laboratories in far less time, with less effort, at a more reasonable cost. This technological advancement leading to greater inclusion in tree ring research may increase more widespread interest future in dendroclimatological studies.

This study aims to determine the effectiveness of performing BI analysis at the southern range limit of Engelmann spruce (*Picea engelmannii* Parry ex Engelmann) and to contribute to the historical temperature data available for the American Southwest. The samples used for this study were collected from the southern extent of the Sangre de Cristo Mountains, a remote mountain range that extends from central Colorado to northern New Mexico. This mountain range comprises the southernmost sub range of the Rocky Mountains, which extends through much of western Canada and the United States. The Sangre de Cristo Mountains, in addition to being the southern range of the Rocky Mountains, are also the location of the southernmost growth limit of Engelmann spruce.

1.1 Research Questions

This study aims to answer the following questions:

- Can total ring width of Engelmann spruce be used as a predictor of historical temperature for its southern range limit in the Sangre de Cristo Mountains, NM?
- Does blue intensity analysis reveal significant correlations with instrumental temperature in Engelmann spruce growth rings at its southern range limit?

CHAPTER TWO

LITERATURE REVIEW

2.1 Temperature Reconstructions Using Tree Rings

Anthropogenic climate change has quickly become an influential topic of discussion for Earth scientists. Recent studies observing instrumental climate records have suggested that Northwestern North America has one of the highest increasing rates of recent temperatures globally (Hartmann and Welder, 2005). Instrumental climate data has a finite timescale, thus, there has been a growing interest in the use of proxy climate records to reconstruct historical fluctuations in climate. Early identification of the potential drivers of global climate change can allow for the development of policies to reduce human influence on climatic alterations.

Proxy records, such as tree rings, are interdisciplinary in nature, spanning across biological and geological sciences, and varying in spatial and temporal resolutions (Stokes and Smiley, 1968). TRW is used as a high-resolution palaeoclimate proxy for historical climate variation (Wilson et al., 2016). Due to its relatively short timescale in relation to other climate proxies such as pollen, TRW is not a useful low-resolution climate proxy. A vast majority of the temperature reconstructions for the Northern Hemisphere are developed from TRW data (D'Arrigo, et al., 2006; Frank, et al., 2007; Wilson, et al., 2016), though maximum latewood density has been shown to be a better recorder of annual summer temperatures (Wilson, et al., 2016).

Since the 1980s, notable dendroclimatologists such as Fritz Schweingruber, Keith Briffa, and Jan Esper have been developing a global network of tree ring density data (Briffa and Schweingruber, 1988, 1992; Schweingruber and Briffa, 1996; Esper et al., 2002). The studies these scientists have conducted observe fluctuations in the MXD of growth rings of tree species that express variations in growth trends related to temperature. Specifically, studies observing MXD as a temperature proxy have found that a positive relationship exists between MXD and maximum annual summer temperature (Briffa et al., 2001, 2002). Additionally, they use specialized equipment and methodology that is both time-consuming and expensive, limiting it to laboratories with ample resources. A rise in the demand for a less costly method to measure tree ring density has surfaced in an attempt to construct a more complete record of historic temperature variability globally.

2.2 Development of Blue Intensity Analysis

Due to the high cost associated with performing X-ray densitometry to reconstruct past temperatures, scientists have been interested in developing a more practical method of determining the cell density of tree rings. The absorption of ultraviolet light by lignified cell tissue, known as ultraviolet microscopy, has long been utilized as a tree ring climate proxy (Lange 1954; Fukazawa 1992). More recently, it has been discovered that with the use of a basic optical scanner and specialized computer software, the reflectivity of certain wavelengths of the visible light spectrum can be quantified (McCarrol et al., 2002; Björklund et al., 2014). Lignified cells readily absorb wavelengths of light in the blue spectrum, thus quantifying the amount of blue light that is reflected off of tracheid cells can provide insight about the amount of lignin that is present in dense latewood bands of cell tissue. The cells of latewood band of tree rings are typically darker than its earlywood counterparts, meaning the latewood will absorb more blue light than it reflects.

Proxies that use cell density to observe past temperatures have been successfully utilized over the past several decades (Briffa et al., 1992, 2001; Schneider et al., 2015; Wilson et al., 2016a). Maximum latewood density of annual growth rings has been recognized as a recorder of past temperature variability (Büntgen et al., 2006; Rydval et al., 2014). Several studies have utilized X-ray densitometry to measure MXD, which has been shown to have a positive relationship with maximum annual summer temperatures (McCarroll et al., 2002; Wilson and Luckman, 2003; Wilson et al., 2016a; Rydval et al., 2017). Many of these existing studies have been conducted across European and Asian countries, as well as Canada, though few have been performed in the United States. This has resulted in a lack of tree ring density data for much of North and South America, likely from the high operation costs associated with X-ray densitometry (Rydval et al., 2014).

With technological advancements in the field of dendroclimatology, the absorption of visible spectrums of light by lignified tracheid cell tissue can be quantified and compared to global temperature data. Wilson (2012) found that this value of absorption and reflectivity, known as blue intensity, has an inverse relationship with past maximum summer temperatures. By producing high-resolution scans of tree ring samples and generating the various BI parameters offered by dendro-specific software such as CooRecorder (Rydval et al., 2014) or WinDendro (Campbell et al., 2011), scientists can have a good understanding of the density associated with various sections of cells making up annual tree growth rings. Additionally, dendro-specific software allows the user to generate both BI data as well as TRW data simultaneously, making the production cost of BI time series data similar to the cost associated with the development of tree ring chronologies.

Though the BI method of generating density data is far more practical in cost and methodology that X-ray densitometry, there are some limiting factors. BI is still a new practice, with the first studies surfacing in the early 2000s (McCarroll et al., 2002; Wilson and

Luckman, 2003). The relatively young age of this type of research has resulted in a lack of BI information in several regions across the globe, most notably North America (Wilson et al., 2016a). Additionally, as with X-ray densitometry (Briffa et al., 1992), useful BI data can only be produced from temperature-sensitive conifers at mid to high latitudes and alpine environments (Wilson et al., 2017).

2.3 Engelmann Spruce

Engelmann spruce, named for physician and botanist George Engelmann, are members of the Pinaceae family, endemic to North America. Their habit is typically characterized as a larger tree, growing upwards of 60 meters tall, with a relatively dense crown dense that forms a narrow cone or spire-like shape. Engelmann spruce branches tend to exhibit horizontal spreading. The lower branches are generally persistent, as it is not a strongly self-pruning species. The bark is red to purplish-brown in color and thin and scaly. Needles are evergreen, borne singly from all sides of stout, yellow-brown twigs. Needle length ranges from 1.6–3.0 cm long. Needles are 4-angled, stiff, sharply pointed on the ends, and blue-green in color. Seed cones are violet to deep purple in color. Upon ripening, cones turn dull-brown, ellipsoid, and pendent, with lengths ranging from 3.0–6.0 cm. The cone scales are relatively small, papery, and flexible, and generally remain intact after cones drop off the tree (Alexander and Shepperd 1990).

Engelmann spruce are endemically distributed from Alberta and British Columbia to the north, and southward through Nevada, Utah, and Colorado, into Arizona and New Mexico. The Sangre de Cristo Mountains are at the southernmost extent of its range. Populations further south such as populations in the Chiricahua Mountains and those down in northern Mexico are considered a subspecies (ssp. *mexicana*). Engelmann spruce occur in montane and subalpine forests. Engelmann spruce and subalpine fir (*Abies lasiocarpa*) form one of the most common forest associations in the Rocky Mountains. With an elevation range anywhere from 1,000–3,000 meters, these trees can occur as stunted, twisted individuals at timberline, or even co-occur down into the fir-aspen belt on moist, north facing slopes and in canyons (Alexander and Shepperd 1990).

The strong shade tolerance of Engelmann spruce allows it to occur both as a persistent long-lived seral species and as a major climax species (Aplet et al. 1988; Alexander and Shepperd 1990). Engelmann spruce will grow steadily for 300 years, long after the growth of most associated tree species slows down (Aplet et al. 1988). Dominant spruces often range from 250–450 years old, and individuals 500–700 years old have been documented in *The Old List* (http://www.rmtrr.org/oldlist.htm). The oldest recorded specimen for this species was sampled by Brown et al. (1995) with an age of 911 years.

While open-growth trees may begin producing seed crops as early as 15 years, the best seed production for Engelmann spruce occurs between 150 and 250 years. Significant seed crops are generally born every 2–5 years. Germination and establishment in typically occur on duff, litter, humus, decaying wood, and mounds of mineral soil upturned by wind thrown trees (Knapp and Smith 1982). Engelmann spruce seedlings do not readily establish in totally open conditions (Knapp and Smith 1982). At high elevations, 40 to 60 percent of full shade is most favorable for seedling establishment (Alexander and Shepperd 1990). Because of their slow initial root penetration and extreme sensitivity to heat in the succulent stage, spruce seedlings are often largely killed due to drought and heat girdling in their first year. Drought losses continue to be significant for the first five years of growth for Engelmann spruce seedlings (Alexander and Shepperd 1990).

Because of having a shallow root system, Engelmann spruce is highly susceptible to windthrow. Downed wood from windthrow also makes a site vulnerable to attack from the spruce beetle, which has caused severe damage in recent years. The western spruce budworm is another potentially damaging insect that attacks both Engelmann spruce and subalpine fir. Complete removal of a spruce-fir stand by fire or logging results in such drastic environmental changes that spruce and fir are usually replaced by lodgepole pine, aspen, or shrub and grass communities (Alexander and Shepperd 1990).

CHAPTER THREE

TESTING THE EFFICACY OF BLUE INTENSITY AS A TEMPERATURE PROXY IN *PICEA ENGELMANNII* FROM ITS SOUTHERN RANGE LIMIT, NORTHERN NEW MEXICO, USA

3.1 Introduction

Increasing global temperatures are continually exacerbated by anthropogenic climate change. Environmental proxies that record fluctuations in historical temperature are crucial to reconstructing and understanding past climates. Currently, climate proxies that are sensitive to temperature, and therefore useful for historic temperature reconstructions, are rare in comparison to proxies used to reconstruct precipitation, drought, and other climate variables. Temperature-sensitive proxies that are currently utilized are more prevalent in mid to high latitudes and in high elevation environments (Campbell et al., 2011; Wilson et al., 2016a).

The study of tree rings to document and place some chronological context to, environmental conditions, ecological processes, and disturbances is known as dendrochronology. Dendrochronology has a number of subfields that have different foci, from dendropyrochronology, which observes historic fire occurrence, to dendroclimatology, which reconstructs historic weather and climate variables. Calendar years are assigned to individual tree growth rings, and the growth structure of each ring is analyzed to determine the environmental conditions present during the time of growth. Dendrochronological analysis can provide a detailed historical record climate that is much longer than the instrumental climate records that are available.

Dendrochronological studies provide detailed reconstructions of a number of regional historical climate variables. Studies using tree rings as a proxy for climate traditionally use visible growth trends such as total ring width (TRW) to reconstruct climate. Programs used to analyze tree ring data can observe a number of additional of additional variables. The datasets from these proxies are extracted from high-resolution scanned images of samples. Dendro-specific software such as Windendro and CooRecorder use these scanned images to delineate tree rings, crossdate samples, measure total ring width, analyze earlywood and latewood, and perform density analysis.

One of the most widely used annually-resolved proxies for climate reconstructions is dendrochronology (Esper et al., 2004). Proxies that reconstruct temperature are rare, though trees of certain species in specific environments can be used to perform these reconstructions. X-ray densitometry is a method of calculating maximum latewood density (MXD), a biological indicator of temperature (Polge 1966; Schweingruber 1988). The density of latewood bands of cells is shown to fluctuate with varying temperatures, though traditional methods of densitometry are rather expensive and required specialized equipment and training. Blue intensity (BI) analysis is a much more widely accessible and affordable method of reconstructing regional temperatures. BI records the amount of blue light that is absorbed by tracheid cells, which provides a numerical reflectivity value that expresses the lignin presence of the latewood of tree growth rings.

To date, there are still many data gaps for temperature reconstructions globally. Temperature reconstructions currently exist for many locations across Europe, as well as a few places in North America (Wilson et al*.,* 2016; Figure 3.1). The American Southwest is one region where no temperature reconstructions have been conducted. Additionally, on a global scale, no temperature reconstructions have been successfully completed as far south as northern New Mexico. This study aims to determine the efficacy of performing BI analysis at high-elevation mixed conifer forest ecosystems in the Sangre de Cristo Mountains of the American Southwest.

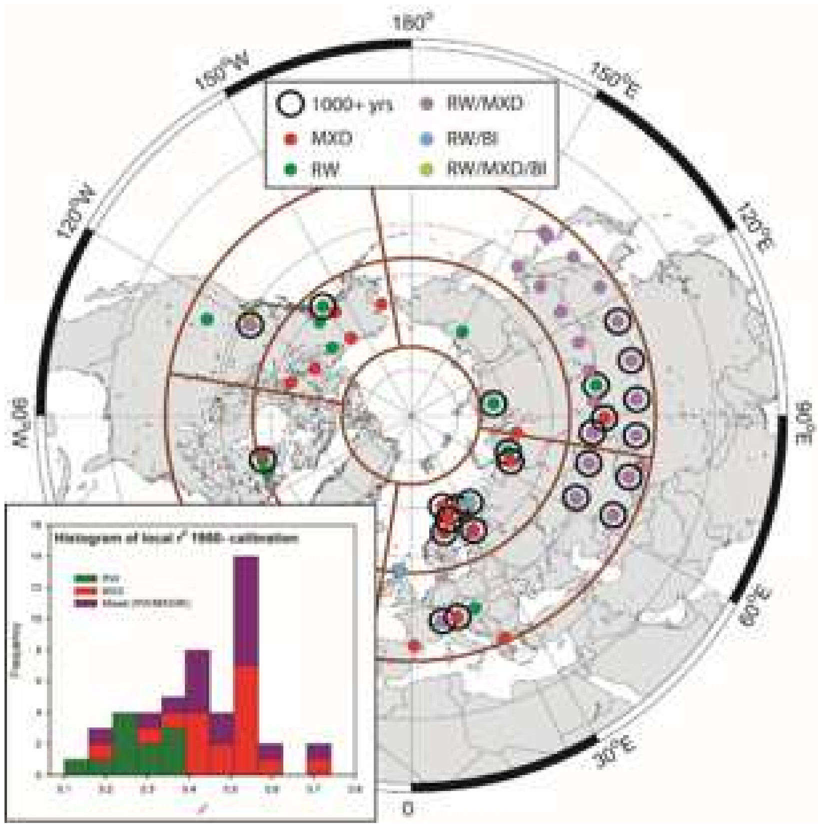

Figure 3.1: Map of the N-TREND network of tree-ring reconstructions depicting lack of North American temperature reconstruction data used in Wilson et al (2016).

3.2 Study Site

This study took place in the Sangre de Cristo Mountain range, which compose the southernmost region of the Rocky Mountains and extend from southern Colorado to northern New Mexico. The Carson National Forest, which lies within the boundaries of the Sangre de Cristo Mountains in north-central New Mexico, encompasses the field site, Wheeler Peak, located at 36°33’25” N 105°25’01” W. Wheeler Peak National Wilderness is located just outside of Taos, New Mexico in the Taos subrange of the Sangre de Cristo Mountains. Wheeler Peak National Wilderness encompasses an area of approximately 8,100 ha and ranges in elevation from 1828 m to 4011 m. The summit of Wheeler Peak sits at just over 4011 m in elevation, making it the highest point of the State of New Mexico.

In Taos County, NM, the monthly annual temperatures range from a low of -11.8 °C in January to a high of 30.4 °C in July, with monthly annual precipitation ranging from 13.97mm in February to 52.3 mm in August (NCDC 2018). The variable elevation, slope aspects, and soil types of Carson National Forest has resulted in a landscape with a mosaic of varying vegetation types. The Sangre de Cristos are a particularly structurally complex range, with igneous, metamorphic, and sedimentary rocks visibly exposed at high elevation sites (Baker 1973). The geology from the Wheeler Peak Wilderness Area primarily consists of Precambrian granite, gneiss, and migmatite (Clark and Read, 1972). Of the area composing the Carson National Forest, 87 percent fall into the classification of forested lands (Menlove 2004). This forested land is majorly composed of pinyon-juniper (*Pinus edulis*; *Juniperus scopulorum*), ponderosa pine (*Pinus ponderosa*), and other mixed conifer woodlands (Menlove 2004). Though only a small portion (~ 4%) of the Carson National Forest is made up of Engelmann spruce trees, this region comprises the southern range limit of the species, making the specimens at this field site sensitive to environmental fluctuations.

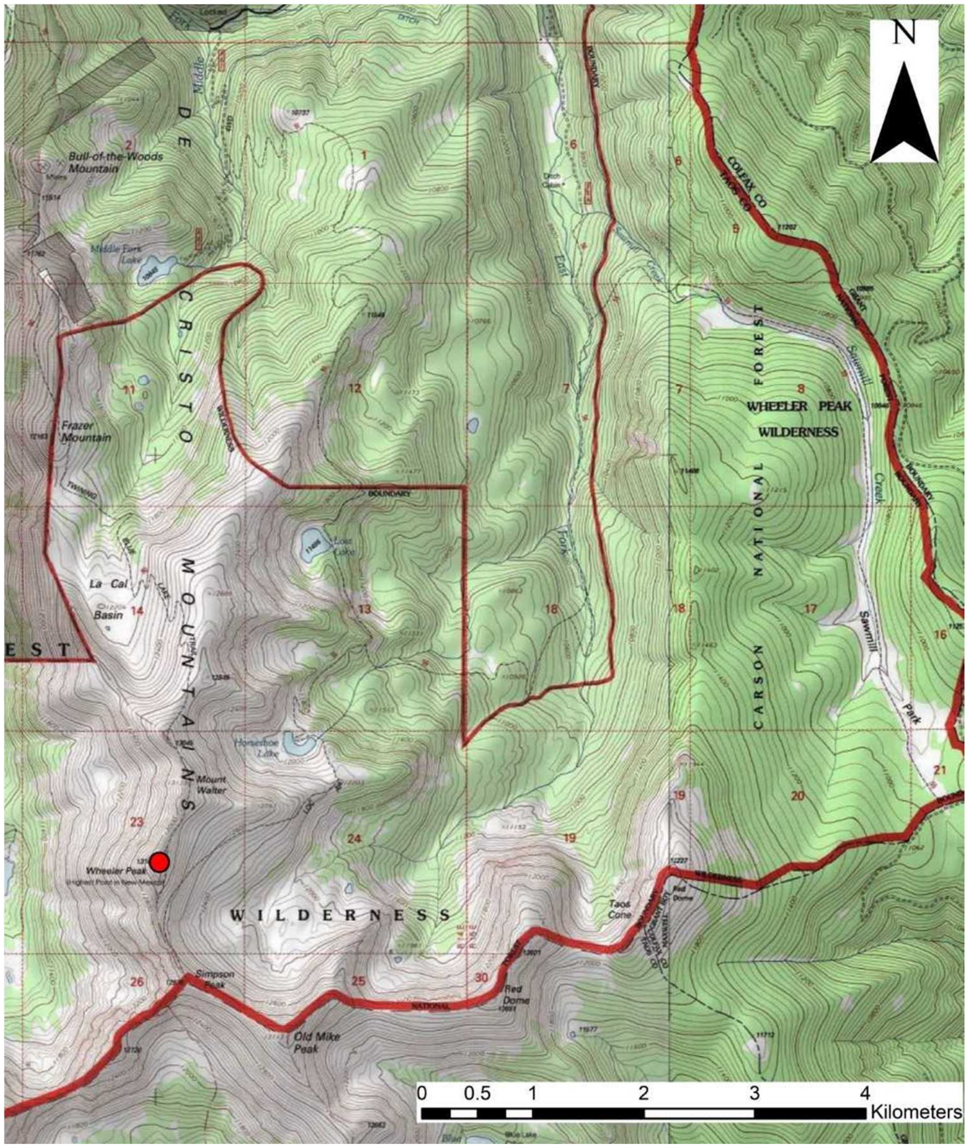

Figure 3.1: Map of the study site (red circle) in the Carson National Forest of the Sangre de Cristo Mountains, New Mexico. Generated using ArcGIS.

Figure 3.2: Map showing distribution Engelmann spruce across North America. Taken from USGS on 28 March 2018.

Figure 3.3: Photograph taken from the field site at Wheeler Peak, NM by Trevis Matheus, August, 2016.

3.3 Methodology

3.3.1 Field Sampling

Increment cores were collected from a variety of ages and sizes of Engelmann spruce, further on referred to by the species code: PIEN, at the high elevation (3500 to 4000 m) mixed-conifer site. Cores were taken at breast height using a 5mm diameter increment borer. A total of 27 increment cores were randomly sampled from 16 PIEN located at the tree line. A minimum of two cores were taken from each tree, parallel to the contour of the slope to reduce abnormalities in ring growth and to increase the likelihood of sampling as many rings between the bark and pith as possible (Tucker 1979; Speer 2010). Upon extraction, each core was labeled and placed into protective packaging for transport. Additionally, at each specimen GPS coordinates were recorded for each individual tree that was sampled.

Figure 3.4: Image taken as example of increment core extraction technique

3.3.2 Sample Preparation and Laboratory Analysis

Increment cores were prepared for analysis using the standard procedures described by Stokes and Smiley (1968; 1996). Samples were air-dried for a minimum of 24 hours. The cores were then positioned to orient the tracheid cells vertically and secured to 5.0mm wooden mounts using Elmer's multi-purpose glue and fasteners. The mounted cores were then allowed to dry for additional 24 hours. Once the samples were dried and mounted, each sample was progressively sanded using a rotating belt sander (80 grit, 120 grit, 220 grit, 320 grit, 400 grit, 800 grit). If samples contained any noticeable scratches or blemishes from mechanical sanding, individual samples were sanded by hand during analysis using 1200-grit sandpaper. The final hand polish removed any imperfections and provided a clearer scanned image.

Prepared increment cores were then scanned into dendro imaging software, CooRecorder. CooRecorder required initial scanner calibration to ensure accuracy of generated BI values. The color intensity values were calibrated using an IT8.7/2 calibration card developed by LaserSoft Imaging coupled with EPSON Scan 2 software and an EPSON XL 12000 scanner. The calibration card was first scanned using 1200 dpi (dots per inch) resolution and 48-bit color parameters. Using CooRecorder's calibration function and a colormetric data file calibrated specifically to the R170419 calibration card that was used, the initial image of the calibration card was visually examined to ensure that each frame was aligned with its appropriate color (Figure 3.5).

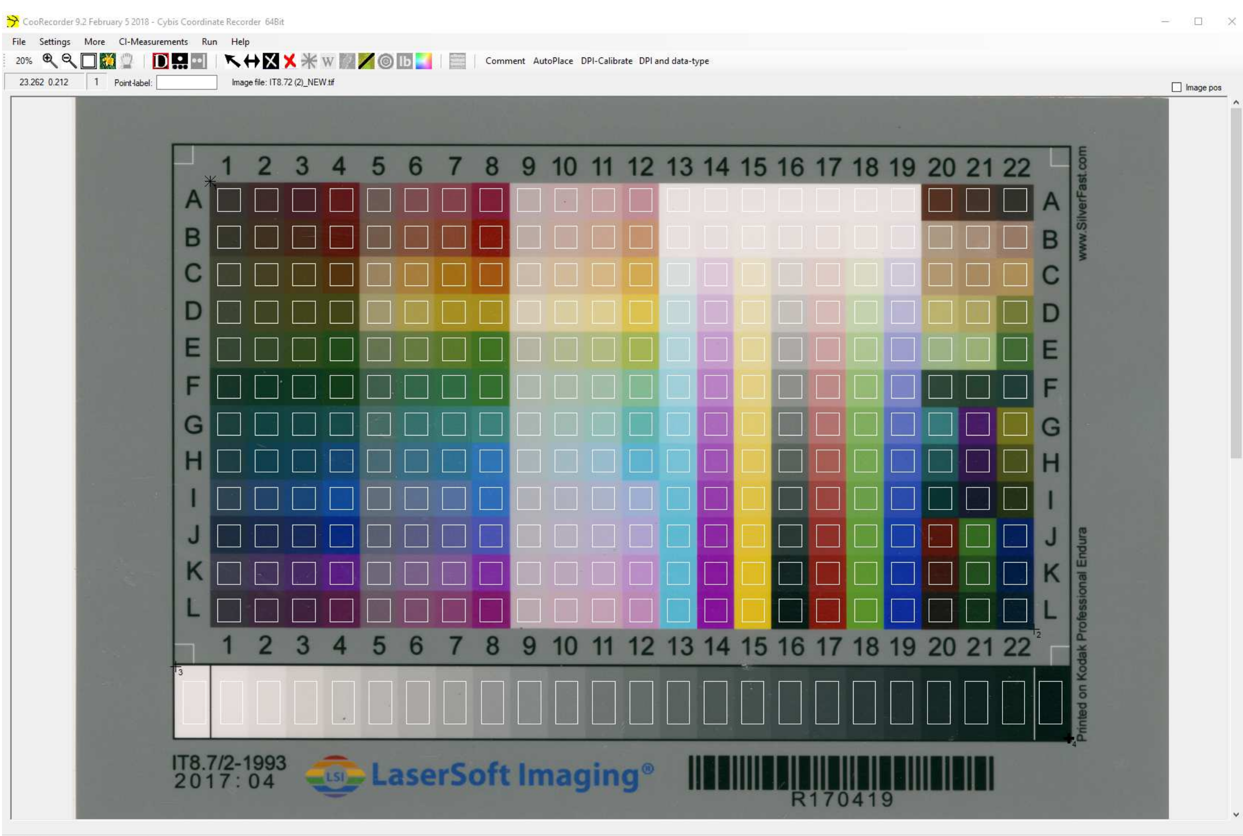

Figure 3.5: Screenshot from CooRecorder showing blue color intensity calibration card with colorimetric data file.

At this point, CooRecorder defined three corresponding color values for each frame, prompting the user to save the "calibration points" file. Coorecorder then generated a scatterplot from the calibration points file and plots them against a line of perfectly calibrated color values. If the image is calibrated correctly, most of the color intensity points will be positioned on or close to the calibrated line. If color intensity values vary from the calibration line, the image is not calibrated correctly, and depending on the value that is misplaced, lower values (darker colors) or higher values (lighter colors) may express discoloration. By generating a reasonably good calibration curve through these methods, additional calibration is not necessary, though more accurate calibration is available by using the 'Transform Current Image by Calibration' function under the 'CI-Measurements' tab. This function utilized a user-defined calibration curve to change the coloration of the image itself, therefore calibrating the image to the selected calibration curve.

Another method to ensure that each individual image is calibrated correctly is to generate 'color patches', which are printed strips of varying shades of blue used to determine the calibration of a scanned image. Blue color patches can be created a number of ways, though this study uses Adobe Illustrator to make two rectangles of shades of blue that are visibly lighter and darker from one another. These blue patches are then scanned into CooRecorder along with the IT8.7/2 calibration card. The densitometer function in CooRecorder allows the user to determine the BI value of a user-defined rectangular space. This function, when utilized with a calibrated image of the IT8.7/2 calibration card allows the user to determine the specific BI value of the color patches, which can then be scanned onto each image to ensure the BI values remain consistent for every image (Figure 3.6).

Figure 3.6: Screenshot from CooRecorder displaying blue color patches and densitometer function used for calibration.

Using an EPSON XL12000, cores were scanned with 1200 dpi (dots per inch) resolution and 48-bit color to produce high-definition imagery. The scanned images were individually loaded into CooRecorder 9.2 software for total ring width (TRW) measurement and blue intensity (BI) analysis. CooRecorder delineated growth rings to produce a visually crossdated image. Individual growth rings for each sample were measured to 0.001 mm accuracy. For increment cores from living trees, the incomplete outmost growth ring was created during the year that sampling took place. By assigning a date to the outermost ring, CooRecorder assigned a calendar year to each individual ring. BI data was calculated simultaneously to TRW by recording the reflectance value from a frame structure characterized by user-defined frame specifications. This study used a frame width of 100, a width-limiting factor of 3, a frame position of 5, a maximum frame deepness of 500, and a relative margin (k) to next ring border. These frame specifications are based on the specifications utilized by Rydval, et al. (2014).

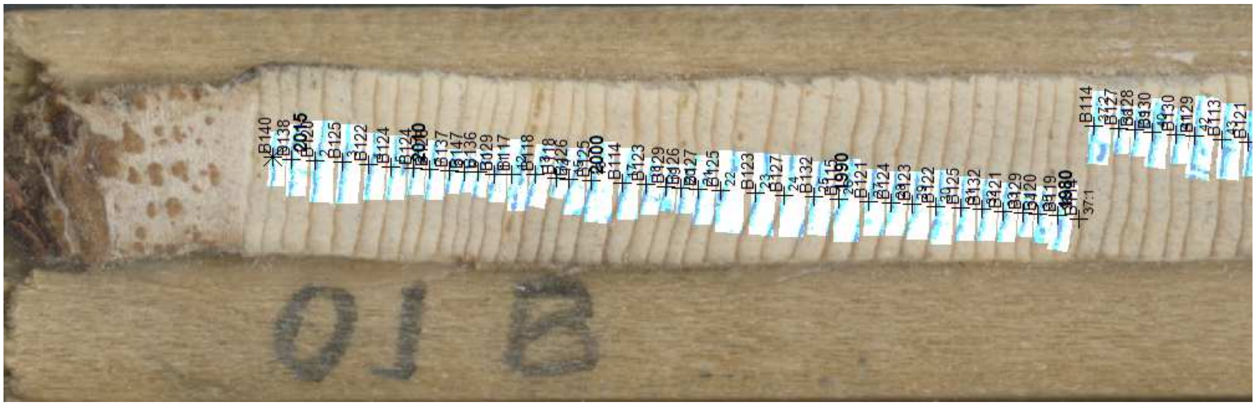

Figure 3.7: Screenshot from CooRecorder displaying the ring delineation process and BI measurements

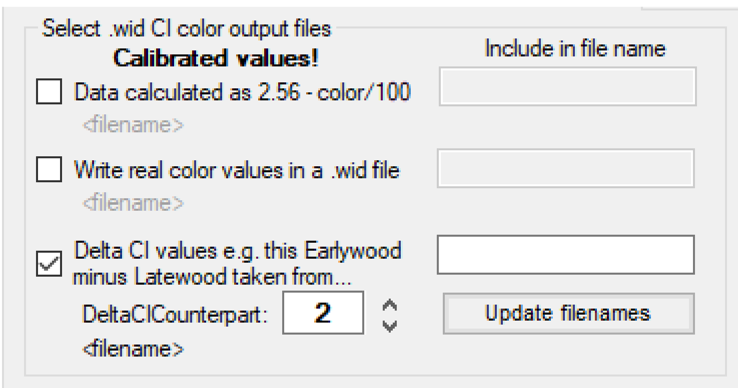

Figure 3.8: Screenshot showing the available data outputs for CooRecorder

CooRecorder has several available data outputs for BI measurements. We used the data output methods of raw latewood BI, inverted latewood BI, inverted earlywood BI, and the difference between earlywood and latewood BI (delta BI). BI values were inverted before exporting so the data could be detrended similarly to detrending methods undergone with maximum latewood density data. All exported time series data was compiled into a collection in CDendro 9.1. CDendro then took the collection of time series data and converted it to Tuscon ring width format to be detrended in ARSTAN. TRW data was crossdated to existing regional chronologies using the software COFECHA to ensure the accuracy of tree ages. In addition to statistically calculating the interseries correlation of the chronology, COFECHA also records parameters such as average mean sensitivity and flags potential errors in the ring delineation process.

3.3.3 Statistical Analysis

The TRW and BI measurements recorded by CooRecorder in this study are processed in the program ARSTAN to detrend the age-related growth trend (Cook and Holmes, 1986) Time series data was then validated using COFECHA, a computer program designed to statistically validate tree ring time series data with existing regional chronologies (Holmes 1983; Grissino-Mayer 2001).

This study utilized a program that performs correlation tests and generates figures to determine the statistical significance of the relationship between tree ring time series data and global climate data. The Royal Netherlands Meteorological Institute (KNMI) developed the web-based application, Climate Explorer, in 1999. To this day, KNMI Climate Explorer is a database of over 10TB of global climate data and it widely utilized by a number or scientists who work with time series data.

KNMI Climate Explorer takes the time series data that the user inputs and calculates the Pearson Correlation Coefficient between the time series data and the user-selected climate data. KNMI Climate Explorer uses gridded raster data and performs this statistical test repeatedly for every grid cell across a user-defined space. Each Person correlation coefficient value is assigned a color, with positive correlation values being represented with yellows, reds, and oranges, and negative correlation values being represented with blues. These statistical analyses can be generated for every month of the year, or specific months to determine the relationship between time series data and seasonal climate fluctuations.

For this study, we performed our statistical tests using instrumental summer temperature records provided by the Parameter-elevation Relationships on Independent Slopes Model (PRISM) surface temperature dataset, which has a 0.25° resolution for the contiguous United States and extends from 1895 to 2015.

3.4 Results

3.4.1 COFECHA

This study contributed to the chronology of PIEN sites that have been sampled in the American Southwest. The locations used for sampling are located on steep gradients and midslope. The oldest PIEN sampled during this study dates back to 1661, with several other samples dating to the late 17th and early 18th centuries (Figures 3.9 and 3.10). To validate the TRW and BI data used in this study, COFECHA was used to verify our chronology to existing regional chronologies.

The PIEN chronologies developed for this study all express exceptional interseries correlation values. An interseries correlation value of 0.328 is necessary for a 99% confidence interval (Speer 2010). The TRW time series data presented an interseries correlation of 0.569. The interseries correlation values for the other two parameter were slightly less, though still significant, with delta BI having a correlation of 0.490 and inverted latewood BI having a correlation of 0.478.

