Reconstructing Late Holocene Climate through Tree-Ring Analysis of Siberian Larch: Altai Mountains, Western Mongolia

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Brittany E. Estes-Gaudette　　　　　　　　　Date

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And THANK YOU, MOM!!!! Look what I can do!! I love you love you. Only because of you am I here.

Abstract

Dendroclimatology utilizes tree-rings to reconstruct past climate. Tree-ring growth is related to limiting growth factors, which can be either internal (biologic) or external (environmental or climatic). A good tree ring record for climate reconstructions is one that is sensitive to its external surroundings, one that records annual changes in climatic parameters such as temperature and precipitation within its annual growth rings. Siberian larches (*Larix siberica*) in the Altai Mountains of Western Mongolia are examples of such stressed trees. Larch forests are not ubiquitous in the region, suggesting that they are at the limit of their environmental extent and are expected to be sensitive to changes to climate patterns and periodicities.

This study attempts to extend paleoclimate records beyond geographically and temporally limited meteorological data for the Altai Mountains, a NNW-SSE trending mountain range along the western border of Mongolia. Studying the climatic patterns of Mongolia prior to instrumental data puts recently observed changes into a broader climatic context. Tree cores were collected from two small larch forests, both occurring on north-facing slopes and at elevations of 2400 to 2900 m. A total of 34 cores were recovered, yielding a 425-year chronology (A.D. 1584). Based on positive correlations with summer temperatures (June through August), this chronology was used as a summer temperature paleoclimate proxy for Mongolia's Altai Mountains and was related to larger climatic systems such as ENSO.

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Introduction

Dendroclimatology utilizes tree-rings to reconstruct past climate. Tree-ring growth is related to limiting growth factors, which can be either internal (biologic) or external (environmental or climatic) (Fritts, 1976). A good tree-ring record for climate reconstructions is one that is sensitive to its external surroundings, such as trees under stress, which are more likely to record changes such as temperature and precipitation within its annual growth rings (Bradley, 1999). Siberian larches (*Larix siberica*) in the Altai Mountains of Western Mongolia are examples of such stressed trees (Fig 1). Larch forests are not ubiquitous in the region, which indicates that they are at the limit of their environmental extent and are therefore sensitive to changes in climate patterns and periodicities.

This study attempts to extend climate records beyond geographically and temporally limited instrumental climate data for the Western Altai Mountains. Studying the climatic patterns of Mongolia prior to instrumental data puts recently observed changes in a broader climatic context. It also provides a precision in dating climatic events, given the annual ring growth. For instance, the Little Ice Age (LIA) is one event whose beginning and end dates are still being debated. One question to ask is whether Mongolia experience the LIA at all? Other recent climate questions might ask if different regions respond to temperature and precipitation changes differently? Mongolia is one of the most sparsely populated countries on Earth, however, it is an important region for climate observation because of its land-locked location and dynamic response to climatic systems.

Tree cores were collected from two small larch forest stands located approximately 60 km from each other (Fig 1). Both stands occur on north-facing slopes and range in elevations from 2400 to 2900 m (Fig 2). A total of 34 cores were recovered, yielding a 425-year old chronology (A.D. 1584) which related to summer temperatures (June through August) from two weather stations, as well as with Standardized Anomalies of the Equatorial Southern Oscillation (EQSOI) Index in Indonesia. Reconstructed temperatures were generated through regression analysis providing a summer temperature paleoclimate proxy for the Altai Mountains 350 years prior to instrumental data.

Paleoclimatology

The earth's climate is a complicated, multi-component system which has experienced many changes and variations throughout its history. These climatic changes have been recorded by different natural systems such as pollen records, ice cores, corals, caves, varves, and tree-rings which can be utilized as archival records of past climates (Bradley, 1999). These paleoclimate proxies are especially valuable in the context of recently observed changes in climate patterns within the last century which have been attributed to global warming. Are these changes "normal" in the Earth's climatic cycle, or do they represent an unnatural forcing due to anthropogenic activity? Answering this question can be accomplished by studying different paleoclimate records that extend beyond instrumental data that can give insight and perspective into past, present, and future climate variation (Fritts, 1991).