Based on the range of acceptable mean sensitivity values for climate reconstruction, 0.1-0.4 (Speer 2010), two out of three of the time series datasets used for this study express adequate mean sensitivity, with the exception of inverted latewood BI. TRW had the highest mean sensitivity value at 0.180, followed by delta BI at 0.129, and, finally, inverted latewood BI at 0.037.

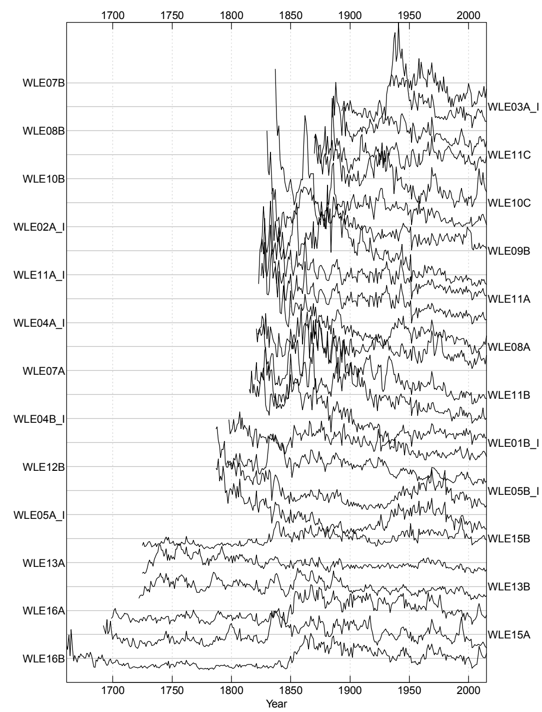

Figure 3.9: Spaghetti plot displaying trends in TRW for the Wheeler Peak, NM samples

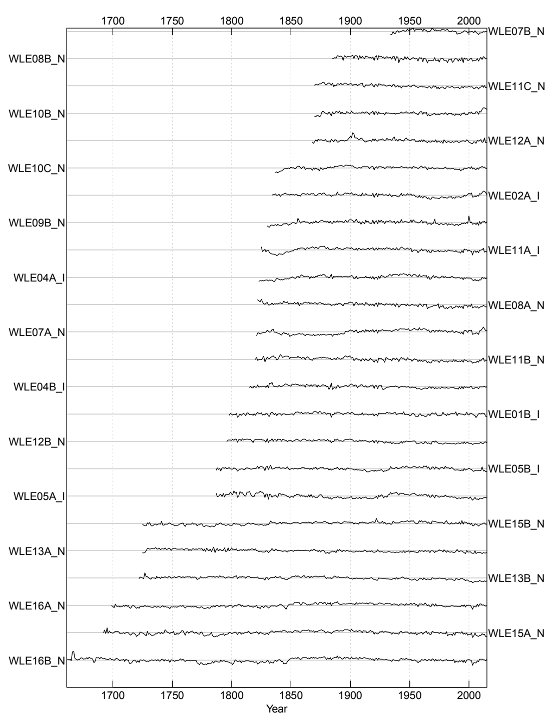

Figure 3.10: Spaghetti plot displaying trends in delta BI for the Wheeler Peak, NM samples

The BI time series data that was generated from CooRecorder were plotted against one another to observe any potential existing relationships between the parameters themselves. A strong positive relationship was observed when comparing inverted latewood BI data and inverted earlywood BI data (Figure 3.11-left). This relationship suggests that greater absorption of blue light in latewood bands of cells results in a greater absorption of blue in earlywood bands of cells. Additionally, a higher density of lignified cells results in a smaller BI value, suggesting the lignin content and cell density is greater with a smaller reflectivity value. A relationship is also present between TRW data and delta BI data (Figure 3.11-right), though it is much weaker than that of inverted latewood BI and inverted earlywood BI. This relationship suggests that BI values are somewhat dependent on annual tree growth. Some outliers are present in both of the scatterplots in Figure 3.11, which may be caused by exceptionally large rings having higher reflectivity and a relatively lower cell density.

The inverted BI parameters and delta BI express similar historical variability (Figure 3.12). Additionally, the start of a growth trend is observable for each of the BI parameters, other than raw values, when nearing the 21st century. When viewing a graph of the PRISM temperature data (Figure 3.13) used in this study, it is evident that this increase in BI follows a global temperature increase. This supports the hypothesis that inverted BI time series data from PIEN at Wheeler Peak, NM is temperature sensitive and follows similar trends as historic temperature variability over the past century.

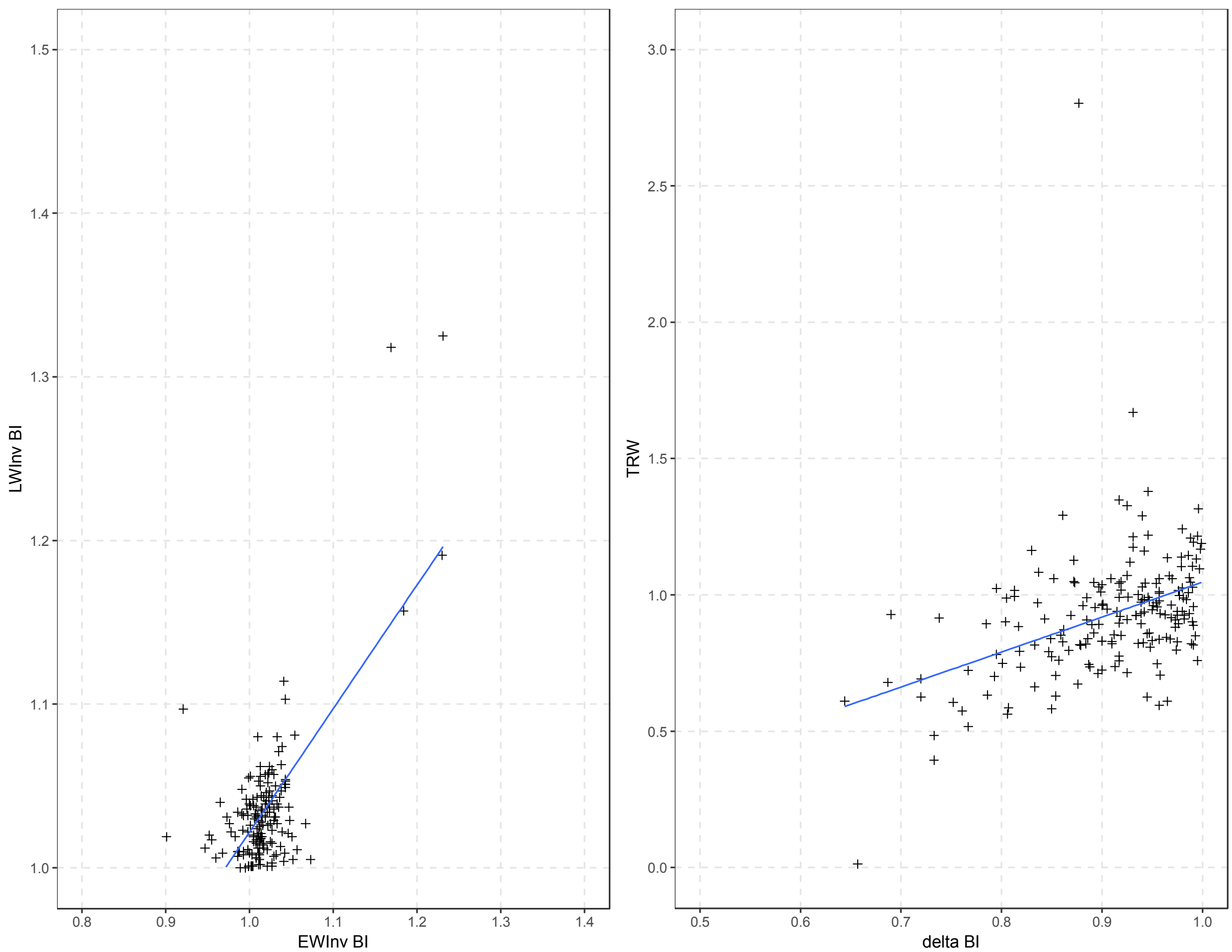

Figure 3.11: Scatterplots showing the strong positive relationship between inverted earlywood BI and inverted latewood BI (left) and the slightly weaker positive relationship between delta BI and TRW (right)

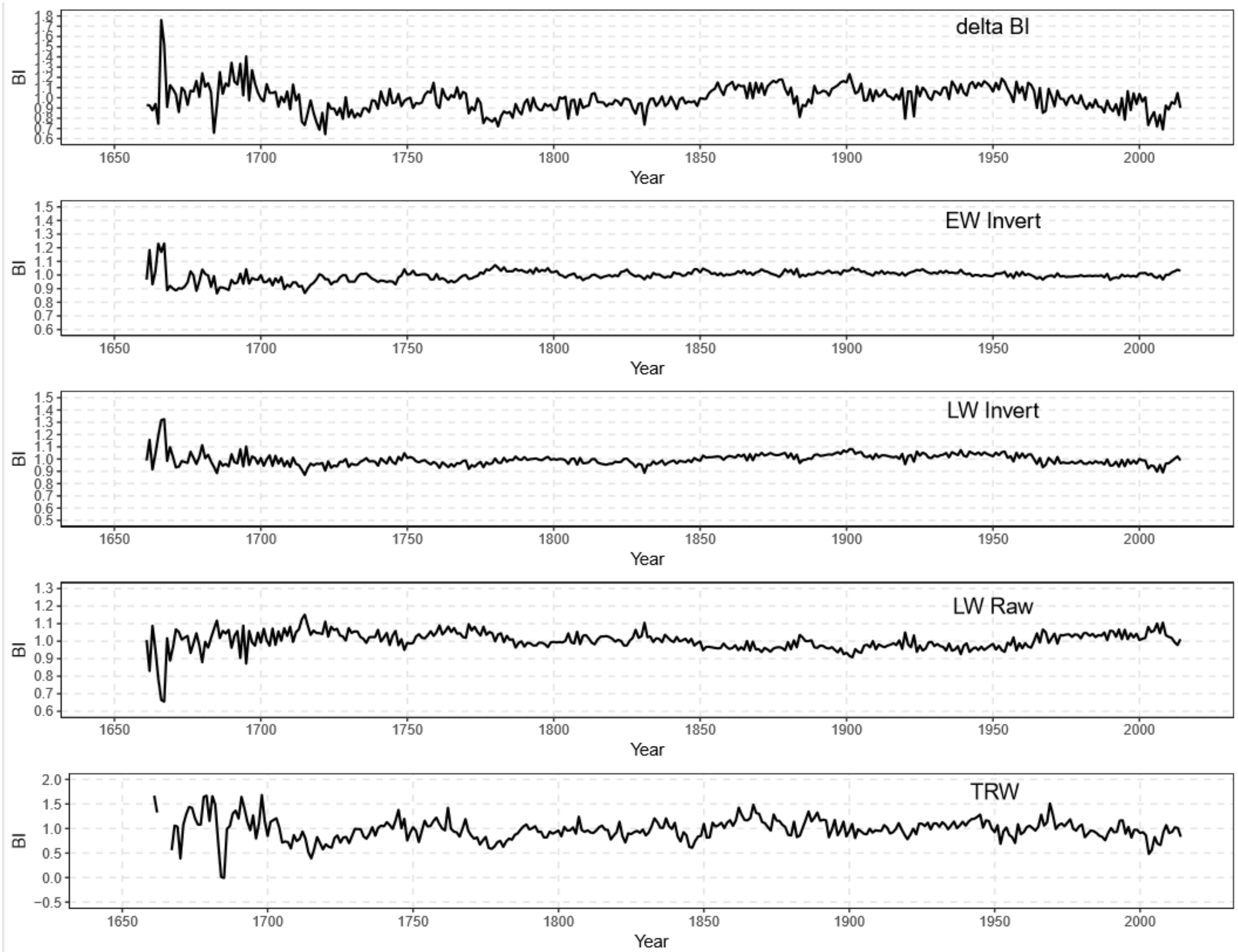

Figure 3.12: TRW and BI parameter time series 1661–2015 CE.

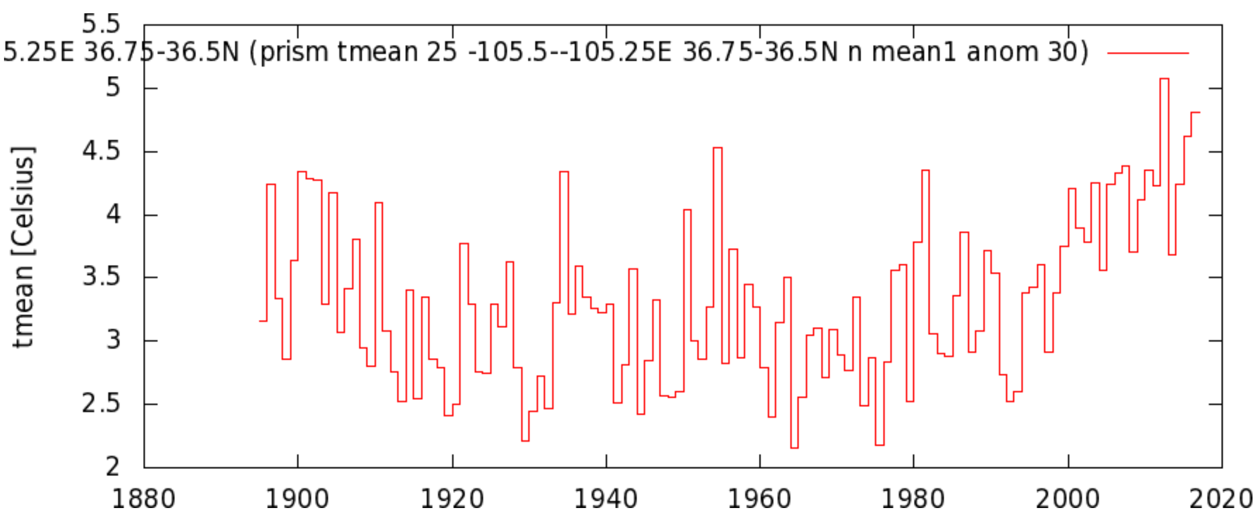

Figure 3.13: PRISM temperature data centered over the study area showing positive trend over the past several decades.

3.4.2 Blue Intensity and Climate Relationships

Our Wheeler Peak, NM tree ring data expressed a statistically significant relationship between the two BI time series used in this study, delta BI and inverted maximum latewood BI, and PRISM instrumental temperature records. To determine seasonal responses in BI parameters, our time series were run against maximum and mean temperature data for August and September separately, averaged maximum and mean temperature data for August through September, and average maximum and mean temperature data for June, July, August, and September (JJAS) temperature data. The figures generated by KNMI Climate Explorer use a blue and red color scheme to display the relationship between the uploaded time series and user-defined climate data, with white showing no correlation, gradually darker blues showing stronger negative correlations, and darker shades of yellows, oranges and reds, showing stronger positive correlations.

3.4.2.1 Statistical Analysis

The correlation between the utilized BI parameters and summer temperature data is significant, expressing the most notable positive correlation in the months of August and September. Delta BI and temperature data from the previous year's May, August and September months have a strong positive correlation, with August and September temperature data having a correlation coefficient of greater than 0.25 (Figure 3.32). Correlation coefficients were also generated for current October through January and the previous year's December through March, for forty-year intervals from 1896 to 2015 (Figure 3.33), which also showed that the strongest correlation values were present in the months of August and September for all 82 intervals that were tested. Similar results were found when generating the same figures using the inverted latewood BI parameter, with the previous year's August and September data have the highest positive correlation with inverted latewood BI time series data (Figures 3.34 and 3.35). When generating these same figures using TRW time series data (Figures 3.36 and 3.37), the signal weakens substantially, with no significant positive relationship present between TRW and any month's temperature data. This supports the hypothesis that BI is a much better predictor of historic temperature variability, as TRW is likely too heavily influenced by other environmental variables that are site-specific, such as moisture availability.

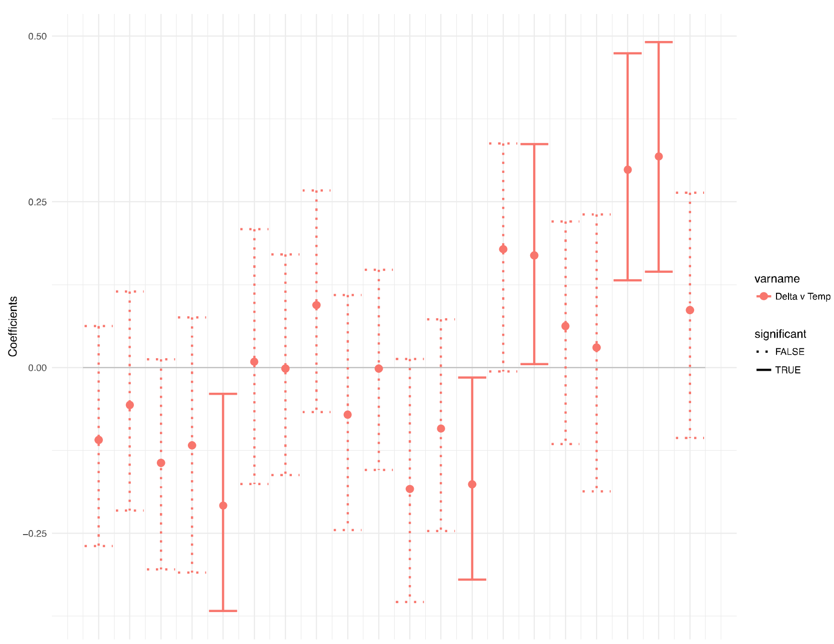

Figure 3.14: Graph showing statistically significant correlations (True) between delta BI parameter and monthly temperature data for current months (Mar-Dec) and the monthly data for the previous year (JAN-OCT).

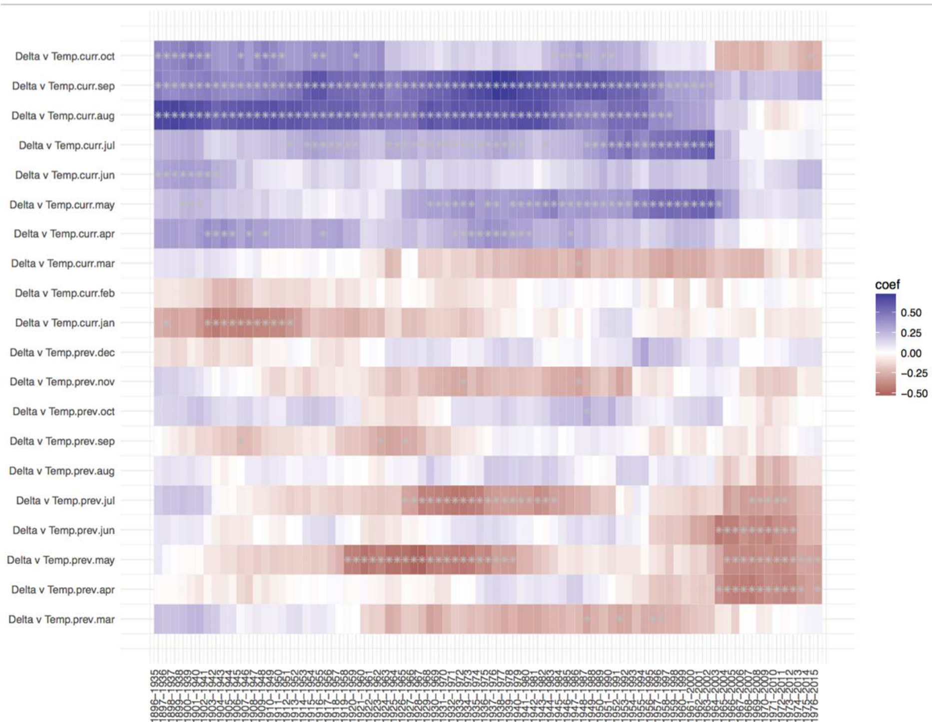

Figure 3.15: Correlation coefficient values expressed as higher positive correlations as gradually darker blues and higher negative correlations as darker reds. Delta BI time series data ran against current year's monthly temperature data and previous year's monthly temperature data over 40 year intervals from 1896 to 2015.

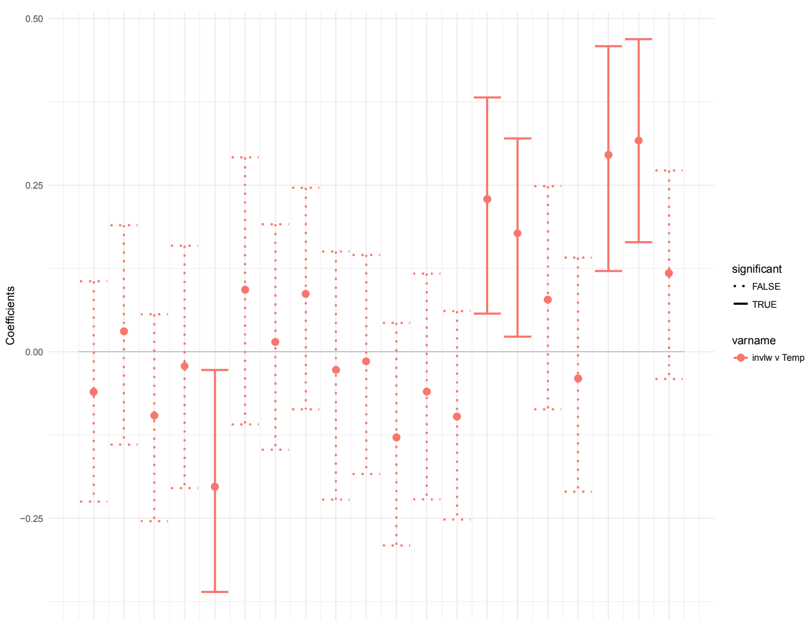

Figure 3.16: Graph showing statistically significant correlations (True) between inverted latewood BI parameter and monthly temperature data for current months (Mar-Dec) and the monthly data for the previous year (JAN-OCT).

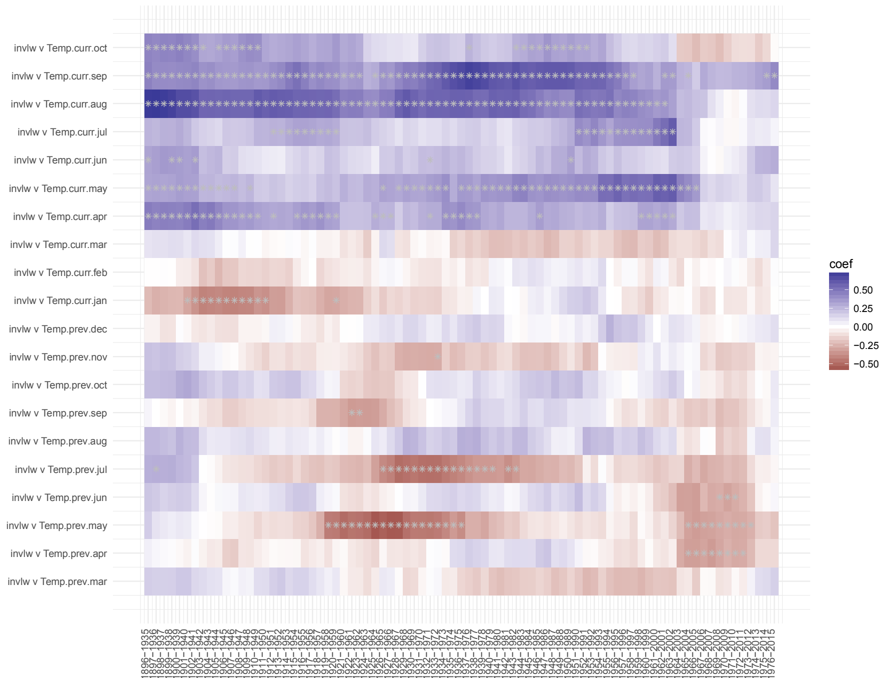

Figure 3.17: Correlation coefficient values expressed as higher positive correlations as gradually darker blues and higher negative correlations as darker reds. Inverted latewood BI time series data ran against current year's monthly temperature data and previous year's monthly temperature data over 40 year intervals from 1896 to 2015.

Figure 3.18: Graph showing statistically significant correlations (True) between TRW and monthly temperature data for current months (Mar-Dec) and the monthly data for the previous year (JAN-OCT).

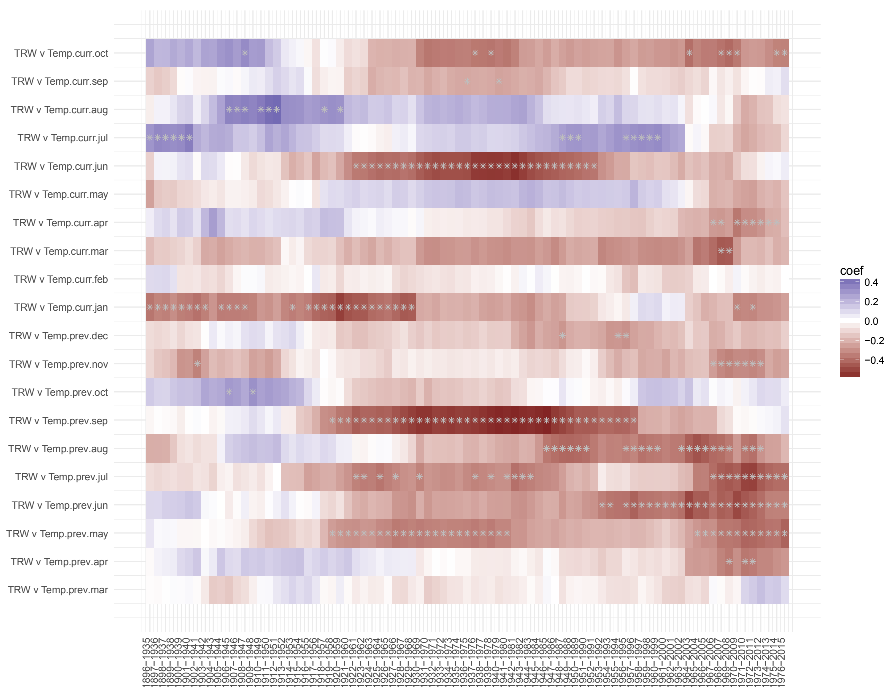

Figure 3.19: Correlation coefficient values expressed as higher positive correlations as gradually darker blues and higher negative correlations as darker reds. TRW time series data ran against current year's monthly temperature data and previous year's monthly temperature data over 40 year intervals from 1896 to 2015.

3.4.2.1 TRW vs. PRISM Summer Temperature Data

In an effort to emphasize the importance of this temperature proxy at its southern range limit, correlation values between averaged JJAS maximum temperature and TRW (Figure 3.30) and mean temperature and TRW (Figure 3.31) calculated. There is virtually no relationship identified between PRISM mean and maximum JJAS temperature data and TRW, with the exception of some areas in the American Southwest depicting slight spurious negative correlations. Though TRW has been used in existing studies as a proxy for temperature (Esper, 2002), the relationship between the temperature and TRW at Wheeler Peak, NM is nonexistent. It is expected that the lack of temperature signal with TRW is a result of the southern extent of the site, as well as the non-climatic signals produced from disturbances and stand dynamics (Buckley 2018).

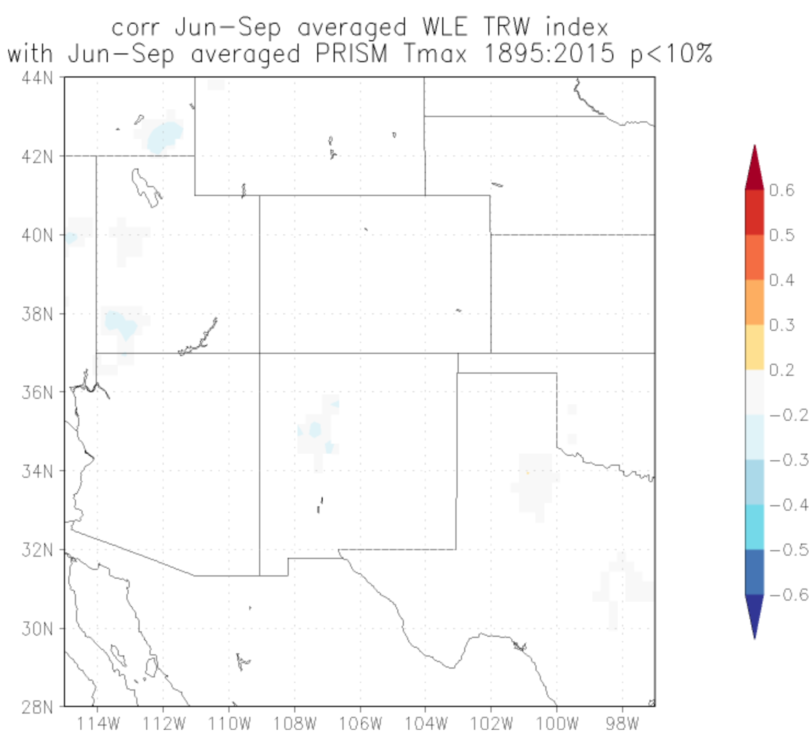

Figure 3.20: KNMI Climate Explorer output displaying correlation between Wheeler Peak, NM TRW time series and maximum summer (JJAS) temperature

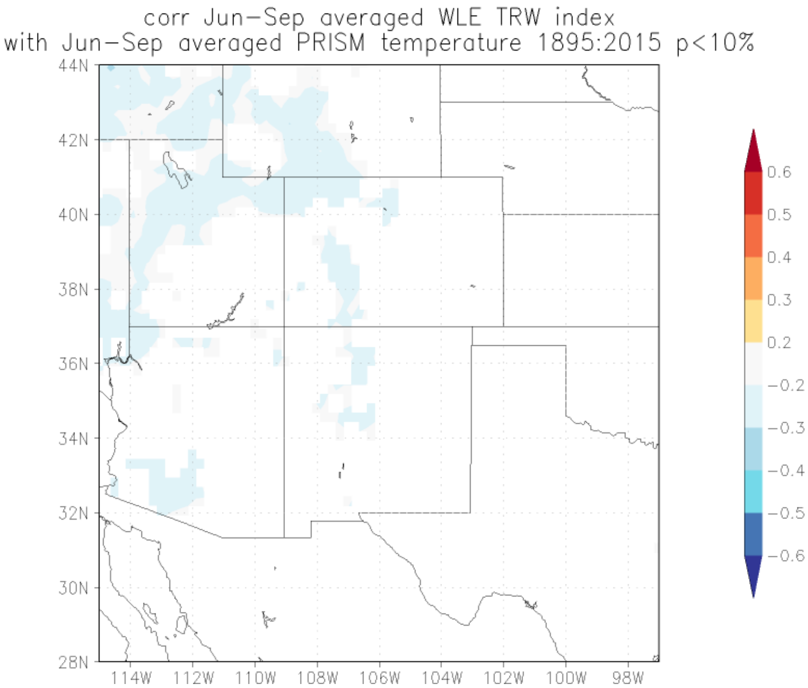

Figure 3.21: KNMI Climate Explorer output displaying correlation between Wheeler Peak, NM TRW time series and averaged summer (JJAS) temperature

3.4.2.2 Delta BI vs. PRISM Summer Temperature Data

When comparing delta BI to maximum summer temperatures, there is a positive correlation between the two variables, with the strongest temperature response centralized across the American Southwest. When observing the relationship between delta BI and August maximum temperature (Figure 3.14) and delta BI and September maximum temperature (Figure 3.14), the value of the Pearson correlation coefficient is the greatest in areas adjacent to the field site for August, and just north of the field site for September. If a strong correlation value is observed at or near the field site, it signifies that our tree ring time series data is in fact responding to monthly and annual temperature variability. The temperature signal generated between maximum September (Figure 3.15) temperature and delta BI is not as strong as the relationship with maximum August temperature.

By averaging the maximum annual temperatures for the months of August and September (Figure 3.16), the climate response becomes even stronger as distance from the field site decreases, with the Pearson correlation coefficient between 0.5-0.6 at the field site and extending greater than 0.6 in central and southern Colorado. Though the signal with averaged JJAS (Figure 3.17) maximum temperature is not as prominent, there is still a statistically significant relationship between delta BI and averaged summer maximum temperatures. The temperature response is also not as fixated over the field site, though correlation values of >0.3 are observed across much of the American Southwest.