Not all paleoclimate records are the same. Different proxies respond to climate on different timescales, producing high (short-term) and low (long-term) frequency proxy records. For example, low frequency paleoclimatic information can be used to reconstruct climate changes as a result of plate tectonics (Fritts, 1991), whereas high frequency proxies, such as ice cores and tree-rings, record yearly and seasonal changes that have occurred within the last millennia or the last century (Bradley, 1999; Schweingruber, 1989).

Dendroclimatology

Dendroclimatology is the study of tree-rings to reconstruct past climate. Tree-rings are excellent paleoclimate proxies for reconstructing temporally specific and spatially distinct climatic conditions, due to their environmentally sensitive annual growth rings, which produce a precise and generally reliable chronology of ecology and climate.

Annual tree-ring growth functions under a limiting growth factor, a biologic principle known as "Liebig's Law of the Minimum" that states that the growth of an organism (such as a trees) cannot proceed faster than is allowed by its most limiting factor (Fig 3; Fritts, 1976; Speer, 2007; Schweingruber, 1989). For trees, the limiting factor can be either internal (biologic) or external (environmental or climatic). Some of these factors can be a limit in nutrient availability or growing conditions such as precipitation and temperature. However, it is important to realize the interconnectedness of these two factors. Internal processes cannot operate without supplies delivered by external forces which enhance the environment signal in tree-ring growth (Fritts, 1976).

Just as different climate proxies respond to different frequencies of climate variation, not all tree-ring records are equally reliable in representing climate variation. A good climate-reconstructing tree-ring record is one that is at its environmental extent and is thus sensitive to its external surroundings (Fig 4). It is hypothesized that certain locations within a stand of trees can be responding to different climatic factors. Fritts (1976) suggests that trees found at upper timber line are sensitive to temperature while trees found at the base of a stand will be limited by precipitation. No matter their location, sensitive tree-ring records show much variation in annual ring width. This variation is a signature of climate change which can be used as a proxy of past climate conditions. Fritts, following an analogy by A.E. Douglass of tree-rings to Morse code, suggests that the sequence of narrow (dots) and wide (dashes) rings in a sensitive ring series conveys messages about the life of the tree [in response to its surroundings]," (Fritts, 1976, p.19)

Tree-Ring Characteristics

Tree-rings are made up of cells called tracheids. Two kinds of tracheids make up the distinct light and dark parts of an annual growth ring, known as earlywood and latewood, respectively. Light-colored earlywood forms in the spring at the beginning of a growing season and has tracheids that are large with thin cell walls. Latewood forms in the late summer/early fall or at the end of the growing season and is dark in color because the tracheids have constricted and their cell walls thickened (Fig 5 & 6). Other anatomical features found within the tree-ring record are resin ducts (Fig 7b), woods rays (which carry resin and nutrients throughout the tree; Fig 6), sapwood (young wood), heartwood (old wood; Fig 5), and heart rot (rotten wood; Fig 7a) (Fritts, 1976).

Tree-rings respond to climate with inter-annual variations in width and density. If growth factors are limited in the extreme, growth will be restricted and will result in a narrow ring (Fig 4 & 6). If all conditions are ideal and not limited, rings will be wide. Tree-rings also respond to climate with intra-annual density fluctuations. One such example of this, known as false rings, can occur in earlywood or latewood as a result of extended episodes of an environemental change. For example, if a tree experiences a cold spring, it will develop a narrow earlywood. If the spring is ideal, but a cold front settles in, this cold front will produce a few dense layers of tracheids within the earlywood, thus creating a false ring (Stokes and Smiley, 1968). Frost rings can also occur with sudden temperature changes. In this case, tracheids look ruptured and will appear as a line of broken cells. In extremely limited growth conditions, a tree may not initiate growth at all during the current growing season. This leads to absent rings which can compromise the accuracy of tree-ring paleoclimate data. All these variations in ring structure in response to climate are what produce indicator rings and the signature of a sensitive ring record which can then be related to other trees in order to establish a large scale climate signal. In some cases these "complicated rings" can be used to infer past climate events (e.g. mid season cold or frost events) but in some cases these "false" rings can be misinterpreted as a complete annual growth increment and can add complexity to resulting chronology.

Cross dating and Calibration

Individual tree cores often show significant inter-annual variation but because other factors can influence the growth of an individual tree from year to year, tree-ring records from multiple trees are needed to produce a robust and climatically significant record of past climate. Matching up the growth signature from multiple samples is called cross-dating. Cross-dating is an essential part of dendrochronology in that it verifies the quality of measurements and helps to isolate anomalous ring patterns. Cross dating is critical to developing an accurate tree-ring chronology because it ensures 1) that every visible ring is placed in its proper time sequence, 2) prevents false rings from being incorporated into a chronology, and 3) facilitates the identification of absent rings. Cross dating can be accomplished with the use of a skeleton plot or with measurement graphs (Schweingruber, 1988). The ability to cross-date a suite of tree-ring samples also validates that a similar climatic/environmental control factor is operating within the area in question (Fritts, 1976). Once a common limiting factor is identified, the next challenge is to identify the climatic factor that is controlling growth variation.

Once a set of tree-rings has been accurately cross-dated and individual cores have been aggregated into a chronology, the chronology must then be verified as a sufficient proxy for climate reconstruction. This step is referred to as calibration which correlates a standardized, composite chronology of tree-ring width with various climatic parameters using statistical equations. This process is referred to as "response function analysis", (Bradley, 1999; Schweingruber, 1989). Calibration can be accomplished by comparing a tree ring chronology with local weather station data. However, comparison with weather station data has drawbacks since complete instrumental data is often limited both temporally and spatially. However, when calibration is successful, it can provide even more accuracy to tree-ring records by isolating which months are contributing to tree growth, which can lead to seasonally specific paleoclimate reconstructions.