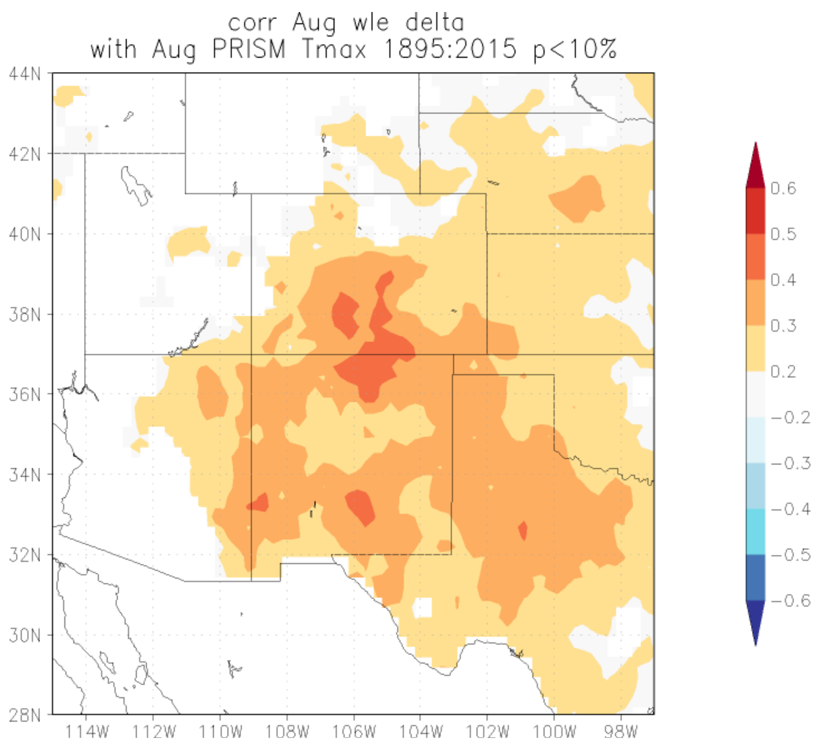

Figure 3.22: KNMI Climate Explorer output displaying correlation between Wheeler Peak, NM delta BI time series and PRISM maximum August temperature

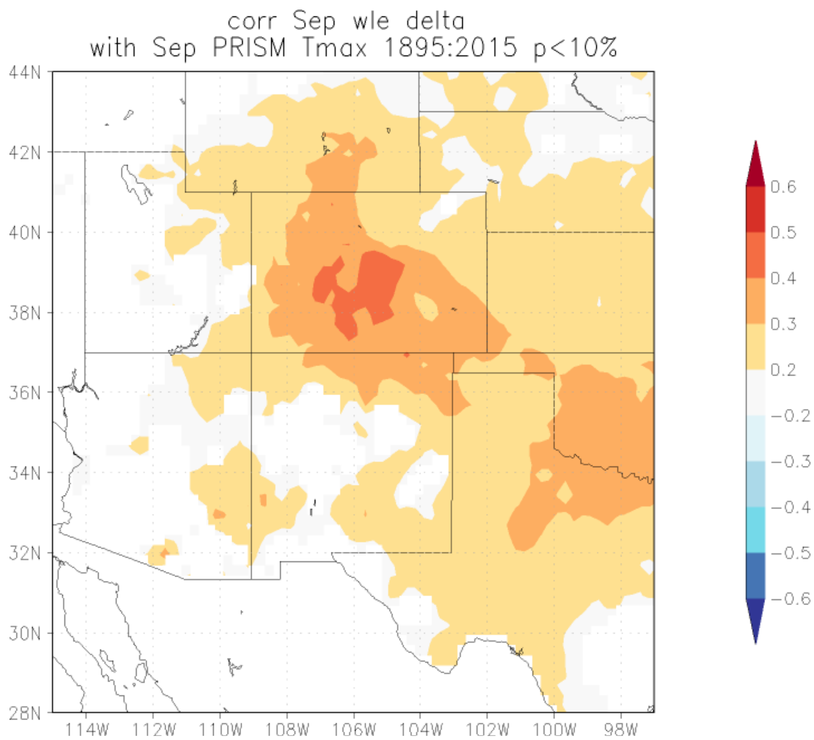

Figure 3.23: KNMI Climate Explorer output displaying correlation between Wheeler Peak, NM delta BI time series and PRISM maximum September temperature

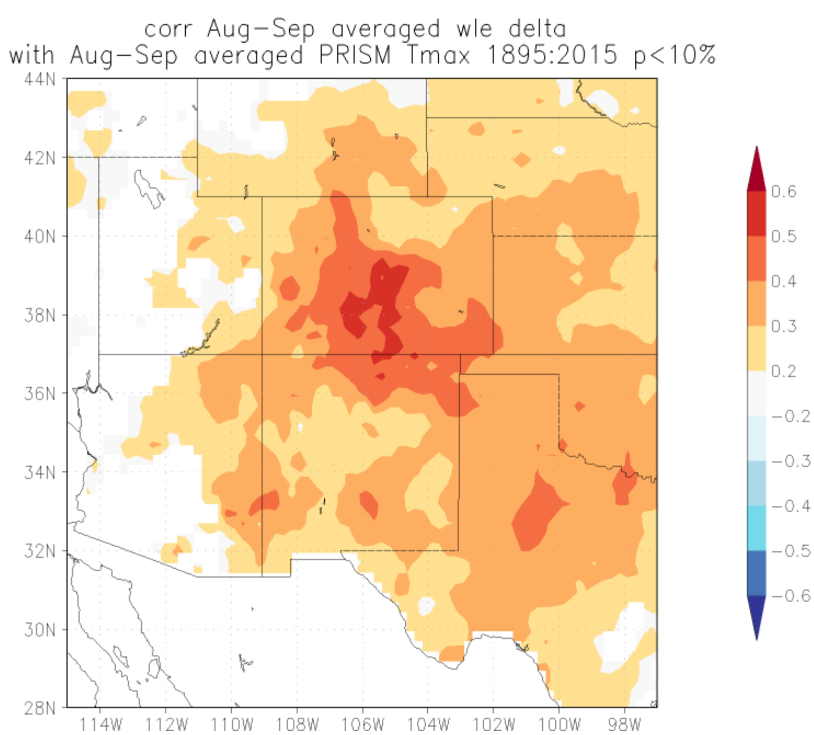

Figure 3.24: KNMI Climate Explorer output displaying correlation between Wheeler Peak, NM delta BI time series and PRISM averaged maximum August-September temperature

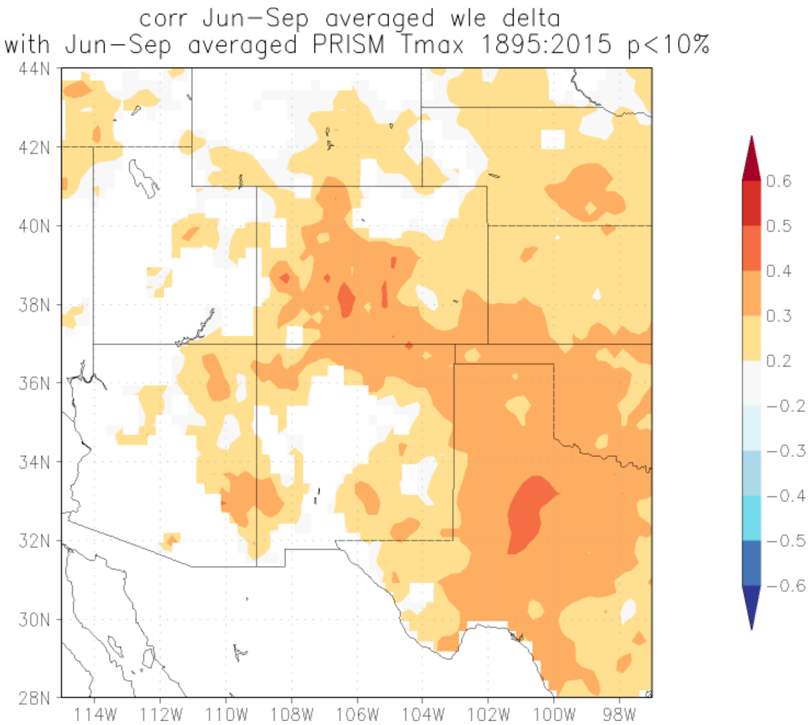

Figure 3.25: KNMI Climate Explorer output displaying correlation between Wheeler Peak, NM delta BI time series and PRISM averaged maximum summer (JJAS) temperature

In addition to determining the relationship between maximum temperatures, we also generated results for each tree ring parameter with averaged monthly temperatures. The results from using averaged monthly temperatures were less significant than maximum temperatures, though a temperature response does exist. The output for mean August temperature (Figure 3.18) shows correlation values between 0.2 and 0.3 across New Mexico, southern Colorado, and central Texas, with a few patches of values in excess of 0.3 in northern New Mexico and southern Colorado. Mean September (Figure 3.19) temperatures show a stronger relationship with delta BI at the field site. Most of the areas expressing higher correlations (0.3-0.4) are located at or near the field site, suggesting that the relationship between delta BI at Wheeler Peak, NM and annual average summer temperatures is positive.

As with delta BI and maximum temperature, when the mean temperatures for August and September (Figure 3.20) are averaged and processed by KNMI Climate Explorer, the temperature signal increases drastically. The signal over the field site and in central Colorado increases to between 0.3 and 0.4, and the signal for northeastern New Mexico, southeastern Colorado, and Texas increases from between 0.2 and 0.3 to between 0.3 and 0.4. The area comprising correlation values between 0.2 and 0.3 stays relatively consistent, with the aforementioned regions experiencing an increased positive relationship. The mean temperature signal expresses a consistent decline when June, July, August and September (Figure 3.21) temperature data is added, similar to the weakened signal of maximum JJAS averaged temperature. The strong positive temperature signal seen in Figure 3.18 shifts to the East, expressing little to no correlation with the field site, though there is still a positive regional signal across much of the American Southwest.

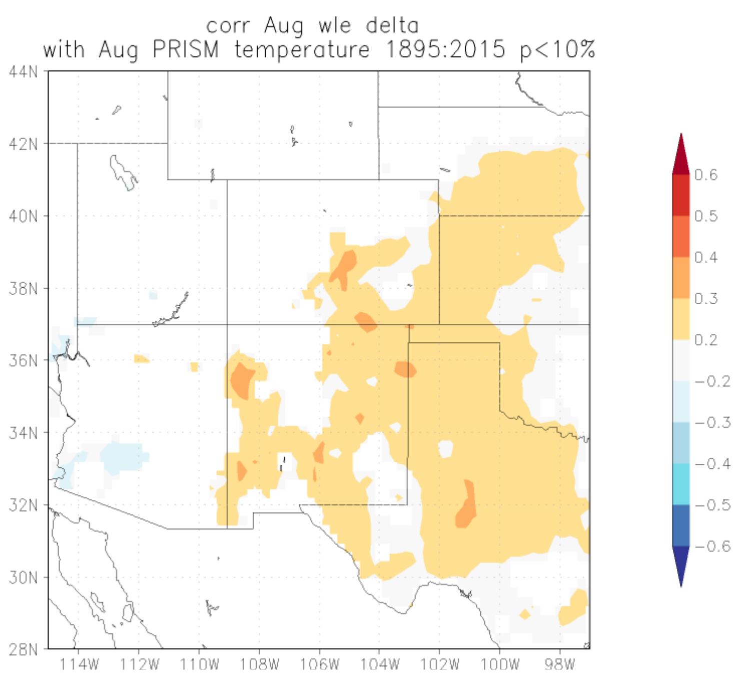

Figure 3.26: KNMI Climate Explorer output displaying correlation between Wheeler Peak, NM delta BI time series and PRISM mean August temperature

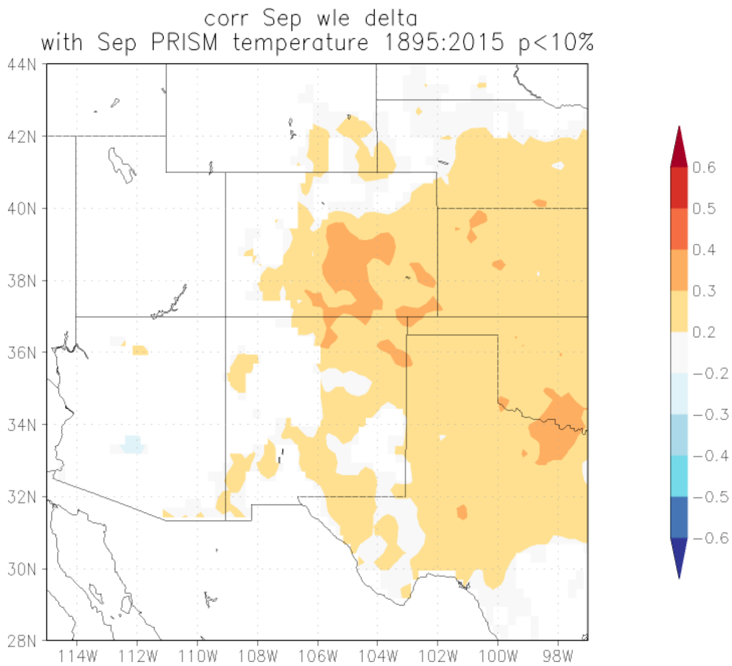

Figure 3.27: KNMI Climate Explorer output displaying correlation between Wheeler Peak, NM delta BI time series and PRISM mean September temperature

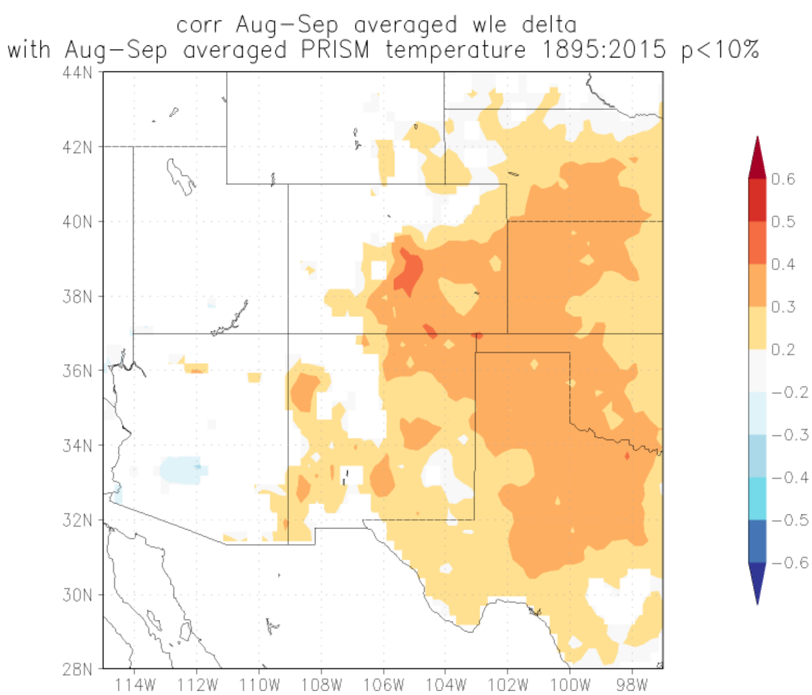

Figure 3.28: KNMI Climate Explorer output displaying correlation between Wheeler Peak, NM delta BI time series and PRISM averaged mean August and September temperature

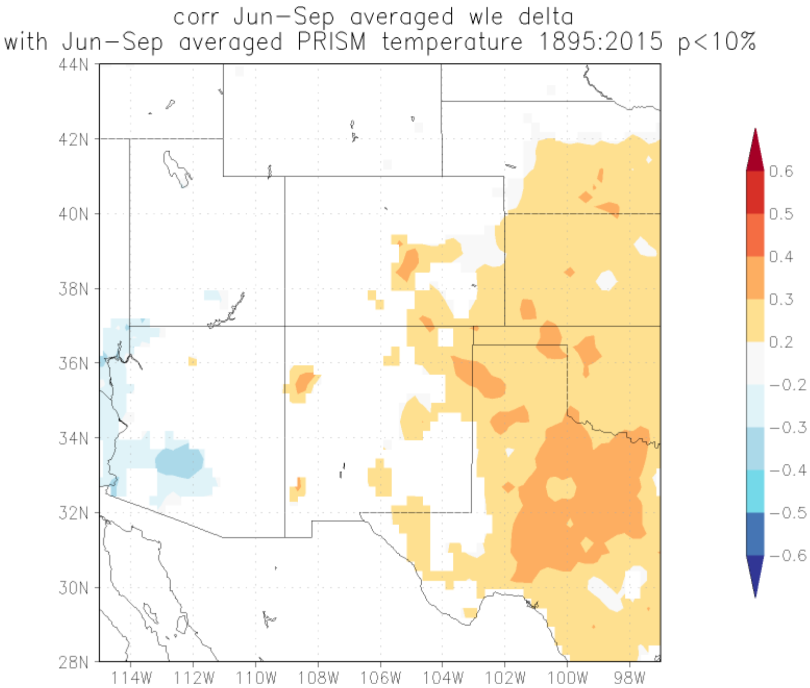

Figure 3.29: KNMI Climate Explorer output displaying correlation between Wheeler Peak, NM delta BI time series and PRISM averaged mean summer (JJAS) temperature

3.4.2.3 Inverted Latewood BI vs. PRISM Summer Temperature Data

A second BI proxy is utilized in this study to determine if other reflectance values express any significant relationships between temperature and BI. CooRecorder 9.2 offers a number of different data output options, including latewood, earlywood, or full-ring, and raw values, inverted values, and difference between earlywood and latewood BI, or delta BI. We used inverted latewood BI as a second parameter, as maximum latewood blue reflectance values have been shown to produce an annual temperature signal similar to maximum latewood density (Björklund 2014).

The relationship between inverted latewood BI and maximum August (Figure 3.22) temperature is strong, expressing correlation coefficients of 0.2 to 0.5 across many of the Southwestern states. The strongest recorded correlation was observed directly over Wheeler Peak, with a value of 0.4 to 0.5. A majority of the area of New Mexico and Texas show a statistically significant correlation, and roughly half of Colorado expresses significant correlation.

By averaging August and September (Figure 3.24) temperature data, the positive correlation is shifted back to the west, with a strong correlation of 0.4 to 0.5 at the study site. When observing the relationship, the inverted latewood BI has with averaged maximum JJAS (Figure 3.25) temperature, it is evident that the signal is still present, though it is weaker than the signal for averaged August and September temperature alone.

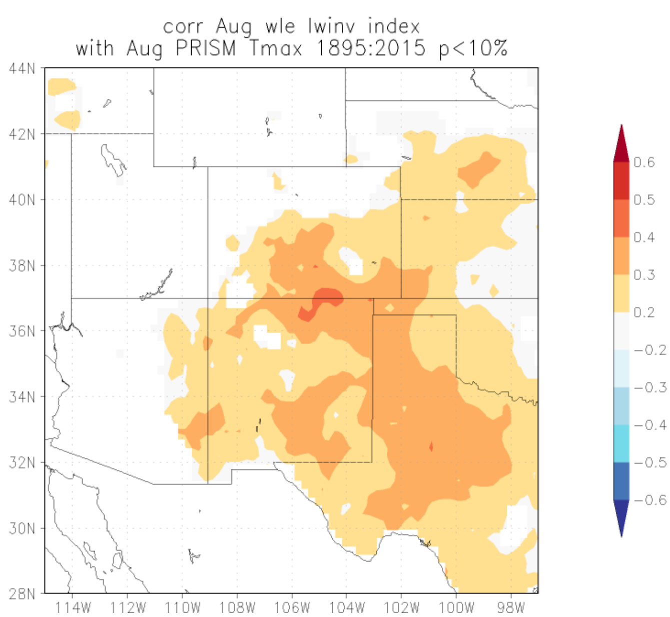

Figure 3.30: KNMI Climate Explorer output displaying correlation between Wheeler Peak, NM inverted latewood BI time series and PRISM maximum August temperature

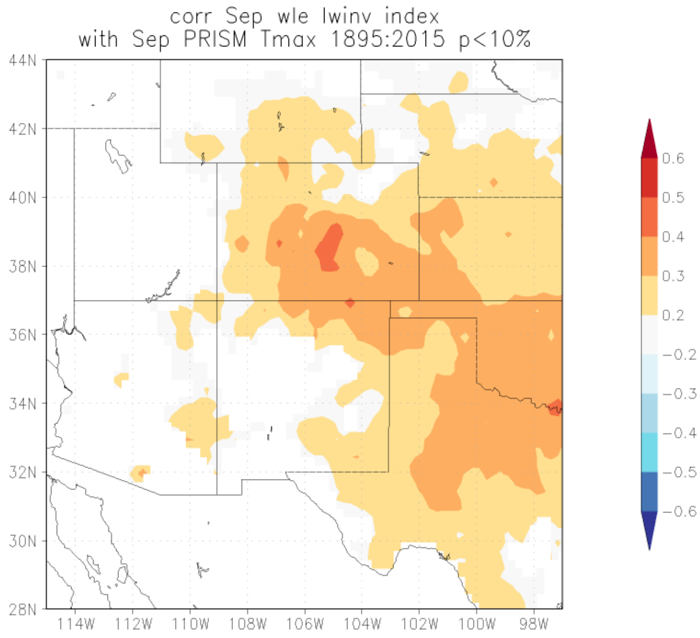

Figure 3.31: KNMI Climate Explorer output displaying correlation between Wheeler Peak, NM inverted latewood BI time series and PRISM maximum September temperature

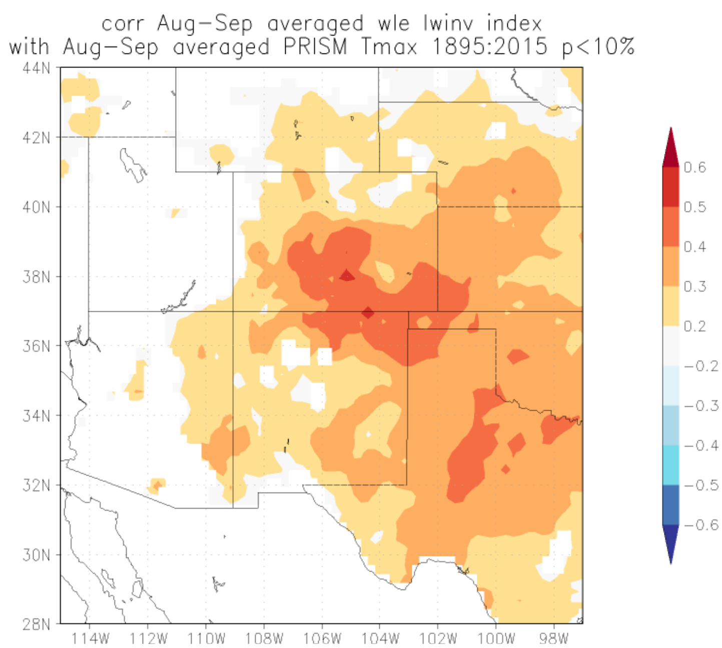

Figure 3.32: KNMI Climate Explorer output displaying correlation between Wheeler Peak, NM inverted latewood BI time series and PRISM averaged maximum August-September temperature

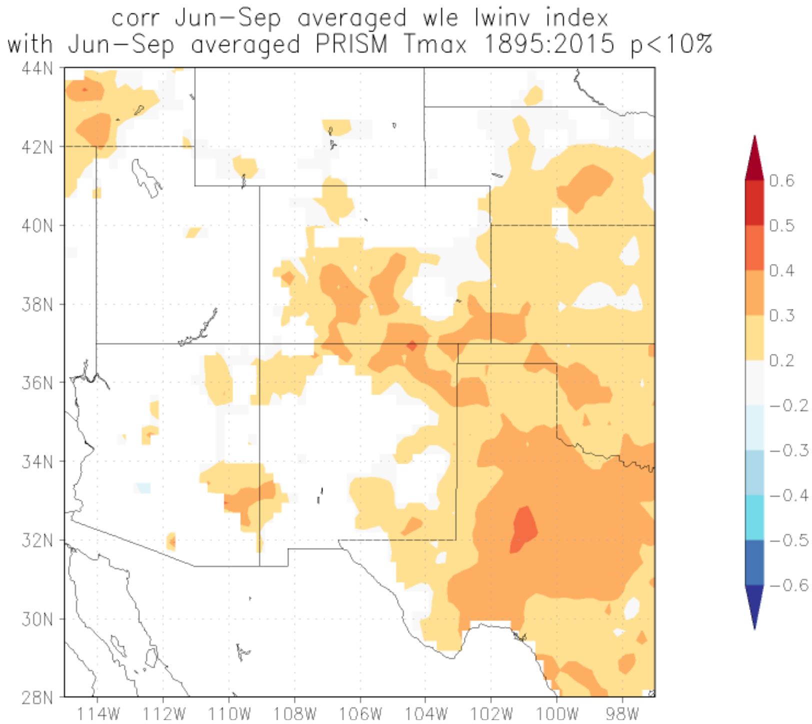

Figure 3.33: KNMI Climate Explorer output displaying correlation between Wheeler Peak, NM inverted latewood BI time series and PRISM averaged maximum summer (JJAS) temperature

When observing the relationship between mean PRISM data and inverted latewood BI, it was evident that a signal between the two parameters exists. For August (Figure 3.26) temperature data, the signal is rather weak across the American Southwest, though patches of significant correlation values are still present. A small patch with a correlation value of 0.3 to 0.4 falls directly over the site as well as southern Colorado. The temperature signal for September (Figure 3.27) was much stronger and more widespread, with correlation coefficients of 0.3 to 0.4 directly over the study site as well as central Colorado and parts of Texas. When running inverted latewood BI against averaged August and September (Figure 3.28) mean summer temperature, the positive correlation is strengthened and more centralized around the study site. At Wheeler Peak, the positive correlation is the highest that is visible, with a correlation coefficient of 0.4 to 0.5.

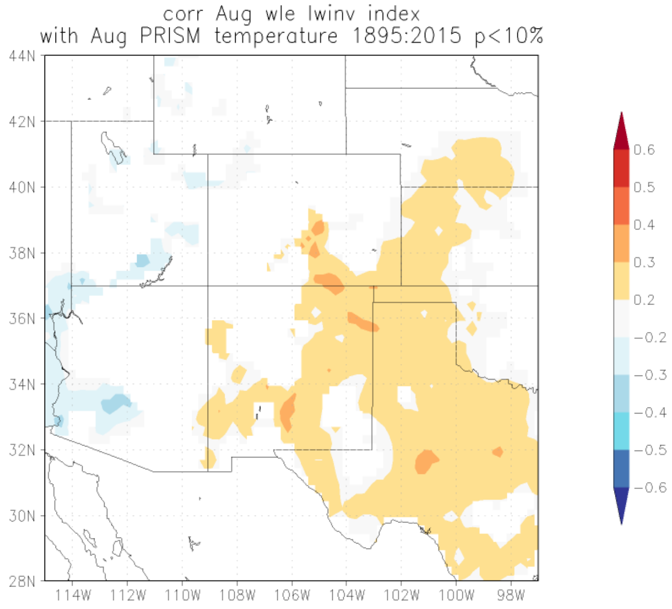

Figure 3.34: KNMI Climate Explorer output displaying correlation between Wheeler Peak, NM inverted latewood BI time series and PRISM mean August temperature

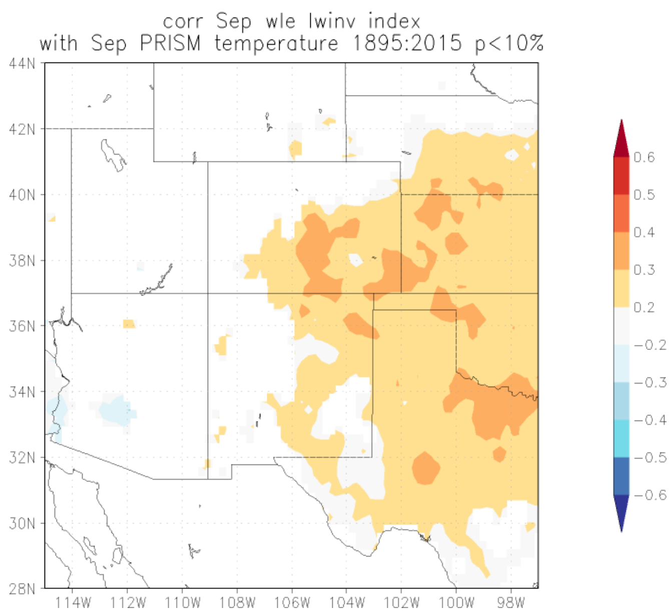

Figure 3.35: KNMI Climate Explorer output displaying correlations between Wheeler Peak, NM inverted latewood BI time series and PRISM mean September temperature

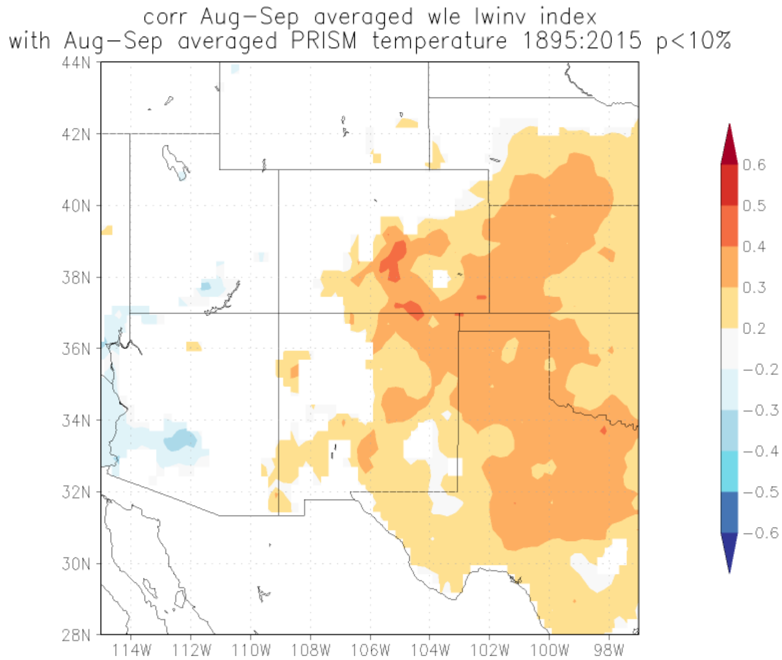

Figure 3.36: KNMI Climate Explorer output displaying correlation between Wheeler Peak, NM inverted latewood BI time series and PRISM averaged mean August and September temperature

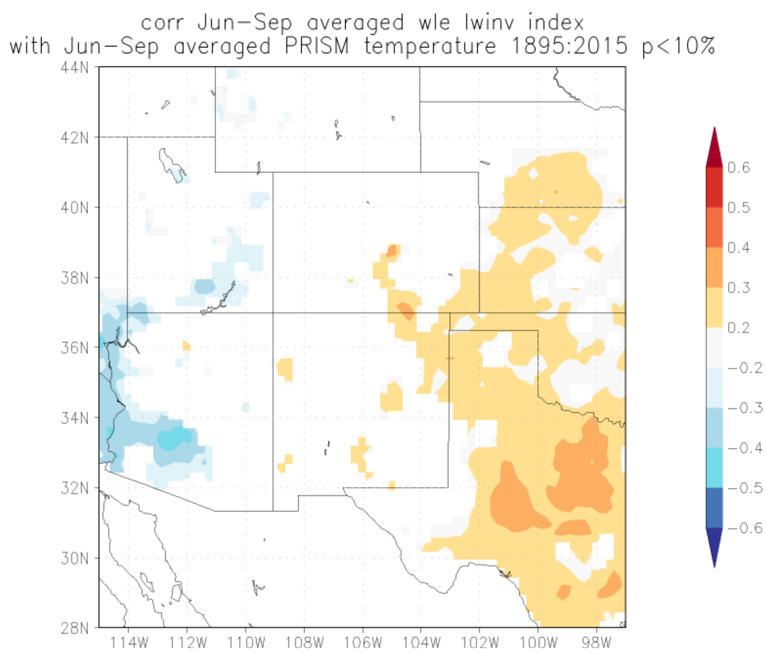

Figure 3.37: KNMI Climate Explorer output displaying correlation between Wheeler Peak, NM inverted latewood BI time series and PRISM averaged mean summer (JJAS) temperature

By observing these parameters, we are able to determine which of the tree ring proxies that are used in this study provide the strongest signal for historic temperature. The signal between delta BI and averaged August and September maximum temperatures is much stronger than the temperature signal between TRW and averaged August and September maximum temperature (Figure 3.28). This strong correlation between temperature and delta BI at the field site suggests that BI parameters, specifically delta BI, would be a much more effective predictor of historical temperature variability than TRW.

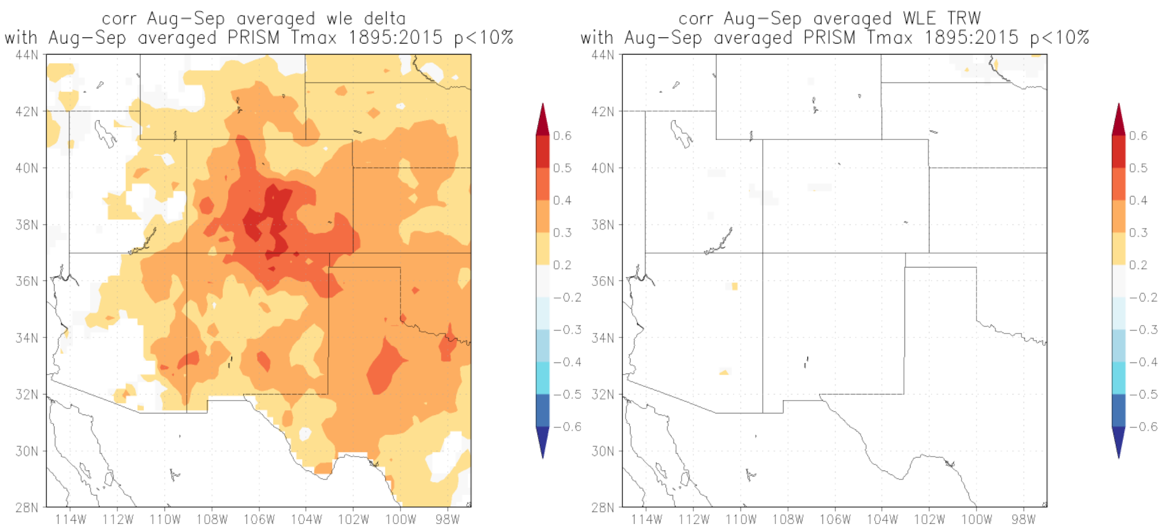

Figure 3.38: KNMI Climate Explorer outputs comparing correlations between delta BI (left) and TRW (right) parameters against averaged August and September maximum temperature

3.5 Discussion

The use of Engelmann spruce for this study allows for the investigation of the variability in historical temperature at Wheeler Peak and the surrounding region. These trees provide exceptionally useful data given that they are located at high latitude and in an alpine environment. Other studies have used different temperature-sensitive tree species, such as Scots pine (*Pinus sylvestris L.*) (McCarroll et al., 2010; Campbell et al., 2011; Wilson et al., 2012), Fujian Cypress (*Fokienia hodginsii*) (Buckley et al., 2018), and bristlecone pine (*Pinus aristata*) (Salzer et al., 2005), in their reconstructions of historical temperature variability.

Previous studies have used networks of tree ring chronologies as well as several different temperature sensitive tree ring parameters including BI, MXD, and TRW (Trouet, et al., 2013; Wilson et al., 2014). These studies had comparable results, finding statistically significant correlations for all of the observed tree ring parameters, though Wilson (2014) found that MXD had a much stronger temperature signal than BI and TRW, which had similar correlations to CRUTS.3 gridded climate data. However, these results deviate from the finding of our study, as we found that TRW expressed no statistically significant correlation at the field site, whereas BI had strong statistical significance. Additionally, studies using BI to reconstruct temperature in North America experience shortcomings resulting from the relatively short instrumental temperature record in comparison to locations in Europe that have much longer instrumental records.