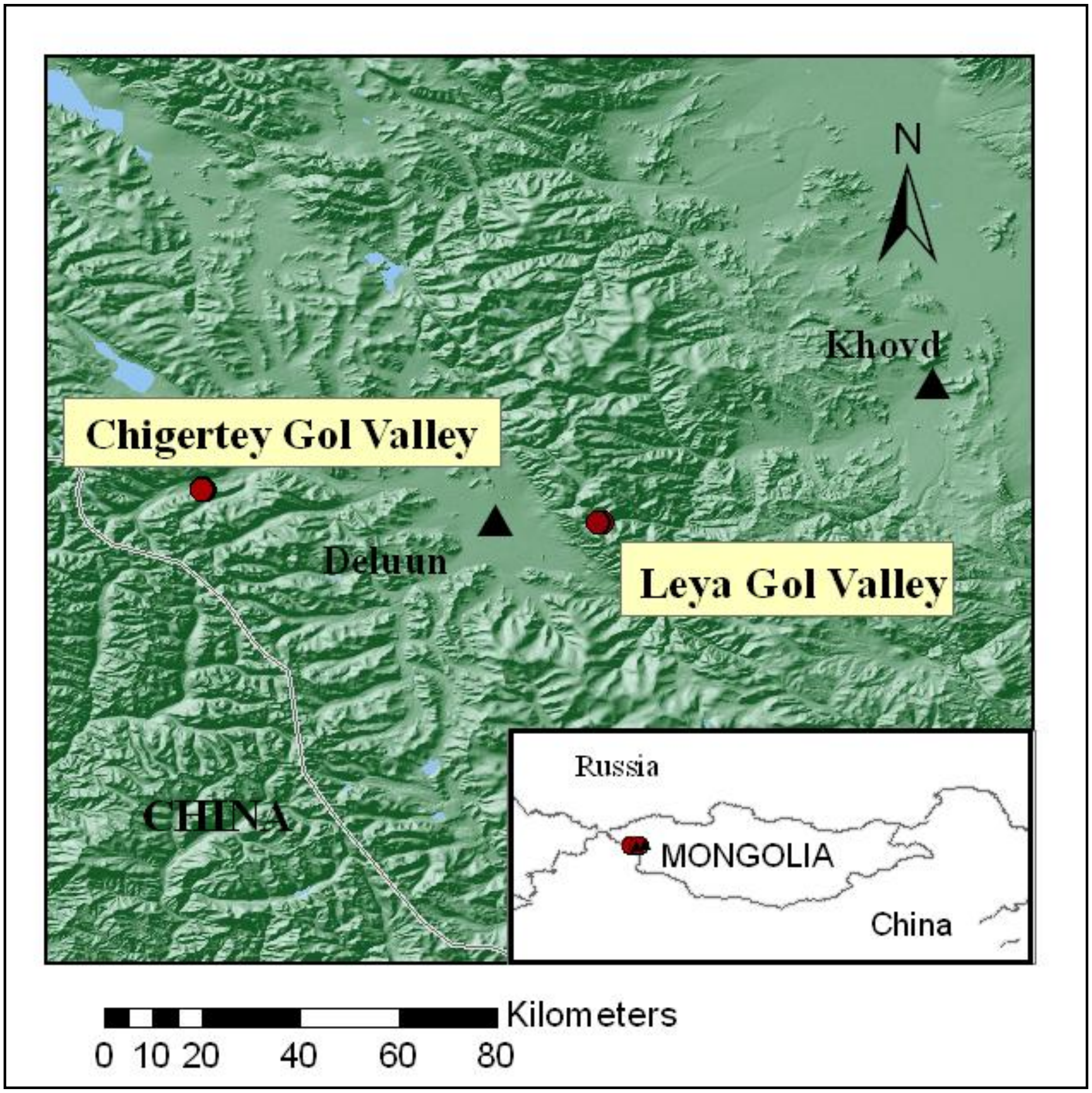


Figure 1: Shaded relief map of Mongolia and larch stands in Chigertey Gol Valley (47.833ºN, 90.313ºE) and Leya Gol Valley (47.77ºN, 91.036ºE) in the Altai Mountains, Western Mongolia. Red dots mark larch stands, triangles mark Delüün and Khovd meteorological stations.

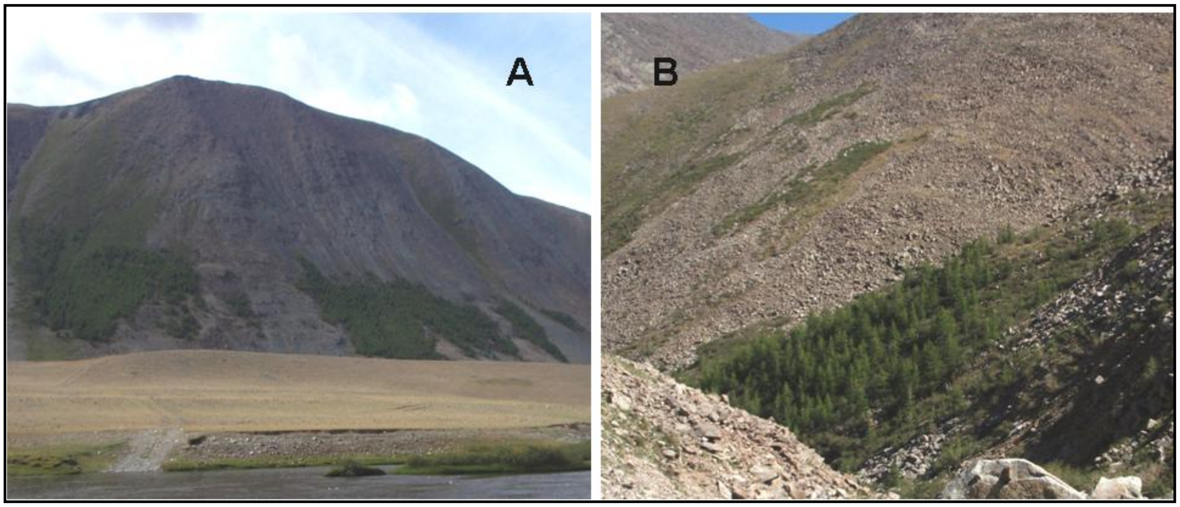
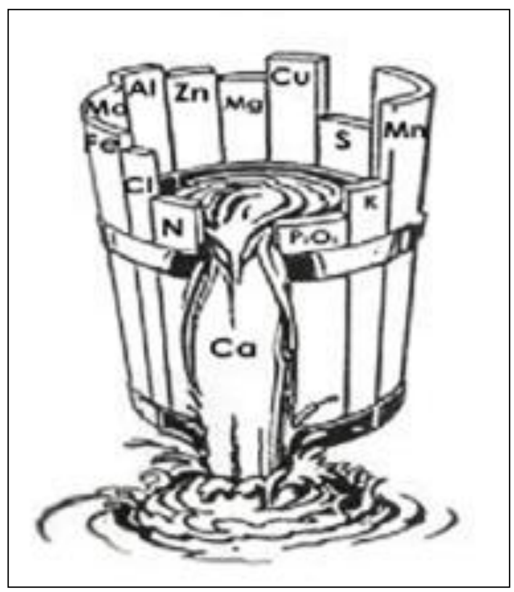


Figure 2: A) North-facing Siberian larch stand in Chigertey Gol Valley and B) Leya Gol Valley and the Altai Mountains of Western Mongolia. Field photos looking south and southeast.

Figure 3: A barrel analogy of Liebig's Law of the Minimum, stating that growth of biologic organism cannot proceed before its most limiting factor. In this example, the barrel of water cannot fill higher than the missing slate. For tree-rings, growth cannot occur faster than its most limited biologic factor, which can be internal (biologic) or external (climatic or environmental) (Fritts, 1976; Speer, 2007).



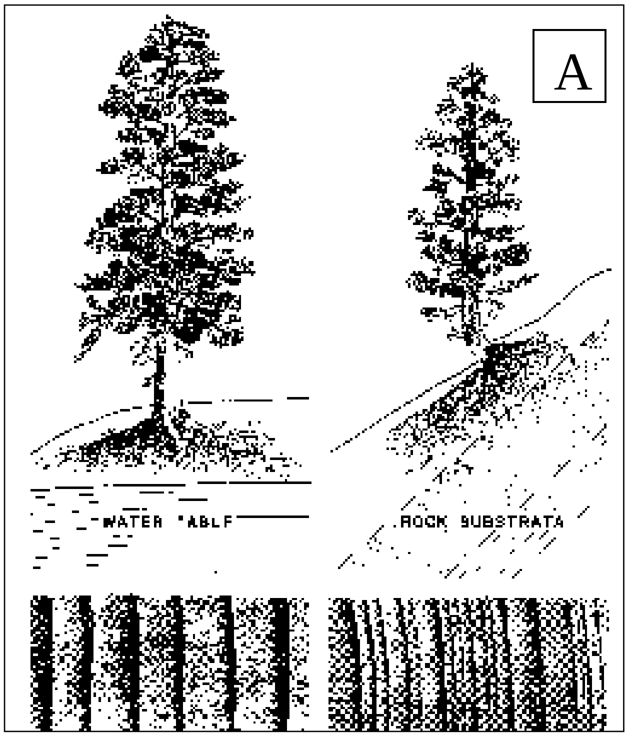
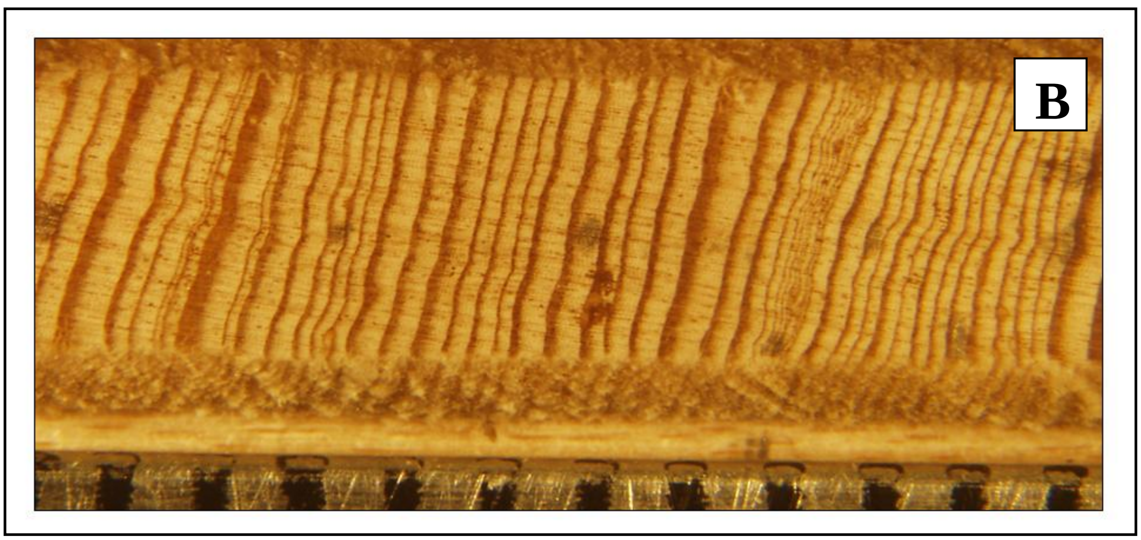


Figure 4: A) Example of different growing conditions that can produce complacent or sensitive tree-ring records. The trees in the picture are presumed to be water sensitive. The tree on the left has an unlimited supply of water (and complacent ring record) while the tree on the right is growing on a slope with an inconsistent supply of water, resulting in sensitive record. B) Photograph of a core Leya Gol (LG) Valley with a very sensitive record (mm scale at base).