The methods utilized in this study are comparable to several temperature reconstructions developed over the past several decades. One of the most notable similarities between my results and published studies is the expression of a 20^{th} century warming trend in BI and MXD time series (Salzar et al., 2005; D’Arrigo et al., 2006; McCarroll et al., 2010; Trouet et al., 2013). D’Arrigo et al. (2006) identify the decades that express the warmest reconstructed temperatures, all of which are in the twentieth century in their study as well as four other studies that have been conducted between 1998 and 2005.

In addition to 20^{th} century warming, several existing studies also describe the strongest correlations between BI and MXD time series and gridded temperature data existing during the August and September months (Briffa et al., 2002; Campbell et al., 2011; Buckley et al., 2018). As the PIEN we sampled express variation in their growth patterns resulting from temperature variability, it is likely that the strongest correlation between BI parameters and instrumental temperature data is during this time due to these months generally experiencing the highest annual temperatures. The studies mentioned previously also use temperature-sensitive tree species in their reconstructions, though PIEN is not the focus species for all of them.

Though Campbell et al. (2011) use slightly different methodologies such as using WinDendro rather than CooRecorder and use a process to remove resinous extractives, they still find that the comparisons between the results derived from MXD and BI data are numerous. The resin removal method utilized by Campbell et al. was experimental, allowing samples to soak in ethanol for different amounts of time before analysis. Samples that have been soaked in ethanol for 30 to 40 hours were found to produce BI results most similar to MXD results, suggesting that, had our samples been soaked in ethanol for this time, our results may have benefited from the samples undergoing the resin removal process. Though resin removal was not utilized in our study, significant correlations between temperature and BI data were still evident.

Wilson et al. (2014, 2016a) suggest that BI studies have a minimum of fourteen series to construct a chronology with an acceptable sample depth. This requirement is much larger than the minimum series depth of eight required by studies using MXD-only chronologies, though the production cost and time required by BI studies are much less. Our study met this threshold and produced results that are comparable to the studies of Wilson et al. (2014, 2016a) Though this minimum requirement of fourteen series has been shown to produce ideal results when reconstructing temperature using BI, several other studies used samples from twenty or more trees (Babst et al., 2009; Bjorklund et al., 2014; Buckley et al., 2018), suggesting that our study may have benefitted from having a larger sample depth.

Ultimately, we found that there is a clear shift in the growth response of Engelmann spruce at the study site when observing the delta BI dataset. For a majority of the duration of the instrumental temperature record (1895-2003), a positive correlation is present between the delta BI time series and the current year's August and September temperature data. At the turn of the 21st century, this positive correlation with the current year's summer temperatures turns to a negative correlation with the previous year's April-July temperatures, suggesting that the trees at Wheeler Peak, NM are having a negative response to growth stresses occurring in the year prior to ring formation. Additionally, when observing trends both the instrumental temperature data and BI time series, there is a noticeable uptick that occurs near the start of the 21st century, which denotes a warming trend in each dataset. This finding is similar to the growth response to atmospheric warming mentioned in Saladyga and Maxwell's (2015) study looking at climate responses of Eastern hemlock (*Tsuga canadensis*) in West Virginia, as well as Grissino-Mayer et al.'s (2005) study observing the climate response of ponderosa pine growth.

CHAPTER 4

CONCLUSIONS AND FUTURE RESEARCH

Tree ring proxies have been used for the past century to reconstruct historic climatological conditions that extend past instrumental climate data. Tree ring chronologies developed globally have been valid for a number of species that are sensitive to changing climate. Alpine tree species that are common at high latitudes have been shown to express reliable climate signals based on a number of different growth parameters. The different time series data recorded from trees that were sampled for this study was successfully crossdated. This allowed us to validate the identity of the age and associated BI parameters of the Engelmann spruce trees located at Wheeler Peak, NM. The Wheeler Peak chronology extends back to 1661, with a majority of the sample depth extending back to the 1800s.

Statistical correlation outputs were derived from each of the BI parameters that were recorded from CooRecorder 9.2. The strongest recorded relationship between a BI parameter and temperature data at the site was with delta BI and averaged August and September maximum temperature. The time series data for each tree ring parameter, delta BI, latewood inverted BI, and TRW, were compared to PRISM temperature data. It was found that a statistically significant relationship exists between maximum and mean summer temperatures and the delta BI and inverted latewood BI parameters at Wheeler Peak, NM as well as regionally across the Midwestern and Southwestern United States.

A warming trend at the turn of the 21st century was present in both the instrumental temperature data as well as the delta BI time series data. This trend was denoted by statistically significant positive correlations for a majority of the duration of the instrumental temperature data followed by the presence of a statistically significant negative correlation around the year 2003. The trees at the study site were initially producing a positive growth response to the current year's summer temperature, but, due to growth stresses, started expressing a negative growth response to the previous year's summer temperature.

This study has contributed to the consistently growing database of tree ring data for the American Southwest, and has provided useful information on the methods of BI analysis. In the literature, there were potential sources of error that can alter the results of BI analysis, thus, this study can be broadened to test these methods. Rydval (2014) mentions the treatment of samples by soaking them in acetone for varying amount of time can alter the reflectance values by removing any extractives that may be contained in the sample.

To further this study in the future, it would be beneficial to sample from multiple sites in the same region. Two other potential high-elevation PIEN field sites that could strengthen the results of this study are San Leonardo Lakes, NM and Jicarita Peak, NM, both of which are located in the Pecos Wilderness of northern New Mexico. Also, sampling high-elevation sites further south to determine the range that BI studies produce effective results would be valuable. This research adds to the existing global network of BI data, while also targeting an area where no BI data is currently available. By expanding BI research to more locations in the American Southwest where BI data is scarce, there will be further validation of BI methods and the development of laboratories that are able to perform BI analysis.

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APPENDIX 1: Wheeler Peak, NM tree ring width COFECHA output

```
 Dendrochronology Program Library                                        Run ZZ     Program COF  17:54  Mon 28 May 2018  Page   1

  P R O G R A M      C O F E C H A                                                                       Version 6.06P    30465
----------------------------------------------------------------------------------------------------------------------------------

                                      QUALITY CONTROL AND DATING CHECK OF TREE-RING MEASUREMENTS

                                                 File of DATED series:   wle_trw.rwl

                                                            CONTENTS:

                                    Part 1:  Title page, options selected, summary, absent rings by series
                                                   Part 2:  Histogram of time spans
                                      Part 3:  Master series with sample depth and absent rings by year
                                                Part 4:  Bar plot of Master Dating Series
                                          Part 5:  Correlation by segment of each series with Master
                     Part 6:  Potential problems: low correlation, divergent year-to-year changes, absent rings, outliers
                                                   Part 7:  Descriptive statistics

                                      RUN CONTROL OPTIONS SELECTED                            VALUE

                                          1  Cubic smoothing spline 50% wavelength cutoff for filtering
                                                                                             32 years
                          2  Segments examined are                           50 years lagged successively by  25 years
                  3  Autoregressive model applied                    A  Residuals are used in master dating series and testing
            4  Series transformed to logarithms               Y  Each series log-transformed for master dating series and testing
                                              5  CORRELATION is Pearson (parametric, quantitative)
                                                 Critical correlation, 99% confidence level   .3281
                                             6  Master dating series saved                         N
                                             7  Ring measurements listed                           N
                                             8  Parts printed                                1234567
                                    9  Absent rings are omitted from master series and segment correlations  (Y)

                                     Time span of Master dating series is  1661 to  2016   356 years
                                     Continuous time span is               1661 to  2016   356 years
                                     Portion with two or more series is    1692 to  2016   325 years

                       >> WLE10A_I    2005 absent in   1 of   23 series, but is not usually narrow: master index is  -.258

                                                                                 ****************************************
                                                                                 *C* Number of dated series       23 *C*
                                                                                 *O* Master series 1661 2016  356 yrs *O*
                                                                                 *F* Total rings in all series   4992 *F*
                                                                                 *E* Total dated rings checked   4961 *E*
                                                                                 *C* Series intercorrelation     .569 *C*
                                                                                 *H* Average mean sensitivity    .180 *H*
```

```
*A* Segments, possible problems   13 *A*
*** Mean length of series      217.0 ***
****************************************
```

ABSENT RINGS listed by SERIES: (See Master Dating Series for absent rings listed by year)

WLE10A_I   2 absent rings: 2005 2006

2 absent rings   .040%

PART 2: TIME PLOT OF TREE-RING SERIES: 17:54 Mon 28 May 2018 Page 2

```
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 1050 1100 1150 1200 1250 1300 1350 1400 1450 1500 1550 1600 1650 1700 1750 1800 1850 1900 1950 2000 2050 Ident   Seq Time-span  Yrs
   :    :    :    :    :    :    :    :    :    :    :    :    :    :    :    :    :    :    :    :    : -------- --- ---- ---- ----
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   .    .    .    .    .    .    .    .    .    .    .    .    .    .    .    .<===================>   . WLE04B_I   5 1815 2016  202
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   .    .    .    .    .    .    .    .    .    .    .    .    .    .    .  <=======================>   . WLE05B     7 1787 2016  230
   .    .    .    .    .    .    .    .    .    .    .    .    .    .    .    . <===================>   . WLE07A     8 1821 2016  196
   .    .    .    .    .    .    .    .    .    .    .    .    .    .    .    .    .    .  <========>   . WLE07B     9 1934 2016   83
   .    .    .    .    .    .    .    .    .    .    .    .    .    .    .    . <===================>   . WLE08A    10 1822 2016  195
   .    .    .    .    .    .    .    .    .    .    .    .    .    .    .    .    .  <=============>   . WLE08B    11 1885 2016  132
   .    .    .    .    .    .    .    .    .    .    .    .    .    .    .    . <===================>   . WLE09B    12 1829 2016  188
   .    .    .    .    .    .    .    .    .    .    .    .    .    .    .  <=======================>   . WLE10A_I  13 1785 2016  232
   .    .    .    .    .    .    .    .    .    .    .    .    .    .    .    .    . <==============>   . WLE10B    14 1870 2016  147
   .    .    .    .    .    .    .    .    .    .    .    .    .    .    .    .  <==================>   . WLE10C    15 1837 2016  180
   .    .    .    .    .    .    .    .    .    .    .    .    .    .    .    .    .<===============>   . WLE12A    16 1868 2016  149
   .    .    .    .    .    .    .    .    .    .    .    .    .    .    .   <======================>   . WLE12B    17 1796 2016  221
   .    .    .    .    .    .    .    .    .    .    .    .    .    . <=============================>   . WLE13A    18 1725 2016  292
   .    .    .    .    .    .    .    .    .    .    .    .    .    . <=============================>   . WLE13B    19 1722 2016  295
   .    .    .    .    .    .    .    .    .    .    .    .    .   <================================>   . WLE15A    20 1692 2016  325
   .    .    .    .    .    .    .    .    .    .    .    .    .    . <=============================>   . WLE15B    21 1725 2016  292
   .    .    .    .    .    .    .    .    .    .    .    .    .   <================================>   . WLE16A    22 1699 2016  318
   .    .    .    .    .    .    .    .    .    .    .    .    .<===================================>   . WLE16B    23 1661 2016  356
   :    :    :    :    :    :    :    :    :    :    :    :    :    :    :    :    :    :    :    :    :
 1050 1100 1150 1200 1250 1300 1350 1400 1450 1500 1550 1600 1650 1700 1750 1800 1850 1900 1950 2000 2050
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PART 3: Master Dating Series: 17:54 Mon 28 May 2018 Page   3

Year	Value	No Ab	Year	Value	No Ab	Year	Value	No Ab	Year	Value	No Ab	Year	Value	No Ab	Year	Value	No Ab
			1700	-1.390	3	1750	-.550	6	1800	-.204	11	1850	1.046	18	1900	-.023	22
			1701	.292	3	1751	-.144	6	1801	-1.576	11	1851	-1.760	18	1901	.620	22
			1702	.910	3	1752	-2.716	6	1802	.694	11	1852	-.803	18	1902	-1.632	22
			1703	1.363	3	1753	-.740	6	1803	-.452	11	1853	.836	18	1903	.746	22
			1704	.611	3	1754	.506	6	1804	.361	11	1854	.369	18	1904	-.336	22
			1705	-.242	3	1755	.146	6	1805	.512	11	1855	.352	18	1905	.057	22
			1706	-.393	3	1756	.085	6	1806	-.399	11	1856	.424	18	1906	-.563	22

			1707	-.929	3	1757	.527	6	1807	2.442	11	1857	-.525	18	1907	.567	22
			1708	-1.041	3	1758	1.134	6	1808	-.335	11	1858	.330	18	1908	-.531	22
			1709	.888	3	1759	.475	6	1809	.609	11	1859	.348	18	1909	.180	22
			1710	.386	3	1760	.147	6	1810	-.132	11	1860	-.459	18	1910	-.830	22
1661	.096	1	1711	1.191	3	1761	-.495	6	1811	-.206	11	1861	.154	18	1911	.073	22
1662	-.358	1	1712	1.688	3	1762	2.577	6	1812	-.375	11	1862	1.344	18	1912	1.039	22
1663	1.709	1	1713	1.448	3	1763	.057	6	1813	.299	11	1863	.552	18	1913	.779	22
1664	-1.245	1	1714	-1.260	3	1764	.466	6	1814	.478	11	1864	.146	18	1914	.079	22
1665	2.756	1	1715	-2.643	3	1765	-.697	6	1815	1.027	12	1865	-.350	18	1915	.015	22
1666	.674	1	1716	-1.307	3	1766	-.548	6	1816	.270	12	1866	.248	18	1916	.825	22
1667	-2.196	1	1717	.835	3	1767	.589	6	1817	.338	12	1867	1.746	18	1917	1.739	22
1668	-.574	1	1718	.479	3	1768	2.066	6	1818	-1.375	12	1868	.295	19	1918	.526	22
1669	-1.289	1	1719	-.947	3	1769	.990	6	1819	-.197	12	1869	.742	19	1919	-.368	22
1670	-2.497	1	1720	-.922	3	1770	.575	6	1820	.208	12	1870	-.432	20	1920	-1.867	22
1671	-.279	1	1721	-1.662	3	1771	-.270	6	1821	1.563	14	1871	-.054	20	1921	-1.217	22
1672	-.510	1	1722	-1.164	4	1772	-.042	6	1822	-.903	15	1872	-.676	20	1922	-.291	22
1673	.708	1	1723	.421	4	1773	-1.259	6	1823	-1.397	15	1873	-.760	20	1923	-.751	22
1674	.356	1	1724	.998	4	1774	.045	6	1824	-.453	15	1874	1.256	20	1924	1.106	22
1675	.175	1	1725	-.534	6	1775	.409	6	1825	-.413	15	1875	.521	20	1925	.439	22
1676	-.225	1	1726	.318	6	1776	-1.255	6	1826	-.025	15	1876	1.062	20	1926	.375	22
1677	-.099	1	1727	.124	6	1777	-1.851	6	1827	.138	15	1877	.014	20	1927	.438	22
1678	1.593	1	1728	-1.013	6	1778	-1.680	6	1828	-.254	15	1878	-.231	20	1928	-.614	22
1679	1.474	1	1729	-.254	6	1779	-.633	6	1829	.474	16	1879	-1.703	20	1929	.231	22
1680	.585	1	1730	.896	6	1780	-.372	6	1830	-.681	16	1880	-1.147	20	1930	.017	22
1681	2.098	1	1731	.744	6	1781	-1.960	6	1831	-.137	16	1881	.477	20	1931	-.138	22
1682	1.170	1	1732	1.028	6	1782	-.971	6	1832	.109	16	1882	-1.559	20	1932	.668	22
1683	-.241	1	1733	-.411	6	1783	-.647	6	1833	1.060	16	1883	-1.034	20	1933	-.201	22
1684	-4.013	1	1734	-.945	6	1784	-.104	6	1834	.313	17	1884	-1.180	20	1934	-1.068	23
1685	-4.122	1	1735	-.741	6	1785	-.213	7	1835	.249	17	1885	.560	21	1935	-.125	23
1686	.114	1	1736	.574	6	1786	.372	7	1836	.385	17	1886	1.228	22	1936	.264	23
1687	-.321	1	1737	-1.248	6	1787	.561	9	1837	1.291	18	1887	.370	22	1937	-.575	23
1688	1.373	1	1738	.104	6	1788	.891	9	1838	.437	18	1888	1.042	22	1938	-.002	23
1689	.863	1	1739	.248	6	1789	1.313	9	1839	.472	18	1889	.952	22	1939	-.343	23
1690	.850	1	1740	.401	6	1790	.347	9	1840	.582	18	1890	.443	22	1940	-.494	23
1691	2.261	1	1741	.841	6	1791	.551	9	1841	-.630	18	1891	.560	22	1941	.329	23
1692	.315	2	1742	.450	6	1792	1.006	9	1842	-.812	18	1892	.703	22	1942	.502	23
1693	.234	2	1743	-.134	6	1793	.014	9	1843	.030	18	1893	-1.764	22	1943	.913	23
1694	-1.281	2	1744	.860	6	1794	.573	9	1844	-.279	18	1894	-.238	22	1944	1.093	23
1695	.020	2	1745	1.944	6	1795	-1.089	9	1845	-1.555	18	1895	.884	22	1945	1.357	23
1696	-1.560	2	1746	.118	6	1796	-.342	10	1846	-1.737	18	1896	-1.144	22	1946	-.435	23
1697	.395	2	1747	1.437	6	1797	.008	10	1847	-1.011	18	1897	-.119	22	1947	1.318	23
1698	2.316	2	1748	-2.945	6	1798	-.224	11	1848	-.343	18	1898	.755	22	1948	.666	23
1699	-.212	3	1749	-.342	6	1799	-.222	11	1849	-.385	18	1899	-1.333	22	1949	.183	23

Year	Value	No Ab	Year	Value	No Ab	Year	Value	No Ab	Year	Value	No Ab	Year	Value	No Ab	Year	Value	No Ab
						1950	-.627	23	2000	.387	23						
						1951	.443	23	2001	.329	23						
						1952	-2.582	23	2002	-.121	23						
						1953	.294	23	2003	-2.763	23						
						1954	.072	23	2004	-1.810	23						
						1955	-.376	23	2005	-.258	23 1<<						
						1956	-1.397	23	2006	-1.084	23 1						
						1957	-2.239	23	2007	-.965	23						
						1958	.890	23	2008	.729	23						
						1959	-.834	23	2009	1.353	23						
						1960	.088	23	2010	.720	23						
						1961	-.098	23	2011	.785	23						
						1962	.295	23	2012	.686	23						
						1963	-.363	23	2013	1.245	23						
						1964	-.960	23	2014	-.184	23						
						1965	.094	23	2015	.199	23						
						1966	1.323	23	2016	-1.170	23						
						1967	-.086	23									
						1968	.577	23									
						1969	2.419	23									
						1970	1.437	23									
						1971	-.335	23									
						1972	-.104	23									
						1973	.005	23									
						1974	.059	23									
						1975	.651	23									
						1976	.902	23									
						1977	-.427	23									
						1978	-.574	23									
						1979	.334	23									
						1980	.787	23									
						1981	-1.736	23									
						1982	-.554	23									
						1983	-.607	23									
						1984	-.204	23									
						1985	-.245	23									
						1986	-.492	23									
						1987	-.993	23									
						1988	-1.677	23									
						1989	-.180	23									
						1990	.716	23									
						1991	.350	23									
						1992	.234	23									
						1993	1.521	23									

```
                                                             1994  1.410  23
                                                             1995   .091  23
                                                             1996   .927  23
                                                             1997  -.761  23
                                                             1998   .799  23
                                                             1999   .694  23
  ------------------------------------------------------------------------------------------------------------------------------------
PART 4:  Master Bar Plot:                                                                          17:54  Mon 28 May 2018  Page   5
  ------------------------------------------------------------------------------------------------------------------------------------
      Year Rel value  Year Rel value  Year Rel value  Year Rel value  Year Rel value  Year Rel value  Year Rel value  Year Rel value
                        1700f           1750--b         1800----a       1850---------D  1900-----@      1950--c         2000------B
                        1701------A     1751----a       1801f           1851g           1901--------B   1951-------B    2001------A
                         1702---------D  1752k           1802--------C   1852--c         1902g           1952j           2002----@
                           1703----------E 1753--c         1803---b        1853---------C  1903--------C   1953------A     2003k
                           1704--------B   1754-------B    1804------A     1854------A     1904---a        1954-----@      2004g
                          1705---a        1755-----A      1805-------B    1855------A     1905-----@      1955---b        2005---a
                           1706---b        1756-----@      1806---b        1856-------B    1906--b         1956f           2006-d
                           1707-d          1757-------B    1807----------J 1857--b         1907-------B    1957i           2007-d
                       1708-d          1758---------E  1808---a        1858------A     1908--b         1958---------D  2008--------C
                      1709---------D  1759-------B    1809--------B   1859------A     1909-----A      1959-c          2009----------E
                       1710------B     1760-----A      1810----a       1860---b        1910-c          1960-----@      2010--------C
       1661-----@      1711---------E  1761--b         1811----a       1861-----A      1911-----@      1961----@       2011--------C
       1662---a        1712----------G 1762----------J 1812---a        1862----------E 1912---------D  1962------A     2012--------C
      1663----------G 1713----------F 1763-----@      1813------A     1863-------B    1913--------C   1963---a        2013----------E
         1664-e          1714-e          1764-------B    1814-------B    1864-----A      1914-----@      1964-d          2014----a
        1665----------K 1715k           1765--c         1815---------D  1865---a        1915-----@      1965-----@      2015-----A
          1666--------C   1716-e          1766--b         1816------A     1866------A     1916---------C  1966----------E 2016-e
                 1667i           1717---------C  1767--------B   1817------A     1867----------G 1917----------G 1967----@
               1668--b         1718-------B    1768----------H 1818-e          1868------A     1918-------B    1968-------B
              1669-e          1719-d          1769---------D  1819----a       1869--------C   1919---a        1969----------J
              1670j           1720-d          1770-------B    1820------A     1870---b        1920g           1970----------F
                  1671---a        1721g           1771---a        1821----------F 1871----@       1921-e          1971---a
                 1672--b         1722-e          1772----@       1822-d          1872--c         1922---a        1972----@
                1673--------C   1723-------B    1773-e          1823f           1873--c         1923--c         1973-----@
                1674------A     1724---------D  1774-----@      1824---b        1874----------E 1924---------D  1974-----@
               1675-----A      1725--b         1775-------B    1825---b        1875-------B    1925-------B    1975--------C
              1676----a       1726------A     1776-e          1826----@       1876---------D  1926------B     1976---------D
                  1677----@       1727-----@      1777g           1827-----A      1877-----@      1927-------B    1977---b
                  1678----------F 1728-d          1778g           1828---a        1878----a       1928--b         1978--b
                1679----------F 1729---a        1779--c         1829-------B    1879g           1929------A     1979------A
               1680--------B   1730---------D  1780---a        1830--c         1880-e          1930-----@      1980--------C
                   1681----------H 1731--------C   1781h           1831----a       1881-------B    1931----a       1981g
                  1682---------E  1732---------D  1782-d          1832-----@      1882f           1932--------C   1982--b
                  1683---a        1733---b        1783--c         1833---------D  1883-d          1933----a       1983--b
                 1684p           1734-d          1784----@       1834------A     1884-e          1934-d          1984----a
                  1685p           1735--c         1785----a       1835------A     1885-------B    1935----@       1985---a
                  1686-----@      1736-------B    1786------A     1836------B     1886---------E  1936------A     1986--b
                   1687---a        1737-e          1787-------B    1837----------E 1887------A     1937--b         1987-d
                   1688----------E 1738-----@      1788---------D  1838-------B    1888---------D  1938-----@      1988g
                 1689---------C  1739------A     1789----------E 1839-------B    1889---------D  1939---a        1989----a
```

```
 1690---------C  1740-------B    1790------A     1840--------B   1890-------B    1940--b         1990--------C
  1691----------I 1741---------C  1791-------B    1841--c         1891-------B    1941------A     1991------A
  1692------A     1742-------B    1792---------D  1842-c          1892--------C   1942-------B    1992------A
1693------A     1743----a       1793-----@      1843-----@      1893g           1943---------D  1993----------F
1694-e          1744---------C  1794-------B    1844---a        1894----a       1944---------D  1994----------F
   1695-----@      1745----------H 1795-d          1845f           1895---------D  1945----------E 1995-----@
1696f           1746-----@      1796---a        1846g           1896-e          1946---b        1996---------D
      1697-------B    1747----------F 1797-----@      1847-d          1897----@       1947----------E 1997--c
 1698----------I 1748l           1798----a       1848---a        1898--------C   1948--------C   1998--------C
 1699----a       1749---a        1799----a       1849---b        1899-e          1949-----A      1999--------C
```

PART 5: CORRELATION OF SERIES BY SEGMENTS: 17:54 Mon 28 May 2018 Page 5

Correlations of 50-year dated segments, lagged 25 years

Flags: A = correlation under .3281 but highest as dated; B = correlation higher at other than dated position

Seq	Series	Time_span	1675	1700	1725	1750	1775	1800	1825	1850	1875	1900	1925	1950	1975
			1724	1749	1774	1799	1824	1849	1874	1899	1924	1949	1974	1999	2024
1	WLE01B_I	1798 2016					.66	.68	.61	.58	.59	.64	.42	.33	.20B
2	WLE02A_I	1834 2016							.56	.66	.77	.47	.61	.60	.43
3	WLE03A	1886 2016									.65	.57	.56	.64	.72
4	WLE04A	1821 2016						.50	.59	.75	.74	.60	.72	.80	.70
5	WLE04B_I	1815 2016						.20B	.24A	.48	.53	.31B	.60	.75	.82
6	WLE05A_I	1787 2016					.36	.49	.42	.60	.67	.53	.57	.66	.73
7	WLE05B	1787 2016					.36	.39	.40	.66	.71	.53	.71	.79	.76
8	WLE07A	1821 2016						.15B	.19A	.38	.47	.33B	.58	.76	.83
9	WLE07B	1934 2016											.42	.38	.57
10	WLE08A	1822 2016						.35	.37	.61	.55	.32A	.53	.52	.60
11	WLE08B	1885 2016									.59	.48	.58	.64	.68
12	WLE09B	1829 2016							.30B	.49	.49	.38	.63	.72	.70
13	WLE10A_I	1785 2016					.39	.62	.66	.67	.57	.55	.56	.46	.29B
14	WLE10B	1870 2016								.54	.55	.33A	.50	.67	.64
15	WLE10C	1837 2016							.36	.35	.43	.37	.64	.65	.59
16	WLE12A	1868 2016								-.11B	-.03B	.39	.44	.44	.39
17	WLE12B	1796 2016					.65	.67	.63	.72	.77	.70	.62	.63	.61
18	WLE13A	1725 2016			.33	.44	.59	.57	.51	.50	.53	.43	.46	.73	.65
19	WLE13B	1722 2016		.62	.61	.62	.56	.60	.59	.70	.66	.53	.60	.70	.53
20	WLE15A	1692 2016	.49	.71	.78	.51	.36	.45	.63	.77	.75	.53	.66	.68	.67
21	WLE15B	1725 2016			.61	.64	.57	.45	.48	.68	.54	.37	.60	.59	.69
22	WLE16A	1699 2016	.71	.71	.79	.68	.70	.80	.68	.75	.81	.71	.56	.67	.76
23	WLE16B	1661 2016	.34	.66	.73	.67	.59	.58	.58	.82	.83	.71	.64	.69	.72
Av segment correlation			.52	.67	.64	.60	.53	.50	.49	.58	.60	.49	.57	.63	.62

PART 6: POTENTIAL PROBLEMS: 17:54 Mon 28 May 2018 Page 6

For each series with potential problems the following diagnostics may appear:

[A] Correlations with master dating series of flagged 50-year segments of series filtered with 32-year spline,
at every point from ten years earlier (-10) to ten years later (+10) than dated

```
                  [B] Effect of those data values which most lower or raise correlation with master series
               Symbol following year indicates value in series is greater (>) or lesser (<) than master series value

                           [C] Year-to-year changes very different from the mean change in other series

                                                     [D] Absent rings (zero values)

                                   [E] Values which are statistical outliers from mean for the year
=====================================================================================================================================

 WLE01B_I  1798 to  2016     219 years                                                                                    Series   1

    [A] Segment   High   -10   -9   -8   -7   -6   -5   -4   -3   -2   -1   +0   +1   +2   +3   +4   +5   +6   +7   +8   +9  +10
       ---------  ----   ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---
       1967 2016   -3   -.12  .07 -.27 -.19  .00 -.12  .17  .31* .06  .02  .20|   -    -    -    -    -    -    -    -    -    -

                                         [B] Entire series, effect on correlation (  .482) is:
        Lower   2003> -.031   1952> -.028   1899> -.009   1966< -.009   1976< -.008   2009< -.008  Higher   1851  .015   1893  .014
                                                              1967 to 2016 segment:
        Lower   2003> -.094   1976< -.037   2009< -.032   2001< -.030   1996< -.029   1980< -.016  Higher   1981  .105   1993  .040

                                    [C] Year-to-year changes diverging by over 4.0 std deviations:
                                                                1951 1952   4.1 SD

                                   [E] Outliers     2   3.0 SD above or -4.5 SD below mean for year
                                                       1952 +3.1 SD;    2003 +4.1 SD
=====================================================================================================================================

 WLE02A_I  1834 to  2016     183 years                                                                                    Series   2

                                         [B] Entire series, effect on correlation (  .576) is:
        Lower   1981> -.026   1874< -.011   1941< -.009   1973< -.008   1946> -.008   1934> -.007  Higher   1952  .045   1879  .011

                                   [E] Outliers     2   3.0 SD above or -4.5 SD below mean for year
                                                       1981 +3.5 SD;    1982 +3.1 SD
=====================================================================================================================================

 WLE03A    1886 to  2016     131 years                                                                                    Series   3

                                         [B] Entire series, effect on correlation (  .677) is:
        Lower   1929< -.012   1934> -.011   1972< -.009   2007> -.009   1886< -.008   1976< -.008  Higher   2003  .045   1952  .017

=====================================================================================================================================

 WLE04A    1821 to  2016     196 years                                                                                    Series   4

                                         [B] Entire series, effect on correlation (  .668) is:
        Lower   1821< -.015   1911< -.013   2016> -.010   1929< -.007   2008< -.006   1822> -.006  Higher   1952  .031   1981  .013
```

```
===========================================================================================================================

 WLE04B_I  1815 to  2016     202 years                                                                           Series   5

    [A] Segment   High   -10   -9   -8   -7   -6   -5   -4   -3   -2   -1   +0   +1   +2   +3   +4   +5   +6   +7   +8   +9  +10
       ---------  ----   ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---
       1815 1864    4    .16 -.15  .06 -.16  .03 -.26 -.19 -.20 -.08 -.08  .20|-.22  .02  .03  .23*-.07  .05  .03 -.18  .16  .12
       1825 1874    0   -.08 -.04  .12 -.08 -.04 -.29 -.10 -.19  .02 -.22  .24*-.19 -.13  .09  .11  .12  .00  .06 -.25 -.01  .12
       - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
       1900 1949   -6   -.04  .15 -.09  .17  .38*-.07  .02  .09 -.12 -.02  .31|-.23  .25 -.10  .07 -.05 -.07 -.17  .04 -.06 -.20

                                        [B] Entire series, effect on correlation (  .548) is:
        Lower   1926< -.028   1884< -.013   1822> -.012   1851> -.009   1821< -.008   1846> -.007  Higher   1952  .041   2003  .037
                                                          1815 to 1864 segment:
        Lower   1822> -.043   1821< -.035   1859< -.032   1846> -.031   1829< -.024   1832< -.018  Higher   1850  .046   1818  .045
                                                          1825 to 1874 segment:
        Lower   1846> -.033   1859< -.027   1829< -.022   1870> -.020   1825> -.017   1832< -.015  Higher   1850  .039   1837  .026
                                                          1900 to 1949 segment:
        Lower   1926< -.142   1920> -.023   1921> -.017   1910> -.016   1923> -.015   1911< -.014  Higher   1902  .073   1945  .028

                                  [E] Outliers     2   3.0 SD above or -4.5 SD below mean for year
                                                    1871 +3.1 SD;    1884 -4.8 SD
===========================================================================================================================

 WLE05A_I  1787 to  2016     230 years                                                                           Series   6

                                        [B] Entire series, effect on correlation (  .584) is:
        Lower   1834< -.029   1797< -.021   1929< -.009   1793> -.008   1988< -.007   1893> -.006  Higher   2003  .029   1981  .014

                                  [E] Outliers     2   3.0 SD above or -4.5 SD below mean for year
                                                    1797 -4.6 SD;    1834 -5.3 SD
===========================================================================================================================

 WLE05B    1787 to  2016     230 years                                                                           Series   7

                                        [B] Entire series, effect on correlation (  .615) is:
        Lower   1834< -.038   1929< -.013   1849< -.012   1806> -.008   1801> -.007   1791< -.007  Higher   1952  .022   2003  .019

                                  [E] Outliers     1   3.0 SD above or -4.5 SD below mean for year
                                                            1834 -4.9 SD
===========================================================================================================================

 WLE07A    1821 to  2016     196 years                                                                           Series   8

    [A] Segment   High   -10   -9   -8   -7   -6   -5   -4   -3   -2   -1   +0   +1   +2   +3   +4   +5   +6   +7   +8   +9  +10
       ---------  ----   ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---
       1821 1870    5   -.04  .00 -.11 -.01  .09 -.19 -.39 -.13 -.06 -.17  .15|-.21  .08  .02  .17  .20* .14  .04 -.04  .02  .09
       1825 1874    0   -.10  .02 -.07  .09  .06 -.16 -.43 -.18 -.03 -.08  .19*-.30  .03  .01  .14  .15  .13  .16 -.18 -.03  .13
       - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
       1900 1949   -9   -.08  .38*-.05  .14  .25 -.13  .06 -.14 -.10 -.05  .33|-.08 -.03  .02 -.07 -.26  .03  .12 -.08  .05  .13
```