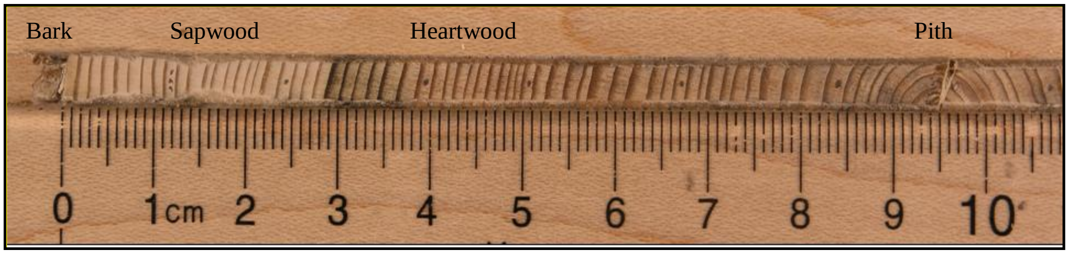


Figure 5: Photograph is of a mounted and sanded tree core from bark to pith taken from the upslope side of a tree in Chigertey Gol (CG). Light portion of core behind core is known as sapwood and the dark portion is known as heartwood.

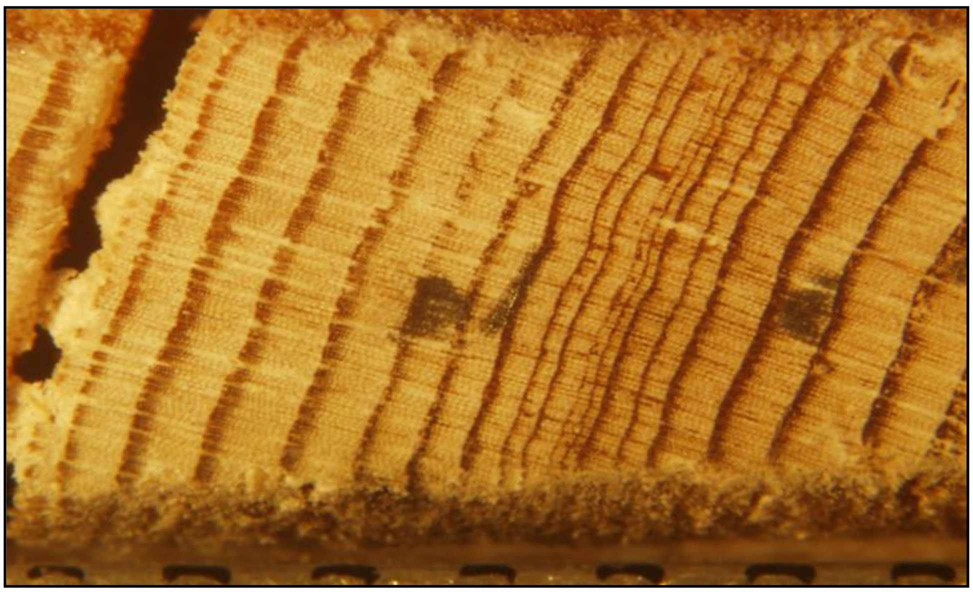


Figure 6: Core in Leya Gol (LG) Valley stand showing interannual ring width variation and perpendicular wood rays (conduits of nutrient transport).

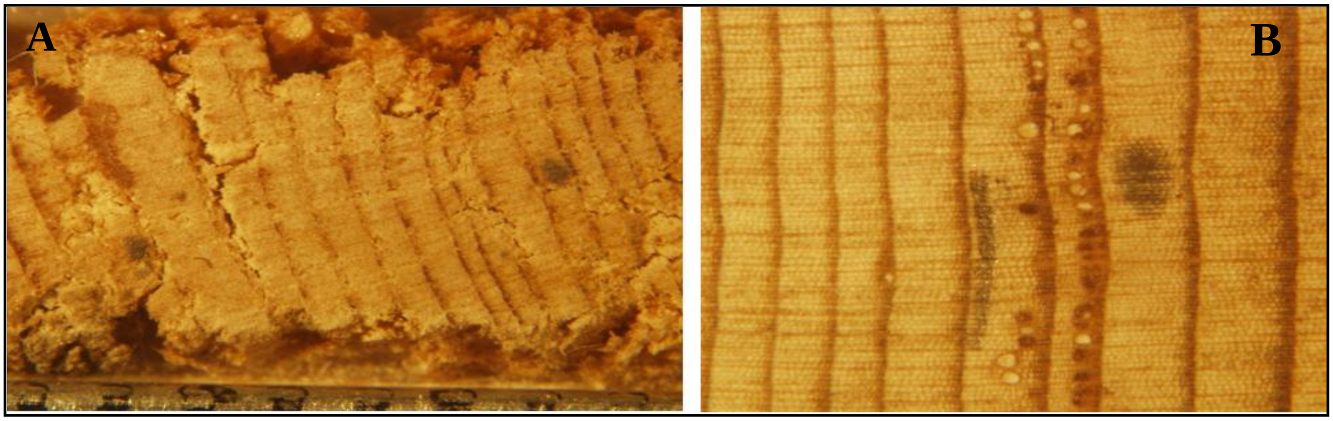


Figure 7: A) Example of heart rot and B) clustered resin ducts.

Regional Setting

Mongolia is a land locked country within continental Asia nestled between Russia and China and spanning the latitudes and longitudes of 30 to 45º N and 40 to 50º E, (Fig 1). The majority of Mongolia lies above an elevation of 1500 m and because of its continental location, experiences the long cold winters, and short but warm and monsoonal summers characteristic of a semi-arid continental region. The lack of regulating bodies of water makes the country a place of extremes. Temperatures in the Altai Mountains in particular average between -30º C in the winter and 15º C in the summer, with large diurnal fluctuations (Gunin, 1999). Annual mean precipitation in the Altai and other mountainous regions range from 300 to 400 mm, with other regions receiving considerably less (Batima, 2005). Mongolia also has a very diverse ecological biome with the Gobi Desert to the south, a dry-steppe zone to the east, a forest-steppe belt to the north, and a very heterogeneous ecology in the Altai Mountains. This large range of ecological diversity in the Altai is a result of the interference of circulation cells by rugged topography. High mountains, forest, forest-steppe, dry-steppe, and desert all exist within the Altai (Gunin, 1999).

One important atmospheric circulation system operating within Mongolia is the Siberian High Pressure Cell which controls much of the variation in the country's weather patterns. The Siberian High is centered over the country during the winter and spring, creating very cold and dry conditions (Pederson et.al., 2005). In the summer, this high pressure cell shifts northward which leads to the onset of the summer monsoons as a high pressure system is swapped for a low pressure system originating from the Pacific (Fan et al., 2008). Other regional climate systems that have been suggested to influence the country's climate include the North Pacific High, El Nino-Southern Oscillation (ENSO), and the East Asian and Indian Monsoons (Pederson, 2001).

Recent Climate

Although these large scale atmospheric circulation patterns are responsible for the overall climatic regime in the region, recent climate changes are also affecting Mongolia. For example, an average annual temperature increase of 1.6º C since 1940, a three year drought from 1999 to 2002, more severe winters (locally known as *dzud*-a winterized natural disaster resulting in multitudinous human and livestock casualties), and a compromised permafrost layer have all been reported (Batima, 2007; Morinaga et al., 2003). In order to place these changes in a broader context, paleoclimate records from different locations within the country are needed to temporally and spatially extend the climate record into the past. These reconstructions can then provide insight into whether present climate change is within the normal range of variability or part of a larger temporal trend as a result of anthropogenic activity and may help constrain the nature and range of future climate change.