```
                                         [B] Entire series, effect on correlation (  .527) is:
       Lower   1851> -.022   1891< -.020   1889< -.019   1927< -.019   1837< -.017   1893> -.012  Higher   1952  .038   2003  .034
                                                         1821 to 1870 segment:
       Lower   1837< -.079   1851> -.072   1866< -.034   1858< -.033   1823> -.027   1821< -.020  Higher   1822  .072   1850  .037
                                                         1825 to 1874 segment:
       Lower   1851> -.087   1837< -.086   1866< -.036   1858< -.035   1839< -.013   1859< -.012  Higher   1874  .043   1850  .035
                                                         1900 to 1949 segment:
       Lower   1927< -.083   1934> -.042   1903< -.037   1945< -.035   1904> -.026   1943< -.026  Higher   1902  .068   1946  .032

                                    [E] Outliers     2   3.0 SD above or -4.5 SD below mean for year
                                                  1851 +3.7 SD;    1934 +3.2 SD
==================================================================================================================================

 WLE07B    1934 to  2016      83 years                                                                                    Series   9

                                         [B] Entire series, effect on correlation (  .528) is:
       Lower   1985< -.033   1957> -.025   1975< -.021   1965< -.017   1937> -.015   1983< -.014  Higher   2003  .079   1969  .017

==================================================================================================================================

 WLE08A    1822 to  2016     195 years                                                                                    Series  10

    [A] Segment   High   -10   -9   -8   -7   -6   -5   -4   -3   -2   -1   +0   +1   +2   +3   +4   +5   +6   +7   +8   +9  +10
        ---------  ----   ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---
        1900 1949    0    .01 -.07  .05  .01  .03  .19 -.23 -.08  .16 -.27  .32*-.09  .07 -.11  .08 -.13  .12 -.02 -.10 -.29 -.08

                                         [B] Entire series, effect on correlation (  .497) is:
       Lower   1860< -.021   1960< -.010   1843< -.010   1988> -.010   1838< -.009   1839< -.008  Higher   2003  .027   1893  .014
                                                         1900 to 1949 segment:
       Lower   1919> -.036   1910> -.035   1934> -.035   1922> -.028   1913< -.020   1931> -.017  Higher   1920  .083   1902  .027

                                    [E] Outliers     1   3.0 SD above or -4.5 SD below mean for year
                                                          1922 +3.8 SD
==================================================================================================================================

 WLE08B    1885 to  2016     132 years                                                                                    Series  11

                                         [B] Entire series, effect on correlation (  .646) is:
       Lower   1981> -.018   1971< -.014   1934> -.012   1941< -.012   1885< -.010   1928> -.010  Higher   2003  .048   1952  .020

                                    [E] Outliers     1   3.0 SD above or -4.5 SD below mean for year
                                                          1929 +3.0 SD
==================================================================================================================================

 WLE09B    1829 to  2016     188 years                                                                                    Series  12

    [A] Segment   High   -10   -9   -8   -7   -6   -5   -4   -3   -2   -1   +0   +1   +2   +3   +4   +5   +6   +7   +8   +9  +10
        ---------  ----   ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---
        1829 1878    7   -.03 -.18 -.20 -.13 -.08 -.03 -.25 -.22  .01 -.27  .30| .11 -.05 -.05 -.04  .00 -.02  .37* .10  .07  .00
```

```
                                        [B] Entire series, effect on correlation (  .528) is:
       Lower   1884< -.022   1910> -.015   1945< -.014   1879> -.011   1840< -.009   1837< -.008  Higher   1952  .049   1893  .015
                                                      1829 to 1878 segment:
       Lower   1840< -.037   1837< -.032   1835< -.025   1842> -.024   1852> -.018   1858< -.014  Higher   1874  .029   1853  .024

                                   [E] Outliers     1   3.0 SD above or -4.5 SD below mean for year
                                                           1910 +4.2 SD
=====================================================================================================================================

 WLE10A_I  1785 to  2016     232 years                                                                                    Series  13

    [A] Segment   High   -10   -9   -8   -7   -6   -5   -4   -3   -2   -1   +0   +1   +2   +3   +4   +5   +6   +7   +8   +9  +10
       ---------  ----   ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---
       1967 2016   -3    .04  .00 -.20 -.12  .12 -.17 -.14  .33*-.19 -.16  .29|   -    -    -    -    -    -    -    -    -    -

                                        [B] Entire series, effect on correlation (  .457) is:
       Lower   1787< -.044   2005< -.016   1952> -.014   1980< -.011   2003> -.010   2009< -.010  Higher   1893  .019   1981  .017
                                                      1967 to 2016 segment:
       Lower   2005< -.061   1980< -.043   2009< -.039   1976< -.035   2014> -.016   1997> -.014  Higher   1981  .118   1969  .039

                                        [D]    2 Absent rings:  Year   Master  N series Absent
                                            2005    -.258      23       1  >> WARNING:  Ring is not usually narrow
                                                                   2006   -1.084      23       1

                                   [E] Outliers     1   3.0 SD above or -4.5 SD below mean for year
                                                           1906 +3.2 SD
=====================================================================================================================================

 WLE10B    1870 to  2016     147 years                                                                                    Series  14

    [A] Segment   High   -10   -9   -8   -7   -6   -5   -4   -3   -2   -1   +0   +1   +2   +3   +4   +5   +6   +7   +8   +9  +10
       ---------  ----   ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---
       1900 1949    0    .01  .29 -.08 -.11  .11 -.12  .00  .24 -.08 -.19  .33*-.03  .12  .01 -.24 -.14 -.03 -.19 -.05  .04 -.04

                                        [B] Entire series, effect on correlation (  .542) is:
       Lower   1937< -.059   1999< -.011   1879> -.011   1876< -.011   1971> -.010   1939> -.010  Higher   1952  .022   2003  .017
                                                      1900 to 1949 segment:
       Lower   1937< -.061   1939> -.027   1921> -.021   1944< -.017   1902> -.016   1945< -.012  Higher   1920  .053   1917  .021

                                   [E] Outliers     2   3.0 SD above or -4.5 SD below mean for year
                                                    1885 +3.2 SD;    1937 -5.4 SD
=====================================================================================================================================

 WLE10C    1837 to  2016     180 years                                                                                    Series  15

                                        [B] Entire series, effect on correlation (  .535) is:
       Lower   1902> -.024   1853< -.014   1994< -.012   1986> -.012   2002> -.011   1956> -.009  Higher   1952  .050   2003  .047

                                   [E] Outliers     4   3.0 SD above or -4.5 SD below mean for year
```

```
                                       1902 +3.4 SD;    1952 -6.3 SD;    1986 +3.4 SD;    2002 +3.2 SD
====================================================================================================================================

 WLE12A    1868 to  2016     149 years                                                                                    Series  16

    [A] Segment   High   -10   -9   -8   -7   -6   -5   -4   -3   -2   -1   +0   +1   +2   +3   +4   +5   +6   +7   +8   +9  +10
       ---------  ----   ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---
       1868 1917   -7    .21 -.02  .03  .24* .10 -.24  .19  .07 -.18  .07 -.11|-.16  .07  .00 -.16 -.11 -.17  .19 -.03  .01  .14
       1875 1924   -7    .21 -.09 -.01  .26* .11 -.30  .07  .04 -.09  .18 -.03|-.16  .05 -.06 -.25 -.07 -.12  .23  .06  .03  .09

                                         [B] Entire series, effect on correlation (  .248) is:
       Lower   1903< -.028   1886< -.025   1890< -.023   2012< -.016   1879> -.014   1893> -.013  Higher   1957  .019   1947  .013
                                                             1868 to 1917 segment:
       Lower   1903< -.056   1886< -.051   1879> -.025   1904> -.025   1889< -.023   1885< -.021  Higher   1902  .049   1917  .047
                                                             1875 to 1924 segment:
       Lower   1903< -.060   1886< -.055   1890< -.032   1879> -.030   1904> -.026   1889< -.025  Higher   1917  .046   1920  .042

                                    [C] Year-to-year changes diverging by over 4.0 std deviations:
                                                               1903 1904   4.4 SD

                                   [E] Outliers     4   3.0 SD above or -4.5 SD below mean for year
                                       1879 +3.2 SD;    1886 -5.1 SD;    1890 -5.5 SD;    1952 +3.0 SD
====================================================================================================================================

 WLE12B    1796 to  2016     221 years                                                                                    Series  17

                                         [B] Entire series, effect on correlation (  .644) is:
       Lower   1952> -.014   1851< -.013   2012< -.011   1971> -.006   2003> -.006   1860> -.006  Higher   1893  .011   1902  .010

                                   [E] Outliers     1   3.0 SD above or -4.5 SD below mean for year
                                                                  1851 -5.2 SD
====================================================================================================================================

 WLE13A    1725 to  2016     292 years                                                                                    Series  18

                                         [B] Entire series, effect on correlation (  .488) is:
       Lower   1925< -.014   1773> -.014   1727< -.013   1737> -.009   1894< -.006   1808> -.006  Higher   1981  .009   1882  .008

                                   [E] Outliers     1   3.0 SD above or -4.5 SD below mean for year
                                                                  1773 +4.6 SD
====================================================================================================================================

 WLE13B    1722 to  2016     295 years                                                                                    Series  19

                                         [B] Entire series, effect on correlation (  .584) is:
       Lower   2002< -.014   1731< -.013   2003> -.013   1737> -.012   1727> -.010   1964< -.006  Higher   1748  .036   1752  .014

                                   [E] Outliers     1   3.0 SD above or -4.5 SD below mean for year
                                                                  1785 +3.2 SD
====================================================================================================================================
```

```
 WLE15A    1692 to  2016     325 years                                                                                    Series  20

                                         [B] Entire series, effect on correlation (  .606) is:
       Lower   1695> -.022   1789< -.008   2016> -.007   1801> -.007   1856< -.006   1981> -.006  Higher   2003  .015   1748  .012

                                     [C] Year-to-year changes diverging by over 4.0 std deviations:
                                                         1694 1695   4.1 SD

                                    [E] Outliers     3   3.0 SD above or -4.5 SD below mean for year
                                              1695 +5.1 SD;    1801 +3.6 SD;    1851 -5.0 SD
=====================================================================================================================================

 WLE15B    1725 to  2016     292 years                                                                                    Series  21

                                         [B] Entire series, effect on correlation (  .571) is:
       Lower   1922< -.021   1748> -.014   1981> -.013   1861< -.011   1833< -.010   1917< -.007  Higher   2003  .020   1851  .011

                                    [E] Outliers     1   3.0 SD above or -4.5 SD below mean for year
                                                           1981 +3.5 SD
=====================================================================================================================================

 WLE16A    1699 to  2016     318 years                                                                                    Series  22

                                         [B] Entire series, effect on correlation (  .709) is:
       Lower   1934< -.008   1952> -.006   1746> -.005   1714> -.005   1700> -.005   1872> -.005  Higher   1748  .028   1981  .006

                                    [E] Outliers     1   3.0 SD above or -4.5 SD below mean for year
                                                           1934 -5.1 SD
=====================================================================================================================================

 WLE16B    1661 to  2016     356 years                                                                                    Series  23

                      [*] Early part of series cannot be checked from 1661 to 1691 -- not matched by another series

                                         [B] Entire series, effect on correlation (  .650) is:
       Lower   1695< -.025   1802< -.008   1733> -.007   1734> -.007   1739< -.005   1729< -.005  Higher   1748  .031   1752  .007

                                     [C] Year-to-year changes diverging by over 4.0 std deviations:
                                                         1694 1695  -4.5 SD

                                    [E] Outliers     3   3.0 SD above or -4.5 SD below mean for year
                                              1695 -5.1 SD;    1734 +3.6 SD;    1981 -4.8 SD
=====================================================================================================================================

PART 7:  DESCRIPTIVE STATISTICS:                                                              17:54  Mon 28 May 2018  Page   7
-------------------------------------------------------------------------------------------------------------------------------------

                                                                           Corr   //-------- Unfiltered --------\\  //---- Filtered -----\\
                                     No.    No.    No.    with   Mean   Max     Std   Auto   Mean   Max     Std   Auto  AR
```

Seq	Series	Interval	Years	Segmt	Flags	Master	msmt	msmt	dev	corr	sens	value	dev	corr	()
1	WLE01B_I	1798 2016	219	9	1	.482	1.05	2.22	.425	.847	.178	2.60	.406	.011	2
2	WLE02A_I	1834 2016	183	7	0	.576	1.52	3.18	.651	.911	.143	2.50	.327	-.012	2
3	WLE03A	1886 2016	131	5	0	.677	1.28	2.58	.525	.869	.177	2.53	.342	.012	1
4	WLE04A	1821 2016	196	8	0	.668	1.69	6.52	1.025	.932	.146	2.62	.386	.012	1
5	WLE04B_I	1815 2016	202	8	3	.548	1.55	3.66	.801	.926	.150	2.52	.390	-.032	1
6	WLE05A_I	1787 2016	230	9	0	.584	1.06	3.27	.573	.901	.197	2.60	.370	.009	1
7	WLE05B	1787 2016	230	9	0	.615	1.04	3.70	.613	.925	.186	2.63	.400	-.015	2
8	WLE07A	1821 2016	196	8	3	.527	1.86	4.32	.917	.892	.159	2.74	.467	-.044	1
9	WLE07B	1934 2016	83	3	0	.528	1.80	4.32	.722	.801	.204	2.69	.549	.001	2
10	WLE08A	1822 2016	195	8	1	.497	1.59	3.22	.488	.691	.177	2.68	.423	-.027	1
11	WLE08B	1885 2016	132	5	0	.646	1.50	3.53	.502	.772	.155	2.73	.424	-.024	1
12	WLE09B	1829 2016	188	7	1	.528	1.96	6.96	1.124	.903	.156	2.53	.355	-.069	1
13	WLE10A_I	1785 2016	232	9	1	.457	1.08	2.62	.585	.912	.207	2.61	.428	.022	2
14	WLE10B	1870 2016	147	6	1	.542	1.68	5.04	.772	.841	.199	2.65	.333	-.015	1
15	WLE10C	1837 2016	180	7	0	.535	1.27	6.84	.973	.919	.201	2.53	.303	-.013	1
16	WLE12A	1868 2016	149	6	2	.248	.58	1.45	.257	.827	.222	2.73	.479	.036	1
17	WLE12B	1796 2016	221	9	0	.644	1.02	2.38	.429	.913	.141	2.47	.263	-.007	2
18	WLE13A	1725 2016	292	11	0	.488	.63	1.40	.248	.845	.179	2.68	.482	-.066	1
19	WLE13B	1722 2016	295	12	0	.584	.73	1.51	.270	.869	.153	2.66	.422	-.041	1
20	WLE15A	1692 2016	325	13	0	.606	.77	1.75	.345	.861	.187	2.64	.288	-.015	1
21	WLE15B	1725 2016	292	11	0	.571	.56	1.40	.245	.811	.192	2.87	.453	-.014	1
22	WLE16A	1699 2016	318	13	0	.709	.75	1.82	.391	.888	.204	2.50	.321	-.036	1
23	WLE16B	1661 2016	356	13	0	.650	.58	1.79	.350	.874	.203	2.53	.312	-.045	1
	Total or mean:		4992	196	13	.569	1.10	6.96	.535	.870	.180	2.87	.381	-.019	

- = [COFECHA ZZ COF] = -

APPENDIX 2: Wheeler Peak, NM delta blue COFECHA output

```
 Dendrochronology Program Library                                        Run ZZ     Program COF  18:37  Mon 28 May 2018  Page   1

 P R O G R A M     C O F E C H A                                                                      Version 6.06P    30465
------------------------------------------------------------------------------------------------------------------------------------

QUALITY CONTROL AND DATING CHECK OF TREE-RING MEASUREMENTS

File of DATED series:   wle_delta_new.rwl

CONTENTS:

   Part 1:  Title page, options selected, summary, absent rings by series
   Part 2:  Histogram of time spans
   Part 3:  Master series with sample depth and absent rings by year
   Part 4:  Bar plot of Master Dating Series
   Part 5:  Correlation by segment of each series with Master
   Part 6:  Potential problems: low correlation, divergent year-to-year changes, absent rings, outliers
   Part 7:  Descriptive statistics

RUN CONTROL OPTIONS SELECTED                             VALUE

        1  Cubic smoothing spline 50% wavelength cutoff for filtering
                                                           32 years
        2  Segments examined are                           50 years lagged successively by  25 years
        3  Autoregressive model applied                     A  Residuals are used in master dating series and testing
        4  Series transformed to logarithms                 Y  Each series log-transformed for master dating series and testing
        5  CORRELATION is Pearson (parametric, quantitative)
           Critical correlation, 99% confidence level   .3281
        6  Master dating series saved                       N
        7  Ring measurements listed                         N
        8  Parts printed                              1234567
        9  Absent rings are omitted from master series and segment correlations  (Y)

Time span of Master dating series is  1661 to  2015   355 years
Continuous time span is               1661 to  2015   355 years
Portion with two or more series is    1692 to  2015   324 years


                                       ****************************************
                                       *C* Number of dated series        24 *C*
                                       *O* Master series 1661 2015  355 yrs *O*
                                       *F* Total rings in all series   5138 *F*
                                       *E* Total dated rings checked   5107 *E*
                                       *C* Series intercorrelation     .490 *C*
                                       *H* Average mean sensitivity    .129 *H*
                                       *A* Segments, possible problems   53 *A*
                                       *** Mean length of series      214.1 ***
```

****

ABSENT RINGS listed by SERIES: (See Master Dating Series for absent rings listed by year)

No ring measurements of zero value

PART 2: TIME PLOT OF TREE-RING SERIES: 18:37 Mon 28 May 2018 Page   2

```
-----------------------------------------------------------------------------------------------------------------------------------
 1050 1100 1150 1200 1250 1300 1350 1400 1450 1500 1550 1600 1650 1700 1750 1800 1850 1900 1950 2000 2050 Ident   Seq Time-span  Yrs
   :    :    :    :    :    :    :    :    :    :    :    :    :    :    :    :    :    :    :    :    :   : -------- --- ---- ---- ----
   .    .    .    .    .    .    .    .    .    .    .    .    .    .    .   <=====================>   . WLE01B_I   1 1798 2015  218
   .    .    .    .    .    .    .    .    .    .    .    .    .    .    .    .   <=================>   . WLE02A_I   2 1834 2015  182
   .    .    .    .    .    .    .    .    .    .    .    .    .    .    .    . <==================>   . WLE04A_I   3 1823 2015  193
   .    .    .    .    .    .    .    .    .    .    .    .    .    .    .    .<===================>   . WLE04B_I   4 1815 2015  201
   .    .    .    .    .    .    .    .    .    .    .    .    .    .    .  <======================>   . WLE05A_I   5 1787 2015  229
   .    .    .    .    .    .    .    .    .    .    .    .    .    .    .  <======================>   . WLE05B_I   6 1787 2015  229
   .    .    .    .    .    .    .    .    .    .    .    .    .    .    .    . <==================>   . WLE07A_N   7 1821 2015  195
   .    .    .    .    .    .    .    .    .    .    .    .    .    .    .    .    .    .  <=======>   . WLE07B_N   8 1934 2015   82
   .    .    .    .    .    .    .    .    .    .    .    .    .    .    .    . <==================>   . WLE08A_N   9 1822 2015  194
   .    .    .    .    .    .    .    .    .    .    .    .    .    .    .    .    .  <============>   . WLE08B_N  10 1885 2015  131
   .    .    .    .    .    .    .    .    .    .    .    .    .    .    .    .  <=================>   . WLE09B_N  11 1830 2015  186
   .    .    .    .    .    .    .    .    .    .    .    .    .    .    .    .    . <=============>   . WLE10B_N  12 1870 2015  146
   .    .    .    .    .    .    .    .    .    .    .    .    .    .    .    .  <=================>   . WLE10C_N  13 1837 2015  179
   .    .    .    .    .    .    .    .    .    .    .    .    .    .    .    . <==================>   . WLE11A_I  14 1825 2015  191
   .    .    .    .    .    .    .    .    .    .    .    .    .    .    .    . <==================>   . WLE11B_N  15 1820 2015  196
   .    .    .    .    .    .    .    .    .    .    .    .    .    .    .    .    . <=============>   . WLE11C_N  16 1870 2015  146
   .    .    .    .    .    .    .    .    .    .    .    .    .    .    .    .    .<==============>   . WLE12A_N  17 1868 2015  148
   .    .    .    .    .    .    .    .    .    .    .    .    .    .    .   <=====================>   . WLE12B_N  18 1796 2015  220
   .    .    .    .    .    .    .    .    .    .    .    .    .    . <============================>   . WLE13A_N  19 1725 2015  291
   .    .    .    .    .    .    .    .    .    .    .    .    .    . <============================>   . WLE13B_N  20 1722 2015  294
   .    .    .    .    .    .    .    .    .    .    .    .    .  <===============================>   . WLE15A_N  21 1692 2015  324
   .    .    .    .    .    .    .    .    .    .    .    .    .    . <============================>   . WLE15B_N  22 1725 2015  291
   .    .    .    .    .    .    .    .    .    .    .    .    .  <===============================>   . WLE16A_N  23 1699 2015  317
   .    .    .    .    .    .    .    .    .    .    .    .    .<==================================>   . WLE16B_N  24 1661 2015  355
   :    :    :    :    :    :    :    :    :    :    :    :    :    :    :    :    :    :    :    :    :   :
 1050 1100 1150 1200 1250 1300 1350 1400 1450 1500 1550 1600 1650 1700 1750 1800 1850 1900 1950 2000 2050
```

PART 3: Master Dating Series: 18:37 Mon 28 May 2018 Page   3

Year	Value	No Ab	Year	Value	No Ab	Year	Value	No Ab	Year	Value	No Ab	Year	Value	No Ab	Year	Value	No Ab
			1700	-.910	3	1750	-.195	6	1800	-.183	10	1850	-.170	19	1900	.605	23
			1701	-1.560	3	1751	.328	6	1801	-.977	10	1851	-.056	19	1901	1.456	23
			1702	1.743	3	1752	-.827	6	1802	.723	10	1852	-.426	19	1902	.289	23
			1703	1.155	3	1753	-.859	6	1803	1.218	10	1853	.332	19	1903	-1.019	23
			1704	1.009	3	1754	-.928	6	1804	1.088	10	1854	.514	19	1904	-.970	23
			1705	.542	3	1755	-.297	6	1805	-2.500	10	1855	.747	19	1905	.791	23
			1706	-1.328	3	1756	.726	6	1806	-.339	10	1856	1.391	19	1906	-1.148	23
			1707	-.266	3	1757	1.043	6	1807	.807	10	1857	-.062	19	1907	-.997	23
			1708	-.079	3	1758	.709	6	1808	-1.115	10	1858	-.598	19	1908	.572	23

Year	Value	No Ab	Year	Value	No Ab	Year	Value	No Ab	Year	Value	No Ab	Year	Value	No Ab	Year	Value	No Ab
			1709	1.265	3	1759	1.613	6	1809	.490	10	1859	.145	19	1909	-.695	23
			1710	-.670	3	1760	-1.197	6	1810	-.363	10	1860	.752	19	1910	.809	23
1661	-.274	1	1711	1.521	3	1761	-1.883	6	1811	-.493	10	1861	.947	19	1911	-.009	23
1662	-.463	1	1712	.746	3	1762	.637	6	1812	-.256	10	1862	-.766	19	1912	-.147	23
1663	-.813	1	1713	1.215	3	1763	.856	6	1813	1.106	10	1863	.209	19	1913	.817	23
1664	-.537	1	1714	-1.812	3	1764	-.191	6	1814	1.625	10	1864	.044	19	1914	-.069	23
1665	-1.573	1	1715	-2.772	3	1765	.630	6	1815	.563	11	1865	.212	19	1915	-.306	23
1666	3.016	1	1716	-.499	3	1766	-.131	6	1816	-.077	11	1866	-1.608	19	1916	-.694	23
1667	3.203	1	1717	1.376	3	1767	1.506	6	1817	-.170	11	1867	.329	19	1917	.443	23
1668	.166	1	1718	.938	3	1768	.650	6	1818	-.780	11	1868	-1.418	20	1918	.005	23
1669	-.696	1	1719	-.439	3	1769	.928	6	1819	.182	11	1869	.654	20	1919	.977	23
1670	-1.345	1	1720	-2.429	3	1770	1.115	6	1820	.253	12	1870	-.446	22	1920	-2.693	23
1671	-.530	1	1721	-.531	3	1771	-1.318	6	1821	.499	13	1871	.577	22	1921	.163	23
1672	-1.007	1	1722	-1.545	4	1772	-.791	6	1822	.215	14	1872	-.807	22	1922	.767	23
1673	.397	1	1723	1.174	4	1773	-.770	6	1823	-.680	15	1873	-.004	22	1923	-2.017	23
1674	.467	1	1724	.919	4	1774	1.177	6	1824	.124	15	1874	.550	22	1924	1.379	23
1675	-.824	1	1725	.320	6	1775	1.156	6	1825	.385	16	1875	1.049	22	1925	.383	23
1676	-.221	1	1726	-.320	6	1776	-1.288	6	1826	.070	16	1876	.909	22	1926	1.090	23
1677	-.185	1	1727	.614	6	1777	-1.456	6	1827	-.478	16	1877	1.157	22	1927	.424	23
1678	1.045	1	1728	-.381	6	1778	-1.437	6	1828	-1.326	16	1878	1.095	22	1928	-.383	23
1679	-.100	1	1729	1.395	6	1779	-.548	6	1829	-.185	16	1879	-.041	22	1929	-1.091	23
1680	1.460	1	1730	.191	6	1780	.210	6	1830	.902	17	1880	-.901	22	1930	.272	23
1681	.634	1	1731	.311	6	1781	-.774	6	1831	-1.661	17	1881	.299	22	1931	.357	23
1682	.677	1	1732	-.654	6	1782	-.368	6	1832	-.482	17	1882	-1.219	22	1932	.072	23
1683	-.273	1	1733	-.532	6	1783	.307	6	1833	.781	17	1883	-.169	22	1933	.512	23
1684	-6.727	1	1734	-.737	6	1784	.095	6	1834	.946	18	1884	-2.237	22	1934	.395	24
1685	-3.697	1	1735	.319	6	1785	.190	6	1835	.114	18	1885	-1.086	23	1935	-1.721	24
1686	1.392	1	1736	.180	6	1786	-1.041	6	1836	-.072	18	1886	-.605	23	1936	.832	24
1687	1.108	1	1737	-.327	6	1787	.817	8	1837	.553	19	1887	.236	23	1937	.430	24
1688	1.465	1	1738	.443	6	1788	.348	8	1838	-.508	19	1888	-.058	23	1938	-.889	24
1689	.086	1	1739	.148	6	1789	-.365	8	1839	-.314	19	1889	1.211	23	1939	.303	24
1690	1.931	1	1740	-1.141	6	1790	.787	8	1840	.669	19	1890	.518	23	1940	-.780	24
1691	.943	1	1741	1.464	6	1791	.752	8	1841	.200	19	1891	.041	23	1941	-1.864	24
1692	-.281	2	1742	.354	6	1792	.061	8	1842	-.727	19	1892	-.014	23	1942	.427	24
1693	1.085	2	1743	-.715	6	1793	.950	8	1843	-.039	19	1893	-.537	23	1943	1.101	24
1694	-.907	2	1744	1.803	6	1794	-.225	8	1844	.477	19	1894	-1.155	23	1944	.391	24
1695	1.128	2	1745	-.116	6	1795	-.858	8	1845	.138	19	1895	.427	23	1945	.705	24
1696	-1.532	2	1746	-.402	6	1796	-.766	9	1846	-.117	19	1896	.487	23	1946	.072	24
1697	.692	2	1747	.747	6	1797	.387	9	1847	-.428	19	1897	.861	23	1947	.598	24
1698	.334	2	1748	-1.325	6	1798	.371	10	1848	-.454	19	1898	.670	23	1948	.608	24
1699	-.339	3	1749	-.814	6	1799	.267	10	1849	-1.252	19	1899	.684	23	1949	.345	24

1950	-.625	24
1951	.301	24
1952	-.308	24
1953	1.066	24
1954	.793	24
1955	-.206	24
1956	-.975	24
1957	-2.130	24
1958	.711	24
1959	.090	24
1960	.880	24
1961	-.769	24
1962	.824	24
1963	.945	24
1964	.409	24
1965	-1.825	24
1966	.312	24
1967	-1.694	24
1968	-1.491	24
1969	1.202	24
1970	.993	24
1971	-.416	24
1972	.878	24
1973	-.076	24
1974	.306	24
1975	-.791	24
1976	.229	24
1977	.873	24
1978	.020	24
1979	-.086	24
1980	.769	24
1981	.236	24
1982	-.749	24
1983	.369	24
1984	-.356	24
1985	.762	24
1986	.001	24
1987	-.087	24
1988	-1.062	24
1989	.455	24
1990	-.315	24
1991	-.647	24
1992	-.026	24
1993	-.994	24
1994	1.056	24
1995	-1.023	24
2000	.991	24
2001	.548	24
2002	.639	24
2003	-2.136	24
2004	-1.135	24
2005	-.125	24
2006	-1.218	24
2007	-.184	24
2008	-1.911	24
2009	.412	24
2010	.356	24
2011	.789	24
2012	.941	24
2013	1.153	24
2014	-.294	24
2015	-.071	24

```
  1996  1.484  24
  1997   .128  24
  1998  1.191  24
  1999   .306  24
```

PART 4: Master Bar Plot: 18:37 Mon 28 May 2018 Page   5

```
   Year Rel value  Year Rel value  Year Rel value  Year Rel value  Year Rel value  Year Rel value  Year Rel value  Year Rel value
                   1700-d          1750----a       1800----a       1850----a       1900-------B    1950--b         2000---------D
                   1701f           1751------A     1801-d          1851----@       1901----------F 1951------A     2001-------B
                   1702----------G 1752--c         1802--------C   1852---b        1902------A     1952---a        2002--------C
                   1703---------E  1753-c          1803----------E 1853------A     1903-d          1953---------D  2003i
                   1704---------D  1754-d          1804---------D  1854-------B    1904-d          1954--------C   2004-e
                   1705-------B    1755---a        1805j           1855--------C   1905--------C   1955----a       2005----@
                   1706-e          1756--------C   1806---a        1856----------F 1906-e          1956-d          2006-e
                   1707---a        1757---------D  1807--------C   1857----@       1907-d          1957i           2007----a
                   1708----@       1758--------C   1808-d          1858--b         1908-------B    1958--------C   2008h
                   1709----------E 1759----------F 1809-------B    1859-----A      1909--c         1959-----@      2009------B
                   1710--c         1760-e          1810---a        1860--------C   1910--------C   1960---------D  2010------A
   1661---a        1711----------F 1761h           1811---b        1861---------D  1911----@       1961--c         2011--------C
   1662---b        1712--------C   1762--------C   1812---a        1862--c         1912----a       1962--------C   2012---------D
   1663--c         1713----------E 1763--------C   1813---------D  1863-----A      1913--------C   1963---------D  2013---------E
   1664--b         1714g           1764----a       1814----------G 1864-----@      1914----@       1964------B     2014---a
   1665f           1715k           1765-------C    1815-------B    1865-----A      1915---a        1965g           2015----@
   1666----------L 1716---b        1766----a       1816----@       1866f           1916--c         1966------A
   1667----------M 1717----------F 1767----------F 1817----a       1867------A     1917-------B    1967g
   1668-----A      1718---------D  1768--------C   1818--c         1868f           1918-----@      1968f
   1669--c         1719---b        1769---------D  1819-----A      1869--------C   1919---------D  1969----------E
   1670-e          1720j           1770---------D  1820------A     1870---b        1920k           1970---------D
   1671--b         1721--b         1771-e          1821-------B    1871-------B    1921-----A      1971---b
   1672-d          1722f           1772--c         1822-----A      1872--c         1922--------C   1972---------D
   1673------B     1723---------E  1773--c         1823--c         1873----@       1923h           1973----@
   1674-------B    1724---------D  1774---------E  1824-----@      1874-------B    1924----------F 1974------A
   1675--c         1725------A     1775---------E  1825------B     1875---------D  1925------B     1975--c
   1676----a       1726---a        1776-e          1826-----@      1876---------D  1926---------D  1976------A
   1677----a       1727-------B    1777f           1827---b        1877---------E  1927-------B    1977---------C
   1678---------D  1728---b        1778f           1828-e          1878---------D  1928---b        1978-----@
   1679----@       1729----------F 1779--b         1829----a       1879----@       1929-d          1979----@
   1680----------F 1730-----A      1780-----A      1830---------D  1880-d          1930------A     1980--------C
   1681--------C   1731------A     1781--c         1831g           1881------A     1931------A     1981------A
   1682--------C   1732--c         1782---a        1832---b        1882-e          1932-----@      1982--c
   1683---a        1733--b         1783------A     1833--------C   1883----a       1933-------B    1983------A
   1684<           1734--c         1784-----@      1834---------D  1884i           1934------B     1984---a
   1685o           1735-----A      1785-----A      1835-----@      1885-d          1935g           1985--------C
   1686----------F 1736-----A      1786-d          1836----@       1886--b         1936--------C   1986---@
   1687---------D  1737---a        1787--------C   1837-------B    1887------A     1937-------B    1987----@
   1688----------F 1738-------B    1788------A     1838---b        1888----@       1938-d          1988-d
   1689-----@      1739-----A      1789---a        1839---a        1889----------E 1939------A     1989-------B
   1690----------H 1740-e          1790--------C   1840--------C   1890-------B    1940--c         1990---a
   1691---------D  1741----------F 1791--------C   1841-----A      1891-----@      1941g           1991--c
```

1692---a	1742------A	1792-----@	1842--c	1892----@	1942-------B	1992----@
1693---------D	1743--c	1793---------D	1843----@	1893--b	1943---------D	1993-d
1694-d	1744----------G	1794----a	1844-------B	1894-e	1944------B	1994---------D
1695---------E	1745----@	1795-c	1845-----A	1895-------B	1945--------C	1995-d
1696f	1746---b	1796--c	1846----@	1896-------B	1946-----@	1996----------F
1697--------C	1747--------C	1797------B	1847---b	1897--------C	1947-------B	1997-----A
1698------A	1748-e	1798------A	1848---b	1898--------C	1948-------B	1998---------E
1699---a	1749--c	1799------A	1849-e	1899--------C	1949------A	1999------A

PART 5: CORRELATION OF SERIES BY SEGMENTS: 18:37 Mon 28 May 2018 Page 5

Correlations of 50-year dated segments, lagged 25 years

Flags: A = correlation under .3281 but highest as dated; B = correlation higher at other than dated position

Seq	Series	Time_span	1675 1724	1700 1749	1725 1774	1750 1799	1775 1824	1800 1849	1825 1874	1850 1899	1875 1924	1900 1949	1925 1974	1950 1999	1975 2024
1	WLE01B_I	1798 2015					.70	.72	.51	.63	.78	.61	.25B	.14B	.16B
2	WLE02A_I	1834 2015							.10B	.37	.85	.81	.74	.75	.75
3	WLE04A_I	1823 2015						.22B	.22B	.34	.54	.72	.67	.70	.74
4	WLE04B_I	1815 2015						.32A	.40	.29A	.40	.50	.26A	.32A	.54
5	WLE05A_I	1787 2015					.55	.64	.61	.69	.60	.41	.55	.57	.63
6	WLE05B_I	1787 2015					.44	.60	.57	.63	.42	.25B	.54	.72	.62
7	WLE07A_N	1821 2015						.22A	.33A	.22B	.45B	.61	.50	.59	.72
8	WLE07B_N	1934 2015											.27B	.23B	.34
9	WLE08A_N	1822 2015						.18B	.22B	.34	.68	.71	.62	.55	.53
10	WLE08B_N	1885 2015									.61	.68	.59	.60	.53
11	WLE09B_N	1830 2015							.56	.61	.62	.53	.45B	.54	.53
12	WLE10B_N	1870 2015								.38	.62	.69	.62	.66	.54
13	WLE10C_N	1837 2015							.13B	.23B	.60	.69	.62	.62	.59
14	WLE11A_I	1825 2015							.03B	.48	.79	.77	.68	.71	.76
15	WLE11B_N	1820 2015						.45	.45	.64	.76	.76	.76	.74	.75
16	WLE11C_N	1870 2015								.26B	.40	.29A	.27A	.47	.41
17	WLE12A_N	1868 2015								-.21B	-.05B	.22A	.54	.35	.22A
18	WLE12B_N	1796 2015					.62	.60	.44	.63	.86	.85	.72	.50	.50
19	WLE13A_N	1725 2015			.01B	.06B	.17B	.28A	.30A	.23B	.15B	.19B	.54	.32A	.23A
20	WLE13B_N	1722 2015		.20B	.19B	.28B	.67	.74	.68	.68	.39	.30A	.49	.33A	.38
21	WLE15A_N	1692 2015	.60	.58	.48	.44	.57	.75	.62	.61	.59	.56	.61	.49	.64
22	WLE15B_N	1725 2015			.44	.63	.27B	.34B	.56	.65	.49	.33	.60	.71	.77
23	WLE16A_N	1699 2015	.56	.53	.46	.65	.24B	.07B	.22B	.58	.66	.69	.77	.67	.64
24	WLE16B_N	1661 2015	.51	.48	.36	.40	.13B	.07B	.28B	.68	.76	.80	.68	.61	.68
Av segment correlation			.56	.45	.33	.41	.44	.41	.38	.45	.56	.56	.55	.54	.55

PART 6: POTENTIAL PROBLEMS: 18:37 Mon 28 May 2018 Page 6

For each series with potential problems the following diagnostics may appear:

[A] Correlations with master dating series of flagged 50-year segments of series filtered with 32-year spline,
at every point from ten years earlier (-10) to ten years later (+10) than dated

```
[B] Effect of those data values which most lower or raise correlation with master series
    Symbol following year indicates value in series is greater (>) or lesser (<) than master series value

[C] Year-to-year changes very different from the mean change in other series

[D] Absent rings (zero values)

[E] Values which are statistical outliers from mean for the year
=====================================================================================================================================

WLE01B_I  1798 to  2015     218 years                                                                                    Series   1

[A] Segment   High   -10   -9   -8   -7   -6   -5   -4   -3   -2   -1   +0   +1   +2   +3   +4   +5   +6   +7   +8   +9  +10
   ---------  ----   ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---
   1925 1974   -6   -.04  .11 -.07  .03  .30*-.06 -.13 -.16 -.26 -.09  .25| .22  .17 -.20 -.01  .02  .09 -.18  .03 -.08  .02
   1950 1999   -6   -.03  .17  .23 -.12  .33*-.11 -.13 -.19  .01 -.26  .14| .21 -.01 -.05 -.08  .09 -.20  .17  .00  .00  .02
   1966 2015   -2   -.12  .11  .12 -.15  .10 -.28 -.18  .01  .20*-.12  .16|   -    -    -    -    -    -    -    -    -    -

[B] Entire series, effect on correlation (  .505) is:
      Lower   2003> -.015   2008> -.014   1939< -.012   1860< -.011   1996< -.010   1965> -.010  Higher   1805  .041   1884  .029
    1925 to 1974 segment:
      Lower   1939< -.063   1963< -.041   1938> -.037   1968> -.035   1965> -.027   1974< -.025  Higher   1957  .053   1935  .033
    1950 to 1999 segment:
      Lower   1996< -.038   1968> -.034   1963< -.032   1965> -.026   1974< -.019   1988> -.017  Higher   1957  .052   1998  .039
    1966 to 2015 segment:
      Lower   2008> -.042   1996< -.038   2003> -.030   1968> -.030   1974< -.019   1981< -.016  Higher   2006  .059   1998  .035

=====================================================================================================================================

WLE02A_I  1834 to  2015     182 years                                                                                    Series   2

[A] Segment   High   -10   -9   -8   -7   -6   -5   -4   -3   -2   -1   +0   +1   +2   +3   +4   +5   +6   +7   +8   +9  +10
   ---------  ----   ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---
   1834 1883   10    .25  .05  .00  .05  .03 -.04  .06  .05 -.11 -.09  .10| .12 -.07 -.17  .00 -.21 -.07 -.25  .25  .00  .26*

[B] Entire series, effect on correlation (  .614) is:
      Lower   1841< -.036   1856< -.035   1871< -.014   1868> -.013   1858< -.012   1904> -.006  Higher   1920  .038   1884  .020
    1834 to 1883 segment:
      Lower   1856< -.102   1841< -.059   1871< -.038   1868> -.031   1853< -.014   1862> -.013  Higher   1849  .033   1858  .030

=====================================================================================================================================

WLE04A_I  1823 to  2015     193 years                                                                                    Series   3

[A] Segment   High   -10   -9   -8   -7   -6   -5   -4   -3   -2   -1   +0   +1   +2   +3   +4   +5   +6   +7   +8   +9  +10
   ---------  ----   ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---
   1823 1872   -4   -.20 -.06  .24 -.08 -.10  .18  .41*-.07 -.02 -.28  .22|-.05  .10 -.15  .04  .04  .07 -.17 -.14 -.15 -.19
   1825 1874   -4   -.22 -.04  .22 -.10 -.09  .13  .42*-.07 -.01 -.29  .22|-.03  .14 -.10  .11  .03  .03 -.14 -.18 -.20 -.21
```

```
 [B] Entire series, effect on correlation (  .521) is:
       Lower   1884> -.048   1836< -.016   1828> -.011   1838> -.010   1854< -.008   1835< -.008  Higher   1920  .017   1923  .017
     1823 to 1872 segment:
       Lower   1828> -.041   1836< -.040   1838> -.033   1854< -.028   1858> -.025   1835< -.022  Higher   1866  .155   1868  .035
     1825 to 1874 segment:
       Lower   1828> -.040   1836< -.039   1838> -.033   1854< -.027   1858> -.025   1835< -.022  Higher   1866  .159   1868  .037

 [C] Year-to-year changes diverging by over 4.0 std deviations:
       1884 1885  -4.5 SD

 [E] Outliers     2   3.0 SD above or -4.5 SD below mean for year
       1838 +3.1 SD;    1884 +4.8 SD
==================================================================================================================================

 WLE04B_I  1815 to  2015     201 years                                                                                Series   4

 [A] Segment   High   -10   -9   -8   -7   -6   -5   -4   -3   -2   -1   +0   +1   +2   +3   +4   +5   +6   +7   +8   +9  +10
    ---------  ----   ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---
    1815 1864    0    .15 -.04  .03 -.02 -.31 -.09 -.06 -.05 -.15 -.12  .32*-.02 -.02 -.04  .19 -.08  .14  .01  .19 -.07  .16
    - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
    1850 1899    0    .04 -.09  .02 -.14 -.06 -.21  .12  .01  .03  .01  .29*-.06  .21 -.10  .17 -.12  .15 -.17  .10 -.05 -.03
    - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
    1925 1974    0    .03  .01  .04  .12  .08 -.10  .13  .04 -.22  .01  .26*-.08 -.11 -.18 -.17  .07  .03  .19  .22  .04  .07
    1950 1999    0   -.19  .13  .02  .11 -.11  .06  .08  .19 -.15 -.06  .32*-.31  .16 -.19  .04 -.13  .10 -.03  .29 -.15 -.03

 [B] Entire series, effect on correlation (  .395) is:
       Lower   1884> -.051   1967> -.027   1960< -.019   1862< -.013   1935> -.011   1938> -.010  Higher   2008  .017   1941  .016
     1815 to 1864 segment:
       Lower   1828> -.030   1832> -.028   1816> -.015   1822> -.014   1847> -.013   1850< -.011  Higher   1831  .055   1834  .021
     1850 to 1899 segment:
       Lower   1884> -.217   1870> -.009   1898< -.008   1850< -.008   1894> -.007   1852> -.007  Higher   1882  .046   1885  .031
     1925 to 1974 segment:
       Lower   1967> -.104   1960< -.069   1935> -.039   1938> -.038   1927< -.031   1952> -.020  Higher   1941  .087   1957  .048
     1950 to 1999 segment:
       Lower   1967> -.125   1960< -.085   1952> -.024   1959< -.018   1976< -.014   1989< -.011  Higher   1957  .048   1996  .028

 [C] Year-to-year changes diverging by over 4.0 std deviations:
       1884 1885  -4.3 SD

 [E] Outliers     2   3.0 SD above or -4.5 SD below mean for year
       1884 +5.4 SD;    1967 +4.2 SD
==================================================================================================================================

 WLE05A_I  1787 to  2015     229 years                                                                                Series   5

 [B] Entire series, effect on correlation (  .572) is:
       Lower   1920> -.018   1990< -.016   1834< -.009   1931< -.009   1938> -.008   1935> -.007  Higher   1884  .022   1805  .020

==================================================================================================================================
```

```
 WLE05B_I  1787 to  2015     229 years                                                                                    Series   6

 [A] Segment   High   -10   -9   -8   -7   -6   -5   -4   -3   -2   -1   +0   +1   +2   +3   +4   +5   +6   +7   +8   +9  +10
    ---------  ----   ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---
    1900 1949   -8    .13  .02  .29* .06 -.18  .04 -.15 -.16  .13 -.11  .25| .08 -.18  .04 -.20  .23  .08  .02  .09 -.06  .06

 [B] Entire series, effect on correlation (  .474) is:
       Lower   1791< -.030   1795> -.010   1856< -.010   1915< -.009   1847> -.009   1834< -.009  Higher   1805  .051   1967  .011
     1900 to 1949 segment:
       Lower   1915< -.034   1935> -.026   1930< -.022   1938> -.021   1923> -.020   1912> -.014  Higher   1920  .029   1941  .021

 [E] Outliers     4   3.0 SD above or -4.5 SD below mean for year
       1791 -4.6 SD;    1847 +3.7 SD;    1934 +3.0 SD;    2011 +3.8 SD
==================================================================================================================================

 WLE07A_N  1821 to  2015     195 years                                                                                    Series   7

 [A] Segment   High   -10   -9   -8   -7   -6   -5   -4   -3   -2   -1   +0   +1   +2   +3   +4   +5   +6   +7   +8   +9  +10
    ---------  ----   ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---
    1821 1870    0    .11 -.04 -.08 -.30 -.17 -.02  .19 -.09  .07  .01  .22*-.15  .06 -.06  .02 -.12 -.04  .10 -.04 -.11  .22
    1825 1874    0    .15 -.10  .04 -.27 -.09 -.08  .25 -.17  .13 -.02  .33*-.15  .01 -.05  .01 -.07  .00 -.14  .00 -.03  .14
    1850 1899   -1   -.08 -.10  .01 -.08  .02  .15  .14  .16  .10  .37* .22| .05 -.05 -.04 -.10 -.08 -.09 -.26 -.07  .00 -.12
    1875 1924   -3   -.12 -.01 -.09  .04 -.08  .26 -.16  .51*-.09  .24  .45|-.15 -.07 -.02 -.19 -.05 -.04 -.23  .01  .13 -.32

 [B] Entire series, effect on correlation (  .441) is:
       Lower   1821< -.025   1884> -.019   1889< -.018   1885< -.016   1831> -.015   1941> -.011  Higher   1923  .027   1967  .014
     1821 to 1870 segment:
       Lower   1821< -.100   1831> -.060   1857> -.015   1858> -.014   1824< -.014   1853< -.010  Higher   1849  .074   1862  .032
     1825 to 1874 segment:
       Lower   1831> -.070   1874< -.021   1857> -.017   1858> -.015   1861< -.014   1840< -.014  Higher   1849  .059   1862  .031
     1850 to 1899 segment:
       Lower   1884> -.058   1889< -.056   1882> -.028   1857> -.015   1858> -.013   1874< -.011  Higher   1885  .030   1862  .028
     1875 to 1924 segment:
       Lower   1884> -.065   1885< -.059   1889< -.051   1882> -.026   1904> -.012   1891< -.007  Higher   1923  .083   1877  .013

 [C] Year-to-year changes diverging by over 4.0 std deviations:
       1884 1885  -4.2 SD

 [E] Outliers     1   3.0 SD above or -4.5 SD below mean for year
       1835 +3.2 SD
==================================================================================================================================

 WLE07B_N  1934 to  2015      82 years                                                                                    Series   8

 [A] Segment   High   -10   -9   -8   -7   -6   -5   -4   -3   -2   -1   +0   +1   +2   +3   +4   +5   +6   +7   +8   +9  +10
    ---------  ----   ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---
    1934 1983    3   -.04  .13  .22 -.24  .17 -.01  .06 -.14  .01 -.32  .27| .02  .09  .33*-.01 -.21  .02  .11 -.11 -.26  .04
    1950 1999    3   -.01  .12  .26 -.22  .08 -.10  .16 -.17  .12 -.28  .23| .08  .19  .29*-.06 -.09 -.19  .01 -.20 -.25 -.05

 [B] Entire series, effect on correlation (  .298) is:
```

```
      Lower   1954< -.089   2003> -.036   1957> -.017   1968> -.017   1982> -.016   1990< -.015  Higher   2008  .069   1965  .043
    1934 to 1983 segment:
      Lower   1954< -.177   1968> -.028   1957> -.028   1982> -.027   1940> -.022   1956> -.015  Higher   1965  .083   1967  .045
    1950 to 1999 segment:
      Lower   1954< -.135   1957> -.028   1968> -.028   1982> -.026   1988> -.016   1956> -.015  Higher   1965  .080   1967  .042

=====================================================================================================================================

 WLE08A_N  1822 to  2015     194 years                                                                                    Series   9

 [A] Segment   High   -10   -9   -8   -7   -6   -5   -4   -3   -2   -1   +0   +1   +2   +3   +4   +5   +6   +7   +8   +9  +10
    ---------  ----   ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---
    1822 1871  -10    .27* .11  .26  .00  .05  .02  .06 -.15 -.13 -.05  .18|-.10 -.21 -.17 -.08 -.03 -.15  .08  .00  .25  .06
    1825 1874  -10    .32* .07  .16 -.02  .08  .01  .12 -.17 -.13 -.08  .22|-.07 -.19 -.17 -.06 -.03 -.19  .09  .01  .27  .02

 [B] Entire series, effect on correlation (  .525) is:
      Lower   1857< -.050   1878< -.012   1862> -.012   1833< -.009   1980< -.009   1947< -.008  Higher   1884  .024   1923  .015
    1822 to 1871 segment:
      Lower   1857< -.119   1862> -.038   1833< -.033   1860< -.023   1847> -.019   1870> -.011  Higher   1831  .063   1828  .043
    1825 to 1874 segment:
      Lower   1857< -.123   1862> -.039   1833< -.032   1860< -.023   1847> -.020   1870> -.012  Higher   1831  .056   1828  .039

 [E] Outliers     1   3.0 SD above or -4.5 SD below mean for year
      1857 -5.4 SD
=====================================================================================================================================

 WLE08B_N  1885 to  2015     131 years                                                                                    Series  10

 [B] Entire series, effect on correlation (  .596) is:
      Lower   1894< -.045   1971> -.015   1906> -.015   1969< -.013   1904> -.010   2003> -.008  Higher   1920  .044   1965  .019

 [E] Outliers     1   3.0 SD above or -4.5 SD below mean for year
      1894 -4.8 SD
=====================================================================================================================================

 WLE09B_N  1830 to  2015     186 years                                                                                    Series  11

 [A] Segment   High   -10   -9   -8   -7   -6   -5   -4   -3   -2   -1   +0   +1   +2   +3   +4   +5   +6   +7   +8   +9  +10
    ---------  ----   ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---
    1925 1974   -9   -.12  .46*-.07  .02  .00 -.28 -.05 -.03 -.14  .30  .45|-.16  .14  .10 -.31 -.12  .08 -.16 -.01  .01  .06

 [B] Entire series, effect on correlation (  .562) is:
      Lower   1971> -.021   1848< -.013   1967> -.010   1935> -.008   1906> -.007   1938< -.006  Higher   2008  .013   1866  .013
    1925 to 1974 segment:
      Lower   1971> -.072   1967> -.029   1935> -.022   1940> -.019   1942< -.014   1936< -.012  Higher   1965  .048   1941  .031

 [E] Outliers     3   3.0 SD above or -4.5 SD below mean for year
      1856 +3.1 SD;    1971 +5.1 SD;    2000 +4.2 SD
=====================================================================================================================================
```

```
 WLE10B_N  1870 to  2015     146 years                                                                                    Series  12

 [B] Entire series, effect on correlation (  .584) is:
       Lower   1882> -.016   1936< -.015   1874< -.013   1969< -.012   1875< -.011   1885> -.011  Higher   1920  .030   1884  .026

====================================================================================================================================

 WLE10C_N  1837 to  2015     179 years                                                                                    Series  13

 [A] Segment   High   -10   -9   -8   -7   -6   -5   -4   -3   -2   -1   +0   +1   +2   +3   +4   +5   +6   +7   +8   +9  +10
    ---------  ----   ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---
    1837 1886   10    .04 -.24  .28 -.14  .20 -.11  .26 -.28  .25 -.05  .13|-.37 -.15 -.14 -.01 -.05  .12  .02  .30 -.04  .36*
    1850 1899   -2    .06 -.21  .04 -.19  .20 -.13  .19 -.32  .31*-.03  .23|-.27 -.06 -.10  .09  .04  .10 -.07  .26 -.06  .25

 [B] Entire series, effect on correlation (  .493) is:
       Lower   1874< -.052   1877< -.014   1839< -.013   1905< -.011   1866> -.010   1941> -.008  Higher   1920  .048   1965  .019
     1837 to 1886 segment:
       Lower   1874< -.136   1877< -.040   1866> -.022   1839< -.017   1854< -.013   1857> -.013  Higher   1868  .053   1862  .032
     1850 to 1899 segment:
       Lower   1874< -.182   1877< -.048   1866> -.022   1857> -.016   1854< -.016   1859< -.009  Higher   1868  .059   1862  .036

 [E] Outliers     1   3.0 SD above or -4.5 SD below mean for year
       1874 -4.9 SD
====================================================================================================================================

 WLE11A_I  1825 to  2015     191 years                                                                                    Series  14

 [A] Segment   High   -10   -9   -8   -7   -6   -5   -4   -3   -2   -1   +0   +1   +2   +3   +4   +5   +6   +7   +8   +9  +10
    ---------  ----   ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---
    1825 1874    4    .11 -.19 -.05  .09 -.06  .00  .03 -.03 -.17 -.13  .03|-.10 -.01 -.04  .16* .05  .13  .00  .01  .11  .12

 [B] Entire series, effect on correlation (  .579) is:
       Lower   1831> -.025   1868> -.019   1828> -.017   1952< -.012   2013< -.010   1858> -.008  Higher   1920  .023   2003  .023
     1825 to 1874 segment:
       Lower   1831> -.070   1868> -.055   1828> -.051   1858> -.024   1834< -.022   1837< -.020  Higher   1862  .097   1856  .043

 [E] Outliers     2   3.0 SD above or -4.5 SD below mean for year
       1831 +3.3 SD;    1868 +3.1 SD
====================================================================================================================================

 WLE11B_N  1820 to  2015     196 years                                                                                    Series  15

 [B] Entire series, effect on correlation (  .657) is:
       Lower   1831> -.010   1828< -.009   2013< -.008   1867< -.008   1827> -.008   1842> -.007  Higher   1884  .016   1923  .012

====================================================================================================================================

 WLE11C_N  1870 to  2015     146 years                                                                                    Series  16

 [A] Segment   High   -10   -9   -8   -7   -6   -5   -4   -3   -2   -1   +0   +1   +2   +3   +4   +5   +6   +7   +8   +9  +10
```

```
   ---------  ----   ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---
   1870 1919   -2   -.22 -.08  .11 -.02  .11  .01  .36  .06  .37*-.07  .26| .05 -.13 -.18  .01 -.04 -.08 -.17  .09  .07 -.13
   - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
   1900 1949    0   -.03 -.02  .20 -.13 -.03  .05 -.14  .25  .14 -.24  .29*-.10 -.21  .09 -.14 -.08 -.04 -.03  .04  .25 -.18
   1925 1974    0   -.01 -.05  .21 -.06  .08 -.06 -.12  .08  .15  .04  .27*-.26 -.04 -.03 -.17 -.16  .06 -.03  .01  .09  .09

[B] Entire series, effect on correlation (  .362) is:
      Lower   1943< -.089   2003> -.023   1967> -.015   1882> -.014   1885> -.011   1909> -.009  Higher   2008  .027   1920  .025
    1870 to 1919 segment:
      Lower   1882> -.050   1885> -.040   1909> -.031   1903> -.017   1886< -.015   1912< -.015  Higher   1906  .031   1877  .025
    1900 to 1949 segment:
      Lower   1943< -.262   1909> -.024   1940> -.015   1903> -.014   1912< -.012   1929> -.011  Higher   1920  .079   1923  .036
    1925 to 1974 segment:
      Lower   1943< -.270   1967> -.039   1940> -.015   1952> -.012   1969< -.010   1929> -.010  Higher   1957  .081   1965  .035

[E] Outliers     1   3.0 SD above or -4.5 SD below mean for year
      1943 -5.6 SD
==================================================================================================================================

WLE12A_N  1868 to  2015     148 years                                                                                Series  17

[A] Segment   High   -10   -9   -8   -7   -6   -5   -4   -3   -2   -1   +0   +1   +2   +3   +4   +5   +6   +7   +8   +9  +10
   ---------  ----   ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---
   1868 1917  -10    .22* .08 -.10  .08  .14  .01  .18  .02  .11  .20 -.21|-.01  .13  .10 -.06 -.01 -.25  .00  .00 -.21  .08
   1875 1924   -2    .11  .17 -.05  .11  .17  .08  .08  .04  .19*-.02 -.05|-.10  .09  .09 -.23  .07 -.21  .05  .00 -.11  .08
   1900 1949    0    .06  .17 -.08 -.03  .06  .15  .06  .14  .08 -.14  .22*-.09 -.07  .08 -.40  .08  .11  .18  .01 -.09 -.02
   - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
   1966 2015    0    .13 -.04  .02 -.16 -.08 -.17 -.35  .13 -.09 -.23  .22*   -    -    -    -    -    -    -    -    -    -

[B] Entire series, effect on correlation (  .186) is:
      Lower   1884> -.039   1913< -.028   1889< -.020   2002< -.019   1869< -.017   1903> -.015  Higher   2003  .032   1965  .020
    1868 to 1917 segment:
      Lower   1884> -.079   1913< -.046   1889< -.043   1903> -.036   1869< -.035   1897< -.015  Higher   1882  .030   1875  .022
    1875 to 1924 segment:
      Lower   1884> -.089   1913< -.058   1889< -.045   1903> -.036   1897< -.016   1890< -.016  Higher   1923  .056   1920  .050
    1900 to 1949 segment:
      Lower   1913< -.092   1903> -.043   1945< -.033   1941> -.029   1943< -.019   1909> -.017  Higher   1923  .040   1935  .037
    1966 to 2015 segment:
      Lower   2002< -.060   1978< -.044   2008> -.038   1995> -.030   1993> -.019   1985< -.016  Higher   2003  .102   1998  .026

[E] Outliers     4   3.0 SD above or -4.5 SD below mean for year
      1884 +4.2 SD;    1902 +3.3 SD;    1903 +4.0 SD;    1979 +3.2 SD
==================================================================================================================================

WLE12B_N  1796 to  2015     220 years                                                                                Series  18

[B] Entire series, effect on correlation (  .626) is:
      Lower   1818< -.024   1866> -.011   1801> -.010   1989< -.009   1851< -.009   1862> -.008  Higher   1805  .036   1884  .021

==================================================================================================================================
```

```
WLE13A_N  1725 to  2015     291 years                                                                                    Series  19

[A] Segment   High   -10   -9   -8   -7   -6   -5   -4   -3   -2   -1   +0   +1   +2   +3   +4   +5   +6   +7   +8   +9  +10
   ---------  ----   ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---
   1725 1774   -6   -.05 -.04 -.12  .04  .29*-.01  .01  .13 -.23  .06  .01|-.14 -.03  .01 -.15  .15  .08  .09 -.02 -.16 -.25
   1750 1799   -5    .16 -.15 -.07  .06  .01  .24* .07 -.07 -.10 -.07  .06|-.01 -.08 -.14 -.17  .11  .08  .09 -.11 -.10 -.02
   1775 1824   -1    .23 -.22 -.13  .16 -.02  .22  .12 -.13 -.13  .31* .17|-.19 -.02  .11 -.17  .06  .00 -.09 -.16  .13  .15
   1800 1849    0   -.07 -.17  .08 -.05 -.14  .13  .18 -.01 -.19  .21  .28*-.11  .08  .11 -.05  .00  .03 -.02 -.33 -.20 -.02
   1825 1874    0   -.10  .00  .02 -.09 -.29  .04  .01  .05 -.12 -.03  .30* .01  .19  .09  .02  .07  .22  .01 -.10 -.26 -.04
   1850 1899    2   -.14 -.03 -.11 -.15 -.17 -.24 -.21  .01  .08 -.12  .23| .04  .29* .11  .20  .21  .24  .01 -.05 -.12 -.01
   1875 1924    3   -.02 -.14  .00 -.18 -.24 -.25 -.19 -.31  .05 -.11  .15| .23  .18  .27* .14  .06  .12 -.11 -.16  .06 -.01
   1900 1949    3    .04 -.08  .10 -.11 -.06  .14 -.31 -.17  .01 -.11  .19| .18 -.03  .24* .04 -.13  .09 -.18 -.25  .08  .01
   - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
   1950 1999    0    .19 -.12 -.25 -.12  .28  .04  .02 -.08  .07 -.27  .32* .08 -.09 -.10  .12 -.22  .09  .01  .14  .02 -.09
   1966 2015    0    .09 -.11 -.13 -.13  .17  .00  .01  .16  .02 -.27  .23*   -    -    -    -    -    -    -    -    -    -

[B] Entire series, effect on correlation (  .195) is:
      Lower   1923> -.027   1761> -.012   1748> -.011   1749< -.010   1752> -.008   2011< -.006  Higher   1967  .017   1957  .013
    1725 to 1774 segment:
      Lower   1761> -.044   1748> -.037   1752> -.033   1727< -.018   1773> -.011   1772> -.011  Higher   1760  .045   1744  .034
    1750 to 1799 segment:
      Lower   1761> -.061   1752> -.043   1783< -.031   1794> -.025   1777> -.018   1779> -.017  Higher   1760  .055   1776  .037
    1775 to 1824 segment:
      Lower   1783< -.041   1818> -.030   1794> -.027   1813< -.023   1809< -.021   1777> -.021  Higher   1805  .103   1776  .035
    1800 to 1849 segment:
      Lower   1818> -.035   1847< -.034   1813< -.024   1809< -.022   1838> -.018   1800> -.016  Higher   1831  .063   1805  .063
    1825 to 1874 segment:
      Lower   1868> -.041   1862> -.039   1847< -.030   1860< -.029   1870> -.024   1838> -.022  Higher   1831  .077   1866  .050
    1850 to 1899 segment:
      Lower   1894> -.035   1862> -.030   1868> -.027   1860< -.026   1875< -.026   1870> -.021  Higher   1882  .066   1866  .060
    1875 to 1924 segment:
      Lower   1923> -.157   1894> -.028   1901< -.025   1919< -.020   1875< -.016   1912> -.015  Higher   1920  .083   1882  .051
    1900 to 1949 segment:
      Lower   1923> -.200   1901< -.028   1912> -.022   1919< -.022   1902< -.011   1930< -.011  Higher   1920  .091   1938  .030
    1950 to 1999 segment:
      Lower   1975> -.041   1965> -.040   1993> -.036   1990> -.035   1968> -.029   1996< -.027  Higher   1967  .099   1957  .072
    1966 to 2015 segment:
      Lower   2011< -.036   1975> -.036   1993> -.031   1990> -.030   1968> -.024   1996< -.023  Higher   1967  .107   2003  .035

[C] Year-to-year changes diverging by over 4.0 std deviations:
      1748 1749  -4.3 SD    1922 1923   4.8 SD    1923 1924  -4.5 SD

[E] Outliers     7   3.0 SD above or -4.5 SD below mean for year
      1752 +3.2 SD;    1761 +3.5 SD;    1912 +3.5 SD;    1923 +6.2 SD;    1975 +3.1 SD;    1990 +3.3 SD;    2005 +3.2 SD
==================================================================================================================================

WLE13B_N  1722 to  2015     294 years                                                                                    Series  20

[A] Segment   High   -10   -9   -8   -7   -6   -5   -4   -3   -2   -1   +0   +1   +2   +3   +4   +5   +6   +7   +8   +9  +10
```

```
    ---------  ----   ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---
    1722 1771  -10    .35*-.20 -.14 -.18  .14 -.01 -.12 -.04 -.11 -.09  .20|-.02  .15  .05 -.19  .02  .13  .15  .08 -.17  .04
    1725 1774  -10    .32*-.18 -.14 -.20  .13 -.02 -.10 -.06 -.17 -.06  .19| .02  .09  .00 -.15  .05  .14  .15  .06 -.13  .05
    1750 1799  -10    .32*-.24 -.13 -.09 -.04  .11 -.34 -.19 -.20 -.15  .28| .10  .04 -.07 -.19  .16  .25  .20  .02 -.14  .27
    - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
    1900 1949    0   -.07 -.16  .07 -.06 -.09  .05 -.25  .01  .00 -.22  .30* .10 -.04 -.02  .00  .04  .10  .06  .02  .13 -.11
    - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
    1950 1999    0    .06  .00 -.29 -.02  .13 -.20 -.09 -.14 -.09 -.24  .33* .27 -.08 -.02  .15  .01  .00  .14 -.10 -.04 -.14

 [B] Entire series, effect on correlation (  .427) is:
       Lower   1748> -.018   1981< -.013   1761> -.012   1902< -.010   1771< -.009   1941> -.008  Higher   1805  .033   2003  .018
     1722 to 1771 segment:
       Lower   1748> -.067   1761> -.044   1752> -.028   1737> -.028   1736< -.023   1727> -.018  Higher   1771  .031   1749  .029
     1725 to 1774 segment:
       Lower   1748> -.070   1761> -.046   1752> -.029   1737> -.028   1736< -.023   1727> -.017  Higher   1771  .035   1744  .029
     1750 to 1799 segment:
       Lower   1761> -.063   1752> -.035   1758< -.019   1781> -.016   1785> -.011   1775< -.010  Higher   1774  .020   1759  .018
     1900 to 1949 segment:
       Lower   1902< -.060   1941> -.046   1922< -.044   1900< -.028   1903> -.025   1919< -.014  Higher   1923  .054   1935  .034
     1950 to 1999 segment:
       Lower   1981< -.092   1993> -.050   1965> -.045   1975> -.044   1995> -.021   1964< -.019  Higher   1967  .043   1969  .033

 [E] Outliers     2   3.0 SD above or -4.5 SD below mean for year
       1727 +4.2 SD;    1748 +3.1 SD
==================================================================================================================================

 WLE15A_N  1692 to  2015     324 years                                                                                   Series  21

 [B] Entire series, effect on correlation (  .568) is:
       Lower   1910< -.012   1701> -.008   1749> -.007   1982< -.007   1771> -.006   1785< -.006  Higher   1805  .018   1884  .013

 [E] Outliers     2   3.0 SD above or -4.5 SD below mean for year
       1695 +3.1 SD;    1783 +3.1 SD
==================================================================================================================================

 WLE15B_N  1725 to  2015     291 years                                                                                   Series  22

 [A] Segment   High   -10   -9   -8   -7   -6   -5   -4   -3   -2   -1   +0   +1   +2   +3   +4   +5   +6   +7   +8   +9  +10
    ---------  ----   ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---
    1775 1824   -3   -.10 -.18 -.16 -.04  .12  .22  .14  .38*-.10 -.12  .27| .07  .05 -.28 -.12 -.04  .02  .03 -.05  .07  .15
    1800 1849   -3   -.04 -.18 -.20  .01  .02 -.06 -.04  .45*-.05 -.16  .34| .05  .06 -.23 -.04  .03 -.31  .02  .10 -.03  .12

 [B] Entire series, effect on correlation (  .501) is:
       Lower   1805> -.025   1748> -.025   1742< -.014   1818> -.007   1934< -.007   1920> -.007  Higher   1884  .020   2003  .011
     1775 to 1824 segment:
       Lower   1805> -.120   1818> -.040   1782< -.024   1785< -.022   1799< -.022   1778> -.016  Higher   1808  .039   1814  .034
     1800 to 1849 segment:
       Lower   1805> -.135   1818> -.039   1829< -.015   1832> -.009   1801> -.009   1800< -.006  Higher   1814  .031   1849  .029

 [E] Outliers     4   3.0 SD above or -4.5 SD below mean for year
```

```
      1748 +3.8 SD;    1805 +3.2 SD;    1922 +3.8 SD;    1923 +3.1 SD
==================================================================================================================================

 WLE16A_N  1699 to  2015     317 years                                                                                  Series  23

 [A] Segment   High   -10   -9   -8   -7   -6   -5   -4   -3   -2   -1   +0   +1   +2   +3   +4   +5   +6   +7   +8   +9  +10
    ---------  ----   ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---
    1775 1824    4    .02 -.22 -.10  .02  .15  .15 -.13  .04 -.15  .04  .24|-.07 -.22 -.05  .41* .10 -.07  .05  .02  .03  .20
    1800 1849    4   -.06 -.19 -.04  .11 -.01  .04  .03  .13 -.14 -.20  .07| .04 -.20  .01  .43* .03 -.09  .21 -.03 -.14 -.19
    1825 1874    4   -.05 -.04 -.08  .04 -.12 -.13  .11 -.01 -.12 -.04  .22| .10  .03  .06  .32* .03 -.03  .06 -.08 -.24 -.25

 [B] Entire series, effect on correlation (  .523) is:
      Lower   1805> -.033   1846< -.017   1748< -.014   1980< -.011   1824< -.011   1828> -.009  Higher   1920  .019   1884  .014
    1775 to 1824 segment:
      Lower   1805> -.203   1824< -.060   1806> -.015   1802< -.015   1790< -.011   1785> -.010  Higher   1814  .027   1777  .026
    1800 to 1849 segment:
      Lower   1805> -.117   1846< -.039   1824< -.037   1828> -.036   1849> -.018   1845< -.016  Higher   1831  .070   1814  .029
    1825 to 1874 segment:
      Lower   1846< -.098   1828> -.059   1845< -.031   1849> -.030   1842> -.015   1844< -.013  Higher   1831  .091   1866  .050

 [C] Year-to-year changes diverging by over 4.0 std deviations:
      1804 1805   4.2 SD

 [E] Outliers     4   3.0 SD above or -4.5 SD below mean for year
      1748 -5.2 SD;    1805 +3.7 SD;    1806 +3.2 SD;    1846 -5.0 SD
==================================================================================================================================

 WLE16B_N  1661 to  2015     355 years                                                                                  Series  24

 [*] Early part of series cannot be checked from 1661 to 1691 -- not matched by another series

 [A] Segment   High   -10   -9   -8   -7   -6   -5   -4   -3   -2   -1   +0   +1   +2   +3   +4   +5   +6   +7   +8   +9  +10
    ---------  ----   ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---
    1775 1824    4   -.04 -.29 -.24 -.11  .04  .12  .05  .10 -.17 -.01  .13| .01 -.20 -.12  .29* .11  .21  .08 -.04  .27  .12
    1800 1849    4   -.07 -.26 -.27 -.02  .08  .10  .12  .08 -.21 -.03  .07|-.13 -.24 -.01  .43* .11  .13  .12 -.08  .21  .04
    1825 1874    4   -.10 -.08 -.02  .04  .19 -.17  .31 -.18 -.10 -.14  .28|-.27  .08  .03  .43*-.09  .01  .11 -.01 -.19 -.08

 [B] Entire series, effect on correlation (  .492) is:
      Lower   1822< -.028   1805> -.018   1749> -.010   1786> -.009   1695< -.008   1831> -.008  Higher   1920  .021   2003  .014
    1775 to 1824 segment:
      Lower   1822< -.100   1805> -.060   1786> -.043   1799< -.012   1794> -.011   1818> -.010  Higher   1776  .030   1808  .028
    1800 to 1849 segment:
      Lower   1822< -.080   1805> -.042   1831> -.031   1844< -.028   1849> -.020   1818> -.009  Higher   1803  .028   1808  .028
    1825 to 1874 segment:
      Lower   1844< -.074   1831> -.068   1849> -.038   1862> -.025   1834< -.023   1845< -.019  Higher   1866  .079   1830  .030

 [E] Outliers     2   3.0 SD above or -4.5 SD below mean for year
      1786 +3.1 SD;    1822 -5.6 SD
==================================================================================================================================
```

PART 7: DESCRIPTIVE STATISTICS: 18:37 Mon 28 May 2018 Page 7

						Corr	//-------- Unfiltered				--------\\	//---- Filtered			-----\\
Seq	Series	Interval	No. Years	No. Segmt	No. Flags	with Master	Mean msmt	Max msmt	Std dev	Auto corr	Mean sens	Max value	Std dev	Auto corr	AR ()
1	WLE01B_I	1798 2015	218	9	3	.505	.30	.40	.043	.448	.116	2.44	.295	-.013	1
2	WLE02A_I	1834 2015	182	7	1	.614	.28	.43	.058	.696	.130	2.61	.412	-.032	1
3	WLE04A_I	1823 2015	193	8	2	.521	.31	.45	.065	.763	.116	2.47	.431	-.026	1
4	WLE04B_I	1815 2015	201	8	4	.395	.30	.46	.051	.517	.119	2.49	.337	-.014	1
5	WLE05A_I	1787 2015	229	9	0	.572	.32	.50	.071	.707	.129	2.59	.424	-.033	1
6	WLE05B_I	1787 2015	229	9	1	.474	.28	.41	.048	.618	.112	2.71	.345	.027	1
7	WLE07A_N	1821 2015	195	8	4	.441	.29	.47	.076	.828	.122	2.46	.341	-.030	1
8	WLE07B_N	1934 2015	82	3	2	.298	.28	.39	.054	.690	.118	2.47	.470	.022	1
9	WLE08A_N	1822 2015	194	8	2	.525	.27	.47	.064	.652	.165	2.53	.351	-.025	1
10	WLE08B_N	1885 2015	131	5	0	.596	.31	.42	.067	.339	.211	2.35	.345	-.043	2
11	WLE09B_N	1830 2015	186	7	1	.562	.30	.55	.061	.482	.149	3.00	.478	-.009	1
12	WLE10B_N	1870 2015	146	6	0	.584	.29	.48	.054	.557	.141	2.60	.464	-.048	1
13	WLE10C_N	1837 2015	179	7	2	.493	.30	.41	.049	.695	.102	2.58	.412	-.046	1
14	WLE11A_I	1825 2015	191	7	1	.579	.32	.46	.070	.782	.113	2.39	.362	-.030	1
15	WLE11B_N	1820 2015	196	8	0	.657	.30	.47	.065	.682	.142	2.44	.401	-.018	1
16	WLE11C_N	1870 2015	146	6	3	.362	.27	.40	.056	.709	.133	2.42	.368	-.036	2
17	WLE12A_N	1868 2015	148	6	4	.186	.24	.52	.060	.586	.176	2.81	.526	.008	1
18	WLE12B_N	1796 2015	220	9	0	.626	.23	.33	.056	.762	.130	2.48	.354	-.021	1
19	WLE13A_N	1725 2015	291	11	10	.195	.24	.37	.050	.641	.129	2.70	.357	-.010	1
20	WLE13B_N	1722 2015	294	12	5	.427	.27	.46	.050	.767	.092	2.68	.333	.028	1
21	WLE15A_N	1692 2015	324	13	0	.568	.29	.47	.058	.656	.132	2.55	.373	-.012	1
22	WLE15B_N	1725 2015	291	11	2	.501	.23	.42	.051	.706	.128	2.82	.382	.012	1
23	WLE16A_N	1699 2015	317	13	3	.523	.28	.42	.058	.766	.116	2.48	.315	.015	1
24	WLE16B_N	1661 2015	355	13	3	.492	.27	.59	.067	.745	.138	2.46	.304	.015	1
Total or mean:			5138	203	53	.490	.28	.59	.058	.670	.129	3.00	.372	-.010	

- = [COFECHA ZZ COF] = -

APPENDIX 3: Wheeler Peak, NM inverted latewood blue intensity COFECHA output

```
 Dendrochronology Program Library                                        Run ZZ     Program COF  18:54  Mon 28 May 2018  Page   1

 P R O G R A M     C O F E C H A                                                                          Version 6.06P    30465
-----------------------------------------------------------------------------------------------------------------------------------

QUALITY CONTROL AND DATING CHECK OF TREE-RING MEASUREMENTS

File of DATED series:   wle_lwinv_new.rwl

CONTENTS:

   Part 1:  Title page, options selected, summary, absent rings by series
   Part 2:  Histogram of time spans
   Part 3:  Master series with sample depth and absent rings by year
   Part 4:  Bar plot of Master Dating Series
   Part 5:  Correlation by segment of each series with Master
   Part 6:  Potential problems: low correlation, divergent year-to-year changes, absent rings, outliers
   Part 7:  Descriptive statistics

RUN CONTROL OPTIONS SELECTED                             VALUE

        1  Cubic smoothing spline 50% wavelength cutoff for filtering
                                                           32 years
        2  Segments examined are                           50 years lagged successively by  25 years
        3  Autoregressive model applied                     A  Residuals are used in master dating series and testing
        4  Series transformed to logarithms                 Y  Each series log-transformed for master dating series and testing
        5  CORRELATION is Pearson (parametric, quantitative)
           Critical correlation, 99% confidence level   .3281
        6  Master dating series saved                       N
        7  Ring measurements listed                         N
        8  Parts printed                              1234567
        9  Absent rings are omitted from master series and segment correlations  (Y)

Time span of Master dating series is  1661 to  2015   355 years
Continuous time span is               1661 to  2015   355 years
Portion with two or more series is    1692 to  2015   324 years

                                       ****************************************
                                       *C* Number of dated series        24 *C*
                                       *O* Master series 1661 2015  355 yrs *O*
                                       *F* Total rings in all series   5138 *F*
                                       *E* Total dated rings checked   5107 *E*
                                       *C* Series intercorrelation     .478 *C*
                                       *H* Average mean sensitivity    .037 *H*
                                       *A* Segments, possible problems   50 *A*
                                       *** Mean length of series      214.1 ***
```

****

ABSENT RINGS listed by SERIES: (See Master Dating Series for absent rings listed by year)

No ring measurements of zero value

PART 2: TIME PLOT OF TREE-RING SERIES: 18:54 Mon 28 May 2018 Page   2

```
----------------------------------------------------------------------------------------------------------------------------
 1050 1100 1150 1200 1250 1300 1350 1400 1450 1500 1550 1600 1650 1700 1750 1800 1850 1900 1950 2000 2050 Ident   Seq Time-span  Yrs
   :    :    :    :    :    :    :    :    :    :    :    :    :    :    :    :    :    :    :    :    : -------- --- ---- ---- ----
   .    .    .    .    .    .    .    .    .    .    .    .    .    .    .   <=====================>   . WLE01B_I   1 1798 2015  218
   .    .    .    .    .    .    .    .    .    .    .    .    .    .    .    .  <=================>   . WLE02A_I   2 1834 2015  182
   .    .    .    .    .    .    .    .    .    .    .    .    .    .    .    . <==================>   . WLE04A_I   3 1823 2015  193
   .    .    .    .    .    .    .    .    .    .    .    .    .    .    .    .<===================>   . WLE04B_I   4 1815 2015  201
   .    .    .    .    .    .    .    .    .    .    .    .    .    .    .  <======================>   . WLE05A_I   5 1787 2015  229
   .    .    .    .    .    .    .    .    .    .    .    .    .    .    .  <======================>   . WLE05B_I   6 1787 2015  229
   .    .    .    .    .    .    .    .    .    .    .    .    .    .    .    . <==================>   . WLE07A_N   7 1821 2015  195
   .    .    .    .    .    .    .    .    .    .    .    .    .    .    .    .    .    .  <=======>   . WLE07B_N   8 1934 2015   82
   .    .    .    .    .    .    .    .    .    .    .    .    .    .    .    . <==================>   . WLE08A_N   9 1822 2015  194
   .    .    .    .    .    .    .    .    .    .    .    .    .    .    .    .    .  <============>   . WLE08B_N  10 1885 2015  131
   .    .    .    .    .    .    .    .    .    .    .    .    .    .    .    .  <=================>   . WLE09B_N  11 1830 2015  186
   .    .    .    .    .    .    .    .    .    .    .    .    .    .    .    .    . <=============>   . WLE10B_N  12 1870 2015  146
   .    .    .    .    .    .    .    .    .    .    .    .    .    .    .    .  <=================>   . WLE10C_N  13 1837 2015  179
   .    .    .    .    .    .    .    .    .    .    .    .    .    .    .    . <==================>   . WLE11A_I  14 1825 2015  191
   .    .    .    .    .    .    .    .    .    .    .    .    .    .    .    . <==================>   . WLE11B_N  15 1820 2015  196
   .    .    .    .    .    .    .    .    .    .    .    .    .    .    .    .    . <=============>   . WLE11C_N  16 1870 2015  146
   .    .    .    .    .    .    .    .    .    .    .    .    .    .    .    .    .<==============>   . WLE12A_N  17 1868 2015  148
   .    .    .    .    .    .    .    .    .    .    .    .    .    .    .   <=====================>   . WLE12B_N  18 1796 2015  220
   .    .    .    .    .    .    .    .    .    .    .    .    .    . <============================>   . WLE13A_N  19 1725 2015  291
   .    .    .    .    .    .    .    .    .    .    .    .    .    . <============================>   . WLE13B_N  20 1722 2015  294
   .    .    .    .    .    .    .    .    .    .    .    .    .   <===============================>   . WLE15A_N  21 1692 2015  324
   .    .    .    .    .    .    .    .    .    .    .    .    .    . <============================>   . WLE15B_N  22 1725 2015  291
   .    .    .    .    .    .    .    .    .    .    .    .    .   <===============================>   . WLE16A_N  23 1699 2015  317
   :    :    :    :    :    :    :    :    :    :    :    :    .<==================================>   . WLE16B_N  24 1661 2015  355
   :    :    :    :    :    :    :    :    :    :    :    :    :    :    :    :    :    :    :    :    :
 1050 1100 1150 1200 1250 1300 1350 1400 1450 1500 1550 1600 1650 1700 1750 1800 1850 1900 1950 2000 2050
```

PART 3: Master Dating Series: 18:54 Mon 28 May 2018 Page   3

Year	Value	No Ab	Year	Value	No Ab	Year	Value	No Ab	Year	Value	No Ab	Year	Value	No Ab	Year	Value	No Ab
			1700	-.367	3	1750	.530	6	1800	-.469	10	1850	-.603	19	1900	.885	23
			1701	-1.821	3	1751	.531	6	1801	-.217	10	1851	1.103	19	1901	1.302	23
			1702	.221	3	1752	.956	6	1802	.145	10	1852	.414	19	1902	1.376	23
			1703	1.352	3	1753	-.380	6	1803	.090	10	1853	.057	19	1903	-.387	23
			1704	-.280	3	1754	-.648	6	1804	.442	10	1854	-.740	19	1904	-.042	23
			1705	.853	3	1755	.067	6	1805	-1.466	10	1855	.191	19	1905	.425	23
			1706	-.715	3	1756	.693	6	1806	.158	10	1856	.867	19	1906	-.677	23
			1707	.547	3	1757	.851	6	1807	1.679	10	1857	.023	19	1907	-1.159	23
			1708	-1.138	3	1758	-1.356	6	1808	-1.150	10	1858	-.980	19	1908	-.317	23

PART 3: Master Dating Series: 18:54 Mon 28 May 2018 Page 4

Year	Value	No Ab	Year	Value	No Ab	Year	Value	No Ab	Year	Value	No Ab	Year	Value	No Ab	Year	Value	No Ab
			1709	.677	3	1759	.101	6	1809	.294	10	1859	-.092	19	1909	-1.587	23
			1710	-.024	3	1760	.148	6	1810	-.970	10	1860	.449	19	1910	.961	23
1661	-1.028	1	1711	2.068	3	1761	-1.628	6	1811	-.973	10	1861	.309	19	1911	-.057	23
1662	.601	1	1712	1.173	3	1762	.031	6	1812	-.451	10	1862	-.495	19	1912	.191	23
1663	-1.284	1	1713	.059	3	1763	.335	6	1813	1.061	10	1863	.717	19	1913	.309	23
1664	-.871	1	1714	-1.619	3	1764	-1.358	6	1814	1.584	10	1864	-.050	19	1914	-.079	23
1665	.954	1	1715	-2.126	3	1765	.114	6	1815	-.071	11	1865	.582	19	1915	-.227	23
1666	3.176	1	1716	-1.440	3	1766	-.893	6	1816	-1.288	11	1866	-1.885	19	1916	-.522	23
1667	3.386	1	1717	.930	3	1767	.474	6	1817	-.585	11	1867	.170	19	1917	.219	23
1668	-1.048	1	1718	.922	3	1768	.933	6	1818	-.522	11	1868	-1.567	20	1918	-.581	23
1669	-1.492	1	1719	.299	3	1769	1.556	6	1819	.281	11	1869	.654	20	1919	.910	23
1670	-1.164	1	1720	-.285	3	1770	1.473	6	1820	.202	12	1870	-.159	22	1920	-2.765	23
1671	-1.134	1	1721	-.300	3	1771	-1.720	6	1821	.462	13	1871	1.444	22	1921	-.197	23
1672	-1.353	1	1722	-1.671	4	1772	-1.784	6	1822	.230	14	1872	-.327	22	1922	.977	23
1673	-.562	1	1723	.800	4	1773	-1.124	6	1823	.026	15	1873	.082	22	1923	-1.080	23
1674	-.360	1	1724	-.509	4	1774	.225	6	1824	1.055	15	1874	.205	22	1924	1.674	23
1675	-.592	1	1725	-.238	6	1775	1.087	6	1825	1.440	16	1875	.330	22	1925	.564	23
1676	1.070	1	1726	-.507	6	1776	-.578	6	1826	.186	16	1876	.192	22	1926	1.489	23
1677	.731	1	1727	1.235	6	1777	.069	6	1827	-.708	16	1877	.088	22	1927	.398	23
1678	-.994	1	1728	.929	6	1778	-.358	6	1828	-1.182	16	1878	.808	22	1928	-.542	23
1679	-.161	1	1729	1.731	6	1779	-.082	6	1829	-.134	16	1879	1.240	22	1929	-1.523	23
1680	3.307	1	1730	-1.147	6	1780	1.750	6	1830	.471	17	1880	-.437	22	1930	.254	23
1681	1.726	1	1731	-.766	6	1781	-.277	6	1831	-2.318	17	1881	.650	22	1931	.013	23
1682	1.010	1	1732	-.548	6	1782	-1.049	6	1832	-.470	17	1882	-1.335	22	1932	.366	23
1683	-1.058	1	1733	-.146	6	1783	.608	6	1833	-.136	17	1883	.793	22	1933	.220	23
1684	-2.396	1	1734	.460	6	1784	-.133	6	1834	1.363	18	1884	-1.957	22	1934	.794	24
1685	-4.266	1	1735	.873	6	1785	.369	6	1835	.472	18	1885	-1.385	23	1935	-1.541	24
1686	-.204	1	1736	1.196	6	1786	-.712	6	1836	-.039	18	1886	-.922	23	1936	.262	24
1687	.085	1	1737	-.020	6	1787	1.496	8	1837	.590	19	1887	.096	23	1937	.138	24
1688	.069	1	1738	-.313	6	1788	.237	8	1838	-.820	19	1888	-.458	23	1938	-.776	24
1689	-1.952	1	1739	-.489	6	1789	-.568	8	1839	-.399	19	1889	.644	23	1939	1.236	24
1690	1.920	1	1740	-1.625	6	1790	.256	8	1840	.019	19	1890	.835	23	1940	-.650	24
1691	.605	1	1741	.399	6	1791	-.292	8	1841	.738	19	1891	.033	23	1941	-2.065	24
1692	-.315	2	1742	.257	6	1792	-.132	8	1842	-.285	19	1892	-.659	23	1942	.352	24
1693	1.867	2	1743	-.988	6	1793	-.063	8	1843	.069	19	1893	-.387	23	1943	.534	24
1694	-.037	2	1744	.593	6	1794	.832	8	1844	-.142	19	1894	-.253	23	1944	.037	24
1695	1.836	2	1745	-.559	6	1795	-.762	8	1845	-.350	19	1895	.037	23	1945	.532	24
1696	-.987	2	1746	-1.517	6	1796	-.365	9	1846	.310	19	1896	.125	23	1946	-.444	24
1697	.816	2	1747	.725	6	1797	.334	9	1847	-.489	19	1897	.878	23	1947	.458	24
1698	-.051	2	1748	.293	6	1798	1.303	10	1848	.563	19	1898	-.311	23	1948	.335	24
1699	-.404	3	1749	2.089	6	1799	.204	10	1849	.245	19	1899	.868	23	1949	-.075	24

1950	-.825	24
1951	.736	24
1952	.232	24
1953	1.190	24
1954	1.418	24
1955	-.808	24
1956	-.623	24
1957	-2.420	24
1958	1.304	24
1959	.159	24
1960	1.372	24
1961	-.509	24
1962	.798	24
1963	.944	24
1964	-.020	24
1965	-2.276	24
1966	.087	24
1967	-1.964	24
1968	-1.320	24
1969	1.141	24
1970	1.034	24
1971	-.658	24
1972	1.399	24
1973	-.180	24
1974	.089	24
1975	-.776	24
1976	.092	24
1977	.608	24
1978	.096	24
1979	.138	24
1980	1.018	24
1981	.266	24
1982	-.605	24
1983	.368	24
1984	-.260	24
1985	.667	24
1986	.101	24
1987	.147	24
1988	-1.129	24
1989	1.276	24
1990	-1.192	24
1991	-1.213	24
1992	-.006	24
1993	-1.042	24
1994	1.464	24
1995	-.703	24
2000	1.467	24
2001	1.141	24
2002	.919	24
2003	-1.671	24
2004	-.696	24
2005	-.413	24
2006	-1.820	24
2007	-.442	24
2008	-2.730	24
2009	-.031	24
2010	.195	24
2011	.638	24
2012	1.007	24
2013	1.313	24
2014	-.221	24
2015	.802	24

```
  1996  1.367  24
  1997   .038  24
  1998   .948  24
  1999  -.037  24
-----------------------------------------------------------------------------------------------------------------------------------

PART 4:  Master Bar Plot:                                                                         18:54  Mon 28 May 2018  Page   5
-----------------------------------------------------------------------------------------------------------------------------------
   Year Rel value  Year Rel value  Year Rel value  Year Rel value  Year Rel value  Year Rel value  Year Rel value  Year Rel value
                   1700---a        1750-------B    1800---b        1850--b         1900---------D  1950--c         2000----------F
                   1701g           1751-------B    1801----a       1851---------D  1901----------E 1951--------C   2001---------E
                   1702------A     1752---------D  1802------A     1852-------B    1902----------F 1952------A     2002---------D
                   1703----------E 1753---b        1803-----@      1853-----@      1903---b        1953---------E  2003g
                   1704---a        1754--c         1804-------B    1854--c         1904----@       1954----------F 2004--c
                   1705--------C   1755-----@      1805f           1855------A     1905-------B    1955--c         2005---b
                   1706--c         1756--------C   1806------A     1856--------C   1906--c         1956--b         2006g
                   1707-------B    1757--------C   1807----------G 1857-----@      1907-e          1957j           2007---b
                   1708-e          1758-e          1808-e          1858-d          1908---a        1958----------E 2008k
                   1709--------C   1759-----@      1809------A     1859----@       1909f           1959------A     2009-----@
                   1710-----@      1760------A     1810-d          1860-------B    1910---------D  1960----------E 2010------A
   1661-d          1711----------H 1761g           1811-d          1861------A     1911----@       1961---b        2011--------C
   1662--------B   1712---------E  1762-----@      1812---b        1862---b        1912------A     1962--------C   2012---------D
   1663-e          1713-----@      1763-------A    1813---------D  1863--------C   1913------A     1963---------D  2013----------E
   1664--c         1714f           1764-e          1814----------F 1864----@       1914----@       1964-----@      2014----a
   1665---------D  1715i           1765-----@      1815----@       1865-------B    1915----a       1965i           2015--------C
   1666----------M 1716f           1766-d          1816-e          1866h           1916--b         1966-----@
   1667----------N 1717---------D  1767-------B    1817--b         1867------A     1917------A     1967h
   1668-d          1718---------D  1768---------D  1818--b         1868f           1918--b         1968-e
   1669f           1719------A     1769----------F 1819------A     1869--------C   1919---------D  1969---------E
   1670-e          1720---a        1770----------F 1820------A     1870----a       1920k           1970---------D
   1671-e          1721---a        1771g           1821-------B    1871----------F 1921----a       1971--c
   1672-e          1722g           1772g           1822------A     1872---a        1922---------D  1972----------F
   1673--b         1723--------C   1773-d          1823-----@      1873-----@      1923-d          1973----a
   1674---a        1724---b        1774------A     1824---------D  1874------A     1924----------G 1974-----@
   1675--b         1725----a       1775---------D  1825----------F 1875------A     1925-------B    1975--c
   1676---------D  1726---b        1776--b         1826------A     1876------A     1926----------F 1976-----@
   1677--------C   1727---------E  1777-----@      1827--c         1877-----@      1927-------B    1977--------B
   1678-d          1728---------D  1778---a        1828-e          1878--------C   1928--b         1978-----@
   1679----a       1729----------G 1779----@       1829----a       1879---------E  1929f           1979-----A
   1680----------M 1730-e          1780----------G 1830-------B    1880---b        1930------A     1980---------D
   1681----------G 1731--c         1781---a        1831i           1881--------C   1931-----@      1981------A
   1682---------D  1732--b         1782-d          1832---b        1882-e          1932-------A    1982--b
   1683-d          1733----a       1783--------B   1833----a       1883--------C   1933------A     1983-------A
   1684j           1734-------B    1784----a       1834----------E 1884h           1934--------C   1984----a
   1685q           1735--------C   1785-------A    1835-------B    1885-f          1935f           1985--------C
   1686----a       1736---------E  1786--c         1836----@       1886-d          1936------A     1986-----@
   1687-----@      1737-----@      1787----------F 1837--------B   1887-----@      1937-----A      1987------A
   1688-----@      1738---a        1788------A     1838--c         1888---b        1938--c         1988-e
   1689h           1739---b        1789--b         1839---b        1889--------C   1939---------E  1989----------E
   1690----------H 1740f           1790------A     1840-----@      1890--------C   1940--c         1990-e
```

```
1691--------B  1741-------B   1791---a       1841--------C  1891-----@     1941h          1991-e
1692---a       1742------A    1792----a      1842---a       1892--c        1942-------A   1992-----@
1693----------G 1743-d        1793----@      1843-----@     1893---b       1943-------B   1993-d
1694----@      1744--------B  1794--------C  1844----a      1894----a      1944-----@     1994----------F
1695----------G 1745--b       1795--c        1845---a       1895-----@     1945-------B   1995--c
1696-d         1746f          1796---a       1846------A    1896-----@     1946---b       1996----------E
1697--------C  1747--------C  1797-------A   1847---b       1897--------D  1947-------B   1997-----@
1698----@      1748------A    1798----------E 1848-------B  1898---a       1948-------A   1998---------D
1699---b       1749----------H 1799------A   1849------A    1899--------C  1949----@      1999----@
```

PART 5: CORRELATION OF SERIES BY SEGMENTS: 18:54 Mon 28 May 2018 Page 5

Correlations of 50-year dated segments, lagged 25 years
Flags: A = correlation under .3281 but highest as dated; B = correlation higher at other than dated position

Seq	Series	Time_span	1675 1724	1700 1749	1725 1774	1750 1799	1775 1824	1800 1849	1825 1874	1850 1899	1875 1924	1900 1949	1925 1974	1950 1999	1975 2024
1	WLE01B_I	1798 2015					.51	.54	.60	.66	.76	.57	.33A	.32A	.27A
2	WLE02A_I	1834 2015							.44	.58	.87	.67	.56	.69	.69
3	WLE04A_I	1823 2015						.42	.46	.45	.46	.67	.69	.72	.69
4	WLE04B_I	1815 2015						.37	.40	.27A	.38	.49	.42	.50	.64
5	WLE05A_I	1787 2015					.64	.63	.65	.63	.56	.43	.59	.66	.63
6	WLE05B_I	1787 2015					.53	.58	.61	.76	.54	.27A	.59	.70	.58
7	WLE07A_N	1821 2015						.33	.44	.40	.52	.64	.67	.73	.74
8	WLE07B_N	1934 2015											.31B	.35	.46
9	WLE08A_N	1822 2015						.21B	.21B	.22B	.57	.67	.66	.54	.57
10	WLE08B_N	1885 2015									.60	.66	.62	.61	.57
11	WLE09B_N	1830 2015							.56	.38	.39	.49	.42B	.55	.61
12	WLE10B_N	1870 2015								-.05B	.20B	.60	.56	.58	.61
13	WLE10C_N	1837 2015							-.05B	-.01B	.33	.53	.56	.65	.70
14	WLE11A_I	1825 2015							-.16B	.29B	.59	.60	.62	.71	.77
15	WLE11B_N	1820 2015						.02B	.03B	.45	.75	.72	.72	.75	.79
16	WLE11C_N	1870 2015								.24B	.39	.28A	.34	.49	.44
17	WLE12A_N	1868 2015								.01B	.22B	.50	.51	.32A	.20A
18	WLE12B_N	1796 2015					.53	.54	.50	.48	.71	.76	.65	.37	.41
19	WLE13A_N	1725 2015			.23B	.20B	.04B	.39	.43	.21B	.02B	.10B	.57	.37	.33A
20	WLE13B_N	1722 2015		.39	.42	.41	.36	.63	.59	.63	.37	.20B	.60	.50	.50
21	WLE15A_N	1692 2015	.20B	.24B	.26B	.22A	.42	.64	.57	.63	.62	.46	.63	.62	.59
22	WLE15B_N	1725 2015			.44	.23B	.22A	.45	.48	.67	.53	.31A	.60	.60	.57
23	WLE16A_N	1699 2015	.29A	.33	.50	.56	.23B	.17B	.30A	.47	.35	.44	.74	.81	.81
24	WLE16B_N	1661 2015	.16B	.19B	.33A	.29B	.18B	.08B	.32B	.72	.77	.70	.69	.70	.77
Av segment correlation			.22	.29	.36	.32	.37	.40	.39	.41	.50	.51	.57	.58	.58

For each series with potential problems the following diagnostics may appear:

[A] Correlations with master dating series of flagged 50-year segments of series filtered with 32-year spline, at every point from ten years earlier (-10) to ten years later (+10) than dated

[B] Effect of those data values which most lower or raise correlation with master series
Symbol following year indicates value in series is greater (>) or lesser (<) than master series value

[C] Year-to-year changes very different from the mean change in other series

[D] Absent rings (zero values)

[E] Values which are statistical outliers from mean for the year

WLE01B_I 1798 to 2015 218 years Series 1

[A]

Segment	High	-10	-9	-8	-7	-6	-5	-4	-3	-2	-1	+0	+1	+2	+3	+4	+5	+6	+7	+8	+9	+10
1925 1974	0	-.08	.15	.01	.11	.28	-.17	-.24	-.09	-.21	-.11	.33*	.15	.20	-.29	-.05	-.02	.00	-.10	.11	-.04	-.02
1950 1999	0	-.01	.08	.26	-.14	.22	-.10	-.19	-.13	.00	-.26	.32*	.27	.02	-.05	-.06	.00	-.32	.15	-.05	.09	.02
1966 2015	0	-.07	.09	.22	-.18	.11	-.27	-.19	.00	.15	-.11	.27*	-	-	-	-	-	-	-	-	-	-

[B] Entire series, effect on correlation (.485) is:
Lower 2008> -.020 2003> -.016 1965> -.013 1803< -.011 1983< -.010 1996< -.007 Higher 1920 .035 1884 .034
1925 to 1974 segment:
Lower 1965> -.038 1944< -.033 1963< -.030 1968> -.029 1960< -.025 1942< -.019 Higher 1957 .054 1967 .026
1950 to 1999 segment:
Lower 1965> -.048 1983< -.043 1968> -.032 1996< -.027 1988> -.026 1963< -.022 Higher 1990 .064 1957 .042
1966 to 2015 segment:
Lower 2008> -.062 2003> -.061 1983< -.043 1996< -.029 1968> -.028 1988> -.022 Higher 2006 .073 1990 .069

[E] Outliers 1 3.0 SD above or -4.5 SD below mean for year
2003 +3.0 SD

WLE02A_I 1834 to 2015 182 years Series 2

[B] Entire series, effect on correlation (.619) is:
Lower 1858< -.021 1838< -.017 1929> -.015 1866> -.009 1940< -.009 1957> -.008 Higher 1920 .032 1884 .028

WLE04A_I 1823 to 2015 193 years Series 3

[B] Entire series, effect on correlation (.554) is:
Lower 1884> -.058 1828> -.021 1838> -.008 1823< -.007 1948< -.007 1925< -.006 Higher 1957 .023 1965 .014

```
 [E] Outliers     1   3.0 SD above or -4.5 SD below mean for year
       1884 +4.5 SD
==================================================================================================================================

 WLE04B_I  1815 to  2015     201 years                                                                                    Series   4

 [A] Segment   High   -10   -9   -8   -7   -6   -5   -4   -3   -2   -1   +0   +1   +2   +3   +4   +5   +6   +7   +8   +9  +10
    ---------  ----   ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---
    1850 1899    0    .01 -.13  .13 -.11 -.05 -.03  .09 -.06 -.06  .03  .27*-.22  .20 -.12  .22 -.16  .15 -.12  .07 -.05  .09

 [B] Entire series, effect on correlation (  .439) is:
       Lower   1884> -.056   1862< -.023   1909> -.015   1935> -.014   1927< -.012   1957> -.011  Higher   1920  .023   1941  .015
     1850 to 1899 segment:
       Lower   1884> -.224   1862< -.032   1868> -.016   1859< -.009   1870> -.006   1854> -.005  Higher   1882  .059   1885  .042

 [C] Year-to-year changes diverging by over 4.0 std deviations:
       1883 1884   4.4 SD    1884 1885  -4.2 SD

 [E] Outliers     2   3.0 SD above or -4.5 SD below mean for year
       1851 +3.3 SD;    1884 +5.2 SD
==================================================================================================================================

 WLE05A_I  1787 to  2015     229 years                                                                                    Series   5

 [B] Entire series, effect on correlation (  .580) is:
       Lower   1935> -.012   1990< -.010   1794< -.007   2000< -.007   1849< -.007   1931< -.006  Higher   1884  .023   1831  .015

==================================================================================================================================

 WLE05B_I  1787 to  2015     229 years                                                                                    Series   6

 [A] Segment   High   -10   -9   -8   -7   -6   -5   -4   -3   -2   -1   +0   +1   +2   +3   +4   +5   +6   +7   +8   +9  +10
    ---------  ----   ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---
    1900 1949    0    .14  .05  .24  .11 -.14 -.03 -.25 -.23  .18  .06  .27* .06 -.08 -.02 -.09  .18  .01 -.04  .00 -.16 -.06

 [B] Entire series, effect on correlation (  .523) is:
       Lower   1792> -.013   1847> -.012   1935> -.010   1930< -.010   1828< -.010   1920> -.009  Higher   1884  .024   1831  .014
     1900 to 1949 segment:
       Lower   1930< -.055   1923> -.032   1935> -.032   1915< -.025   1938> -.021   1943< -.012  Higher   1929  .034   1939  .025

 [E] Outliers     3   3.0 SD above or -4.5 SD below mean for year
       1792 +3.0 SD;    1847 +4.0 SD;    2011 +4.0 SD
==================================================================================================================================

 WLE07A_N  1821 to  2015     195 years                                                                                    Series   7

 [B] Entire series, effect on correlation (  .546) is:
       Lower   1885< -.030   1929> -.018   1821< -.017   1975> -.009   1828> -.008   1909> -.007  Higher   1920  .020   1967  .011
```

```
 [E] Outliers     1   3.0 SD above or -4.5 SD below mean for year
       1835 +3.1 SD
==================================================================================================================================

 WLE07B_N  1934 to  2015      82 years                                                                                  Series   8

 [A] Segment   High   -10   -9   -8   -7   -6   -5   -4   -3   -2   -1   +0   +1   +2   +3   +4   +5   +6   +7   +8   +9  +10
    ---------  ----   ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---
    1934 1983   -8    .09  .21  .35*-.39  .18 -.13  .00 -.04  .02 -.08  .31| .04  .03  .24 -.06 -.27 -.07 -.03  .03 -.21  .07

 [B] Entire series, effect on correlation (  .390) is:
       Lower   1954< -.039   1957> -.037   2003> -.029   1935> -.028   1982> -.014   1988> -.010  Higher   2008  .082   1965  .043
     1934 to 1983 segment:
       Lower   1954< -.080   1957> -.061   1935> -.047   1982> -.026   1976< -.018   1955> -.017  Higher   1965  .107   1941  .063

==================================================================================================================================

 WLE08A_N  1822 to  2015     194 years                                                                                  Series   9

 [A] Segment   High   -10   -9   -8   -7   -6   -5   -4   -3   -2   -1   +0   +1   +2   +3   +4   +5   +6   +7   +8   +9  +10
    ---------  ----   ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---
    1822 1871    9    .19 -.01 -.03  .08 -.22 -.04  .05 -.12  .04 -.01  .21| .13  .06 -.17  .04 -.03 -.16  .09  .04  .30*-.03
    1825 1874    9    .18 -.01 -.10  .07 -.23 -.04  .04 -.09  .04 -.01  .21| .13  .05 -.17  .09  .03 -.13  .13  .01  .38*-.12
    1850 1899  -10    .28*-.03 -.12  .00 -.30 -.07 -.09 -.07  .17 -.08  .22| .08  .17 -.15  .19  .03  .06  .08 -.04  .28 -.17

 [B] Entire series, effect on correlation (  .497) is:
       Lower   1857< -.065   1990> -.010   1850> -.009   1860< -.009   1947< -.009   1878< -.008  Higher   2008  .024   1920  .023
     1822 to 1871 segment:
       Lower   1857< -.169   1850> -.029   1860< -.026   1858> -.015   1830< -.011   1844> -.011  Higher   1831  .062   1871  .033
     1825 to 1874 segment:
       Lower   1857< -.166   1850> -.028   1860< -.027   1858> -.014   1830< -.012   1844> -.009  Higher   1831  .063   1871  .033
     1850 to 1899 segment:
       Lower   1857< -.148   1850> -.028   1860< -.024   1878< -.022   1887< -.019   1858> -.015  Higher   1884  .110   1871  .031

==================================================================================================================================

 WLE08B_N  1885 to  2015     131 years                                                                                  Series  10

 [B] Entire series, effect on correlation (  .617) is:
       Lower   1894< -.042   1990> -.018   1971> -.014   1945< -.013   1912< -.010   1940> -.009  Higher   1920  .032   2008  .027

==================================================================================================================================

 WLE09B_N  1830 to  2015     186 years                                                                                  Series  11

 [A] Segment   High   -10   -9   -8   -7   -6   -5   -4   -3   -2   -1   +0   +1   +2   +3   +4   +5   +6   +7   +8   +9  +10
    ---------  ----   ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---
    1925 1974   -9   -.10  .46*-.07 -.01 -.09 -.29 -.09 -.03  .03  .34  .42|-.20  .08 -.07 -.25 -.09  .13 -.12  .17  .03  .01

 [B] Entire series, effect on correlation (  .512) is:
```

```
      Lower   1884> -.037   1971> -.024   1890< -.022   1942< -.018   1848< -.015   1935> -.012  Higher   2008  .021   1866  .018
    1925 to 1974 segment:
      Lower   1971> -.083   1942< -.068   1935> -.033   1940> -.020   1966< -.016   1939< -.014  Higher   1965  .055   1929  .053

 [E] Outliers     3   3.0 SD above or -4.5 SD below mean for year
      1856 +4.7 SD;    1971 +5.1 SD;    2000 +5.2 SD
==================================================================================================================================

 WLE10B_N  1870 to  2015     146 years                                                                                    Series  12

 [A] Segment   High   -10   -9   -8   -7   -6   -5   -4   -3   -2   -1   +0   +1   +2   +3   +4   +5   +6   +7   +8   +9  +10
    ---------  ----   ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---
    1870 1919   -7   -.06  .19  .05  .32*-.20  .24 -.02  .02 -.03  .13 -.05|-.18 -.09 -.08 -.08 -.12 -.15  .08 -.14  .14  .01
    1875 1924   -5   -.11  .21 -.05  .34 -.28  .38*-.11  .17 -.08 -.03  .20|-.17 -.12  .00 -.13 -.10 -.19  .00 -.18  .27 -.10

 [B] Entire series, effect on correlation (  .466) is:
      Lower   1884> -.042   1889< -.036   1875< -.014   1882> -.012   1972< -.012   1969< -.010  Higher   2008  .046   1920  .034
    1870 to 1919 segment:
      Lower   1889< -.072   1884> -.067   1875< -.025   1882> -.024   1899< -.019   1907> -.016  Higher   1871  .042   1885  .035
    1875 to 1924 segment:
      Lower   1889< -.093   1884> -.089   1875< -.034   1882> -.026   1899< -.019   1896< -.019  Higher   1920  .179   1923  .026

==================================================================================================================================

 WLE10C_N  1837 to  2015     179 years                                                                                    Series  13

 [A] Segment   High   -10   -9   -8   -7   -6   -5   -4   -3   -2   -1   +0   +1   +2   +3   +4   +5   +6   +7   +8   +9  +10
    ---------  ----   ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---
    1837 1886   -8   -.12  .06  .43*-.07  .03 -.08  .20 -.21  .12 -.07 -.05|-.34 -.07 -.11 -.01 -.12  .02  .18  .26 -.13  .26
    1850 1899    8   -.10 -.12  .10 -.14  .05 -.09  .14 -.17  .06 -.13 -.01|-.36 -.05 -.14 -.06 -.04  .07  .17  .38*-.04  .26

 [B] Entire series, effect on correlation (  .436) is:
      Lower   1884> -.029   1868> -.015   1874< -.015   1840< -.010   1877< -.010   1882> -.008  Higher   1965  .031   1920  .026
    1837 to 1886 segment:
      Lower   1884> -.045   1868> -.037   1874< -.031   1840< -.021   1882> -.017   1858> -.016  Higher   1866  .041   1879  .020
    1850 to 1899 segment:
      Lower   1884> -.048   1868> -.037   1874< -.035   1877< -.019   1892> -.018   1882> -.017  Higher   1866  .043   1897  .021

 [E] Outliers     1   3.0 SD above or -4.5 SD below mean for year
      1892 +3.0 SD
==================================================================================================================================

 WLE11A_I  1825 to  2015     191 years                                                                                    Series  14

 [A] Segment   High   -10   -9   -8   -7   -6   -5   -4   -3   -2   -1   +0   +1   +2   +3   +4   +5   +6   +7   +8   +9  +10
    ---------  ----   ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---
    1825 1874   -7   -.01 -.04  .21  .43* .12  .01  .04  .09 -.11 -.24 -.16| .02  .07 -.11 -.04  .03 -.20 -.01 -.06  .09 -.09
    1850 1899    2   -.01 -.11  .13  .13 -.10 -.14  .01 -.10  .10 -.16  .29| .02  .35* .15  .03  .01 -.22 -.15 -.15 -.14 -.13

 [B] Entire series, effect on correlation (  .486) is:
```

```
      Lower   1828> -.031   1868> -.027   1831> -.023   1952< -.012   1834< -.011   1879< -.008  Higher   1920  .025   1957  .020
    1825 to 1874 segment:
      Lower   1828> -.096   1868> -.081   1834< -.037   1831> -.026   1865< -.024   1862> -.021  Higher   1866  .124   1838  .051
    1850 to 1899 segment:
      Lower   1868> -.114   1879< -.039   1865< -.037   1862> -.030   1873< -.021   1887< -.010  Higher   1866  .069   1882  .069

[E] Outliers     2   3.0 SD above or -4.5 SD below mean for year
      1828 +4.2 SD;    1868 +4.1 SD
==================================================================================================================================

WLE11B_N  1820 to  2015     196 years                                                                                Series  15

[A] Segment   High   -10   -9   -8   -7   -6   -5   -4   -3   -2   -1   +0   +1   +2   +3   +4   +5   +6   +7   +8   +9  +10
   ---------  ----   ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---
   1820 1869    9    .03 -.04  .06  .10 -.02  .17  .01 -.06  .03  .09  .02|-.06  .03 -.23 -.15 -.01 -.06  .21 -.09  .21*-.17
   1825 1874    7   -.01 -.05  .17  .02 -.01  .08  .10 -.08  .14  .05  .03|-.14  .09 -.21 -.15 -.02 -.13  .32*-.16  .00 -.04

[B] Entire series, effect on correlation (  .579) is:
      Lower   1828> -.028   1850> -.012   1866> -.010   1837< -.009   1855< -.009   2013< -.007  Higher   1884  .024   1920  .023
    1820 to 1869 segment:
      Lower   1828> -.094   1850> -.037   1837< -.028   1855< -.023   1861< -.019   1822< -.018  Higher   1831  .060   1868  .050
    1825 to 1874 segment:
      Lower   1828> -.093   1850> -.036   1837< -.028   1855< -.023   1861< -.020   1862> -.015  Higher   1831  .056   1868  .047

[E] Outliers     3   3.0 SD above or -4.5 SD below mean for year
      1828 +3.7 SD;    1849 +3.0 SD;    1850 +3.5 SD
==================================================================================================================================

WLE11C_N  1870 to  2015     146 years                                                                                Series  16

[A] Segment   High   -10   -9   -8   -7   -6   -5   -4   -3   -2   -1   +0   +1   +2   +3   +4   +5   +6   +7   +8   +9  +10
   ---------  ----   ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---
   1870 1919   -4   -.21 -.17  .05 -.01  .25 -.07  .34* .09  .20 -.14  .24|-.08 -.19 -.21 -.09 -.07 -.08 -.11  .06  .08 -.06
   - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
   1900 1949    0   -.06 -.01  .14 -.10  .07 -.02 -.29  .23  .15 -.19  .28*-.06 -.09  .10 -.22 -.10  .11 -.03 -.03  .12 -.27

[B] Entire series, effect on correlation (  .386) is:
      Lower   1943< -.085   2003> -.017   1882> -.015   1967> -.013   1885> -.009   1990> -.009  Higher   2008  .058   1957  .034
    1870 to 1919 segment:
      Lower   1882> -.057   1885> -.035   1918> -.032   1903> -.023   1912< -.014   1902< -.013  Higher   1910  .029   1909  .026
    1900 to 1949 segment:
      Lower   1943< -.247   1918> -.019   1940> -.015   1903> -.015   1927< -.009   1912< -.008  Higher   1920  .057   1929  .040

[E] Outliers     2   3.0 SD above or -4.5 SD below mean for year
      1918 +3.0 SD;    1943 -5.1 SD
==================================================================================================================================

WLE12A_N  1868 to  2015     148 years                                                                                Series  17

[A] Segment   High   -10   -9   -8   -7   -6   -5   -4   -3   -2   -1   +0   +1   +2   +3   +4   +5   +6   +7   +8   +9  +10
```

```
   --------- ----   ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---
   1868 1917   -4    .05  .13  .04 -.07  .19 -.02  .41*-.16  .20  .22  .01|-.07 -.11 -.04 -.23 -.25 -.02 -.02  .07 -.23  .28
   1875 1924   -9    .01  .29*-.11  .03  .07  .13  .17 -.13  .17  .11  .22|-.08  .02  .04 -.25 -.19 -.10 -.04 -.05 -.05  .15
   - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
   1950 1999    0    .08  .07  .14  .03  .07 -.14 -.16 -.11  .00 -.29  .32* .08  .12  .24  .00 -.08  .07 -.10 -.19  .01  .03
   1966 2015    0    .14  .02 -.01 -.12  .01 -.15 -.26  .02 -.01 -.33  .20*   -    -    -    -    -    -    -    -    -    -

[B] Entire series, effect on correlation (  .301) is:
      Lower   1868> -.029   1882> -.014   2002< -.013   1957> -.012   1884> -.010   1978< -.010  Higher   1965  .034   1935  .032
    1868 to 1917 segment:
      Lower   1868> -.100   1882> -.045   1878< -.023   1880> -.022   1897< -.021   1910< -.020  Higher   1879  .045   1902  .038
    1875 to 1924 segment:
      Lower   1882> -.048   1878< -.028   1897< -.026   1910< -.025   1880> -.025   1906> -.020  Higher   1920  .087   1879  .032
    1950 to 1999 segment:
      Lower   1957> -.037   1978< -.035   1964< -.030   1985< -.028   1993> -.028   1981< -.025  Higher   1965  .122   1989  .026
    1966 to 2015 segment:
      Lower   2002< -.042   1978< -.031   1985< -.028   1993> -.027   1981< -.023   2000< -.020  Higher   2003  .047   1989  .034

[E] Outliers     1   3.0 SD above or -4.5 SD below mean for year
      1868 +3.9 SD
==================================================================================================================================

WLE12B_N  1796 to  2015     220 years                                                                                Series  18

[B] Entire series, effect on correlation (  .542) is:
      Lower   1986< -.011   1971> -.008   1985< -.008   1871< -.008   1866> -.008   1811> -.006  Higher   1831  .021   1884  .018

==================================================================================================================================

WLE13A_N  1725 to  2015     291 years                                                                                Series  19

[A] Segment   High   -10   -9   -8   -7   -6   -5   -4   -3   -2   -1   +0   +1   +2   +3   +4   +5   +6   +7   +8   +9  +10
   --------- ----   ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---
   1725 1774   -3    .21 -.05 -.04 -.16  .24  .09 -.18  .30*-.11 -.08  .23| .07  .07 -.15 -.18  .00 -.19  .12  .19 -.20 -.08
   1750 1799    7    .20 -.12 -.15  .03  .03  .07 -.05  .14 -.13 -.10  .20| .06  .06 -.16 -.15 -.01 -.15  .26* .11 -.09  .23
   1775 1824   10    .21 -.13 -.21  .11 -.04  .07  .13  .01 -.22  .06  .04|-.13 -.08 -.17 -.13  .16  .15  .25 -.04 -.02  .36*
   - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
   1850 1899    2    .03 -.14 -.09 -.11  .00 -.25 -.03 -.31  .27 -.25  .21|-.11  .28*-.02  .25  .12  .26  .11  .19  .11  .07
   1875 1924    3    .00 -.21 -.03 -.24 -.08 -.23 -.02 -.46  .13  .00  .02| .06  .17  .21* .17 -.03  .10  .05 -.01  .10  .05
   1900 1949   -8    .05 -.20  .18*-.15  .04  .16 -.28 -.31  .10  .07  .10| .09 -.02  .14  .07 -.14  .12 -.05 -.21  .05 -.10
   - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
   1966 2015    0    .07 -.05 -.16 -.29  .16 -.10 -.07  .09  .10 -.14  .33*   -    -    -    -    -    -    -    -    -    -

[B] Entire series, effect on correlation (  .260) is:
      Lower   1923> -.020   1990> -.010   1901< -.009   1860< -.009   1798< -.009   1737> -.007  Higher   1828  .015   1957  .014
    1725 to 1774 segment:
      Lower   1737> -.040   1730> -.034   1742< -.031   1773> -.027   1748> -.018   1760< -.017  Higher   1771  .053   1740  .031
    1750 to 1799 segment:
      Lower   1798< -.041   1773> -.028   1783< -.024   1779> -.016   1760< -.015   1769< -.013  Higher   1771  .055   1764  .039
    1775 to 1824 segment:
```

```
      Lower   1798< -.052   1809< -.036   1817> -.033   1783< -.032   1779> -.016   1800> -.015  Higher   1807  .041   1795  .040
    1850 to 1899 segment:
      Lower   1860< -.077   1879< -.041   1881< -.035   1885> -.032   1850> -.029   1875< -.016  Higher   1884  .067   1866  .059
    1875 to 1924 segment:
      Lower   1923> -.104   1901< -.047   1885> -.027   1879< -.023   1905< -.021   1881< -.021  Higher   1884  .069   1920  .061
    1900 to 1949 segment:
      Lower   1923> -.117   1901< -.048   1905< -.022   1929> -.015   1917< -.014   1943< -.013  Higher   1935  .067   1920  .045
    1966 to 2015 segment:
      Lower   1990> -.067   1968> -.046   1975> -.033   1996< -.026   1993> -.022   1985< -.021  Higher   1967  .078   2006  .063

 [C] Year-to-year changes diverging by over 4.0 std deviations:
      1922 1923   4.4 SD    1923 1924  -5.1 SD

 [E] Outliers     4   3.0 SD above or -4.5 SD below mean for year
      1752 +3.2 SD;    1817 +3.9 SD;    1923 +6.6 SD;    1990 +3.2 SD
========================================================================================================================

 WLE13B_N  1722 to  2015     294 years                                                                            Series  20

 [A] Segment   High   -10   -9   -8   -7   -6   -5   -4   -3   -2   -1   +0   +1   +2   +3   +4   +5   +6   +7   +8   +9  +10
   ---------  ----   ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---
   1900 1949    7   -.09 -.18  .08 -.11 -.05 -.01 -.16  .10  .13 -.17  .20|-.03 -.04 -.15 -.12  .04  .06  .31*-.03  .20 -.03

 [B] Entire series, effect on correlation (  .454) is:
      Lower   1902< -.032   1965> -.011   1748> -.011   1737> -.010   1993> -.008   1903> -.006  Higher   1884  .027   1831  .019
    1900 to 1949 segment:
      Lower   1902< -.181   1903> -.030   1901< -.026   1922< -.024   1929> -.019   1911< -.013  Higher   1920  .083   1924  .038

 [C] Year-to-year changes diverging by over 4.0 std deviations:
      1902 1903   5.0 SD

 [E] Outliers     3   3.0 SD above or -4.5 SD below mean for year
      1748 +3.8 SD;    1902 -4.8 SD;    1993 +3.3 SD
========================================================================================================================

 WLE15A_N  1692 to  2015     324 years                                                                            Series  21

 [A] Segment   High   -10   -9   -8   -7   -6   -5   -4   -3   -2   -1   +0   +1   +2   +3   +4   +5   +6   +7   +8   +9  +10
   ---------  ----   ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---
   1692 1741   -7   -.21  .00 -.03  .26* .12  .12 -.21 -.25 -.10 -.19  .20| .08  .19 -.07 -.17 -.12  .22  .02  .18  .12  .02
   1700 1749    6   -.13 -.10  .01  .23  .17  .00 -.26 -.33 -.13 -.24  .24| .17  .14  .06 -.20 -.16  .33*-.01  .27  .14 -.03
   1725 1774    6   -.07 -.29  .06  .30 -.03 -.04 -.12 -.31 -.13 -.04  .26| .02 -.11  .27 -.20 -.03  .34*-.15  .10  .01  .03
   1750 1799    0    .07 -.25  .09  .14  .02  .19 -.12 -.19 -.13  .10  .22*-.11 -.12  .08 -.04  .04  .18 -.16 -.14 -.21  .08

 [B] Entire series, effect on correlation (  .457) is:
      Lower   1737< -.020   1716> -.011   1929> -.009   1771> -.008   1764> -.008   1698> -.008  Higher   1884  .025   1957  .017
    1692 to 1741 segment:
      Lower   1737< -.082   1716> -.039   1698> -.037   1694< -.033   1713< -.032   1721< -.020  Higher   1730  .034   1722  .028
    1700 to 1749 segment:
      Lower   1737< -.109   1713< -.039   1716> -.038   1743> -.034   1721< -.026   1700< -.018  Higher   1749  .033   1730  .032
```

```
    1725 to 1774 segment:
      Lower   1737< -.109   1743> -.039   1764> -.038   1771> -.038   1750< -.025   1752< -.017  Higher   1761  .043   1749  .035
    1750 to 1799 segment:
      Lower   1792> -.043   1764> -.043   1771> -.041   1794< -.039   1750< -.031   1752< -.021  Higher   1761  .061   1758  .045

==================================================================================================================================

 WLE15B_N  1725 to  2015     291 years                                                                                  Series  22

 [A] Segment   High   -10   -9   -8   -7   -6   -5   -4   -3   -2   -1   +0   +1   +2   +3   +4   +5   +6   +7   +8   +9  +10
    ---------  ----   ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---
   1750 1799    7    .08 -.03 -.13  .02 -.11 -.30 -.05  .13 -.12  .12  .23|-.09 -.12  .04 -.11  .06  .14  .25*-.09 -.08  .04
   1775 1824    0    .12  .05 -.03  .04 -.05 -.26  .04  .07 -.22  .08  .22*-.08  .06  .05  .03 -.08 -.07  .04 -.22 -.06  .04
    - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
   1900 1949    0   -.13 -.01 -.06 -.26  .09  .03 -.09 -.01 -.17 -.11  .31*-.08 -.08  .14  .06  .17  .20  .00 -.02 -.01 -.12

 [B] Entire series, effect on correlation (  .473) is:
      Lower   1920> -.012   1856< -.009   1834< -.008   1727< -.008   1929> -.008   1934< -.008  Higher   1884  .029   2008  .021
    1750 to 1799 segment:
      Lower   1793< -.044   1776> -.040   1792< -.032   1775< -.025   1785< -.024   1756< -.023  Higher   1771  .057   1787  .036
    1775 to 1824 segment:
      Lower   1776> -.044   1793< -.043   1819< -.036   1775< -.030   1785< -.025   1792< -.024  Higher   1805  .065   1807  .049
    1900 to 1949 segment:
      Lower   1920> -.061   1929> -.044   1934< -.042   1923> -.032   1915< -.030   1918> -.012  Higher   1941  .081   1935  .045

 [E] Outliers     1   3.0 SD above or -4.5 SD below mean for year
      1981 +3.1 SD
==================================================================================================================================

 WLE16A_N  1699 to  2015     317 years                                                                                  Series  23

 [A] Segment   High   -10   -9   -8   -7   -6   -5   -4   -3   -2   -1   +0   +1   +2   +3   +4   +5   +6   +7   +8   +9  +10
    ---------  ----   ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---
   1699 1748    0   -.02  .06  .01  .03  .18  .10 -.03 -.05 -.04 -.16  .29* .08  .10 -.30 -.23 -.07 -.04  .21  .18  .03 -.02
    - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
   1775 1824   -5    .21 -.16  .01  .01  .10  .29* .02 -.10 -.22 -.23  .23| .02 -.03 -.19  .11 -.01  .01 -.01 -.01  .07 -.13
   1800 1849    1   -.06 -.23  .11  .12 -.09  .11  .13  .04 -.19 -.19  .17| .18*-.04 -.22  .13 -.12 -.07  .07  .07  .01 -.32
   1825 1874    0   -.24 -.20  .08  .02 -.21  .03  .21  .12  .01  .01  .30*-.03 -.08 -.23  .09 -.06 -.23  .06  .03  .10 -.19

 [B] Entire series, effect on correlation (  .481) is:
      Lower   1913< -.023   1716> -.022   1805> -.015   1828> -.012   1869< -.008   1909> -.006  Higher   1957  .011   2003  .010
    1699 to 1748 segment:
      Lower   1716> -.116   1733< -.025   1734< -.024   1737> -.022   1710> -.021   1730> -.021  Higher   1715  .032   1711  .032
    1775 to 1824 segment:
      Lower   1805> -.125   1792> -.045   1817> -.021   1777< -.019   1802< -.018   1797< -.015  Higher   1816  .053   1807  .044
    1800 to 1849 segment:
      Lower   1805> -.098   1828> -.075   1846< -.031   1817> -.017   1802< -.015   1830< -.015  Higher   1831  .118   1807  .045
    1825 to 1874 segment:
      Lower   1828> -.086   1869< -.062   1846< -.042   1863< -.032   1854> -.029   1830< -.020  Higher   1831  .110   1866  .056
```

```
 [E] Outliers     1   3.0 SD above or -4.5 SD below mean for year
       1805 +3.2 SD
=====================================================================================================================================

 WLE16B_N  1661 to  2015     355 years                                                                                    Series  24

 [*] Early part of series cannot be checked from 1661 to 1691 -- not matched by another series

 [A] Segment   High   -10   -9   -8   -7   -6   -5   -4   -3   -2   -1   +0   +1   +2   +3   +4   +5   +6   +7   +8   +9  +10
    ---------  ----   ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---
    1692 1741   -2    .09  .05  .05  .13 -.11 -.20 -.18 -.06  .30* .16  .16|-.24 -.15 -.13 -.10  .11  .27 -.04  .12  .04  .00
    1700 1749   -2    .13  .11  .28 -.02 -.07 -.12 -.27  .06  .28* .16  .19|-.36 -.16 -.02 -.13  .09  .19  .00  .05 -.09  .10
    1725 1774    0    .08  .14  .20  .03 -.03  .05 -.29  .04  .06 -.13  .33*-.08 -.21  .12 -.31 -.04  .12 -.02 -.09 -.08  .30
    1750 1799   10    .13 -.02  .09  .16  .08  .00 -.04  .00 -.15 -.17  .29| .09 -.41  .02 -.16  .04  .04 -.06 -.13 -.12  .37*
    1775 1824   -3    .16 -.15  .01 -.13  .10  .07  .17  .22*-.30 -.21  .18| .10 -.10 -.11  .03 -.05 -.12  .03  .03 -.03  .16
    1800 1849   -4   -.09 -.25 -.08 -.06  .13  .16  .25* .03 -.22  .12  .08|-.07 -.06 -.15  .15 -.15 -.11 -.03  .06  .04  .06
    1825 1874   -4   -.09 -.17 -.04 -.02  .17 -.02  .32*-.27  .05  .05  .32|-.21 -.03 -.19  .28 -.14 -.01 -.12  .13 -.06  .12

 [B] Entire series, effect on correlation (  .448) is:
       Lower   1716< -.029   1748< -.018   1831> -.016   1694> -.009   1805> -.009   1708> -.008  Higher   1884  .022   1920  .012
     1692 to 1741 segment:
       Lower   1716< -.139   1694> -.037   1698< -.032   1708> -.028   1713> -.022   1721> -.022  Higher   1715  .037   1722  .032
     1700 to 1749 segment:
       Lower   1716< -.116   1748< -.068   1708> -.030   1713> -.022   1721> -.021   1746> -.019  Higher   1715  .032   1722  .028
     1725 to 1774 segment:
       Lower   1748< -.139   1764> -.029   1746> -.025   1752< -.020   1758> -.020   1726> -.014  Higher   1771  .035   1761  .031
     1750 to 1799 segment:
       Lower   1785< -.047   1791> -.041   1764> -.035   1781< -.030   1758> -.024   1752< -.023  Higher   1771  .048   1761  .041
     1775 to 1824 segment:
       Lower   1805> -.064   1791> -.040   1785< -.036   1820< -.027   1817> -.021   1806< -.018  Higher   1808  .070   1780  .039
     1800 to 1849 segment:
       Lower   1831> -.096   1805> -.048   1820< -.025   1828> -.019   1806< -.016   1817> -.016  Higher   1808  .067   1824  .032
     1825 to 1874 segment:
       Lower   1831> -.136   1850> -.034   1828> -.034   1832< -.026   1844< -.020   1835< -.016  Higher   1868  .085   1866  .041

 [C] Year-to-year changes diverging by over 4.0 std deviations:
       1694 1695  -4.5 SD

 [E] Outliers     3   3.0 SD above or -4.5 SD below mean for year
       1694 +3.0 SD;    1759 +3.0 SD;    1831 +3.7 SD
=====================================================================================================================================
```

PART 7: DESCRIPTIVE STATISTICS: 18:54 Mon 28 May 2018 Page 7

						Corr	//-------- Unfiltered --------\\					//---- Filtered -----\\			
Seq	Series	Interval	No. Years	No. Segmt	No. Flags	with Master	Mean msmt	Max msmt	Std dev	Auto corr	Mean sens	Max value	Std dev	Auto corr	AR ()
1	WLE01B_I	1798 2015	218	9	3	.485	1.40	1.66	.097	.765	.034	2.41	.261	.003	1
2	WLE02A_I	1834 2015	182	7	0	.619	1.24	1.54	.082	.692	.041	2.42	.395	-.022	2
3	WLE04A_I	1823 2015	193	8	0	.554	1.38	1.54	.067	.579	.034	2.49	.373	-.022	2
4	WLE04B_I	1815 2015	201	8	1	.439	1.32	1.58	.074	.560	.036	2.69	.385	-.034	1
5	WLE05A_I	1787 2015	229	9	0	.580	1.28	1.49	.093	.765	.037	2.45	.340	-.026	1
6	WLE05B_I	1787 2015	229	9	1	.523	1.19	1.36	.065	.678	.034	2.62	.309	-.009	1
7	WLE07A_N	1821 2015	195	8	0	.546	1.21	1.50	.111	.883	.034	2.47	.316	.015	1
8	WLE07B_N	1934 2015	82	3	1	.390	1.14	1.52	.093	.767	.038	2.51	.395	.008	1
9	WLE08A_N	1822 2015	194	8	3	.497	1.46	1.75	.132	.833	.042	2.45	.326	-.058	1
10	WLE08B_N	1885 2015	131	5	0	.617	1.35	1.64	.139	.779	.055	2.44	.474	-.064	1
11	WLE09B_N	1830 2015	186	7	1	.512	1.19	1.50	.108	.738	.045	3.09	.457	-.050	1
12	WLE10B_N	1870 2015	146	6	2	.466	1.36	1.61	.102	.838	.032	2.43	.387	-.045	1
13	WLE10C_N	1837 2015	179	7	2	.436	1.31	1.44	.058	.596	.031	2.45	.348	-.018	2
14	WLE11A_I	1825 2015	191	7	2	.486	1.24	1.55	.101	.798	.039	2.48	.359	-.017	1
15	WLE11B_N	1820 2015	196	8	2	.579	1.37	1.62	.094	.754	.038	2.60	.462	-.039	3
16	WLE11C_N	1870 2015	146	6	2	.386	1.43	1.62	.076	.727	.031	2.42	.338	.001	1
17	WLE12A_N	1868 2015	148	6	4	.301	1.45	1.99	.193	.907	.042	2.45	.346	-.018	1
18	WLE12B_N	1796 2015	220	9	0	.542	1.37	1.59	.123	.880	.034	2.47	.364	-.024	1
19	WLE13A_N	1725 2015	291	11	7	.260	1.34	1.65	.100	.839	.032	2.80	.357	-.029	1
20	WLE13B_N	1722 2015	294	12	1	.454	1.34	1.56	.077	.786	.029	2.57	.366	.004	1
21	WLE15A_N	1692 2015	324	13	4	.457	1.40	1.72	.123	.786	.042	2.57	.389	.000	1
22	WLE15B_N	1725 2015	291	11	3	.473	1.30	1.67	.086	.690	.040	2.55	.347	.002	1
23	WLE16A_N	1699 2015	317	13	4	.481	1.35	1.56	.083	.687	.037	2.44	.325	-.007	1
24	WLE16B_N	1661 2015	355	13	7	.448	1.26	1.82	.103	.763	.040	2.53	.391	-.033	3
Total or mean:			5138	203	50	.478	1.32	1.99	.098	.752	.037	3.09	.364	-.019	

- = [COFECHA ZZ COF] = -