Previous Climate Reconstructions

Published paleoclimate reconstructions of Mongolia were produced as early as 1970. However, most of this work was conducted by Russian and Mongolian scientists who published in their respective languages making access to results difficult. Most of the studies utilized pollen data to reconstruct the vegetation history of the area within the Pleistocene and Holocene, and unfortunately, they also suffer from poor age control (making correlations and interpretations difficult). A brief reinterpreted summary of these pollen studies by Gunin (1999) suggests that the Early Holocene (10,000 to 8,000 yr B.P) was colder and drier than today and that the Middle Holocene (8,000 to 4,000yr B.P.), was warmer and wetter as vegetation reached its maximum, but shifted to the cooler, drier present-day conditions in the Late Holocene (4,000 to 2,000 yr B.P.).

Beginning in 1995, a group called MATRIP (Mongolian-American Tree-Ring Project) began a concerted effort to reconstruct climate for different regions of Mongolia using tree-ring records. Jacoby et al. (1996) first sampled trees in the Tarvagaty Mountains located in Central Mongolia. This study utilized north-facing, upper tree-line Siberian pines at elevations of 2400-2500m. These particular trees were chosen to isolate temperature climate signals within the tree-ring record for upper timber-line trees. D’Arrigo et al. (2000), who also sampled in the Tarvagaty, Hangay, and Altai Mountains, chose to sample temperature sensitive Siberian larches and pines at upper tree-line and developed a chronology that dates back to AD 262. The results from both studies produced similar temperature reconstructions for central and western Mongolia with cooling in the early 1700's and late 1800's, and warming in the late 1700's and 1900's. The coldest period in the 1800's is from 1852-1876, and is interpreted as the Little Ice Age maximum. The warmest periods occurred in 1974-1993. In both studies, carry-over effects from the previous growing season were a factor in current year growth, but did not account for significant variation in growth signals.

Other MATRIP sponsored studies such as Jacoby et al. (1999), Pederson et al. (2001), and Davi et al. (2006), sampled trees from lower tree-lines where precipitation is presumed to be the dominant limiting growth factor in north and central regions of Mongolia. These three studies observed a modest increase in precipitation since 1940. However, the results were not profound and were found to be in the realm of normal variations. As opposed to temperature reconstructions, tree-rings with precipitation as the limiting control factor show stronger signals in regards to spectral analysis and solar induced climate oscillations. In all three studies, the following climate oscillations were observed: 2-year wind and precipitation oscillations, 4 and 8-year ENSO (El Nino-Southern Oscillation), 16-19-year lunar nodal, and 22-24 year solar nodal (Hale Magnetic Solar Cycle), and 35-50-year PDO (Pacific decadal oscillation). These tree-ring records also showed a high carry over signal from the previous year which accounted for more variation than did the temperature reconstructions.

A study conducted in the Wrangell Mountains of Alaska (Davi et al. 2003), utilized maximum latewood densities as well as tree-ring widths from upper tree-line White Spruce to reconstruct regional continental climate for the past four centuries. Their results showed positive correlation of summer (July, August, and September) temperatures with their maximum latewood density chronology. This, as well as previous work done by Schweingruber (1993) and Fritts, indicates that density rather than tree-ring width is a more accurate proxy for summer temperatures. Panyushkina et al. (2005) have also shown through comparison of tree-ring widths and weather station data that Siberian Larch chronologies from the Russian Southeast Altai are most likely responding to June and July temperatures. The results from the Davi et al. (2003) chronology show overall trends similar to those found by D'Arrigo and Jacoby with some discrepancies in the 1700's: cold in the 1600, warming in the early 1700's, cooling in the late 1700's, severe cooling in the 1800's, and extreme warming in the 1900's.

Stratton (2007) studied tree-rings in the Hangay Mountains of central Mongolia. Stratton sampling mostly upper tree-line Siberian larches at elevations of ~2500m on North-facing slopes. The oldest sampled tree from this study dated back to 1388 A.D., the second oldest record in Mongolia. The climate signal expressed by her trees however, were highly variable within and between sites. Stratton hypothesizes that her trees are controlled predominantly by precipitation based on their North-facing orientation, but are extremely sensitive to local influences. Though she was not able to reconstruct past precipitation, the chronologies successfully exhibited oscillations, with the most prominent being a 54-57 year periodicity associated with the Pacific Multidecadal Oscillation.

STUDY SITES

Chigertey Gol Valley

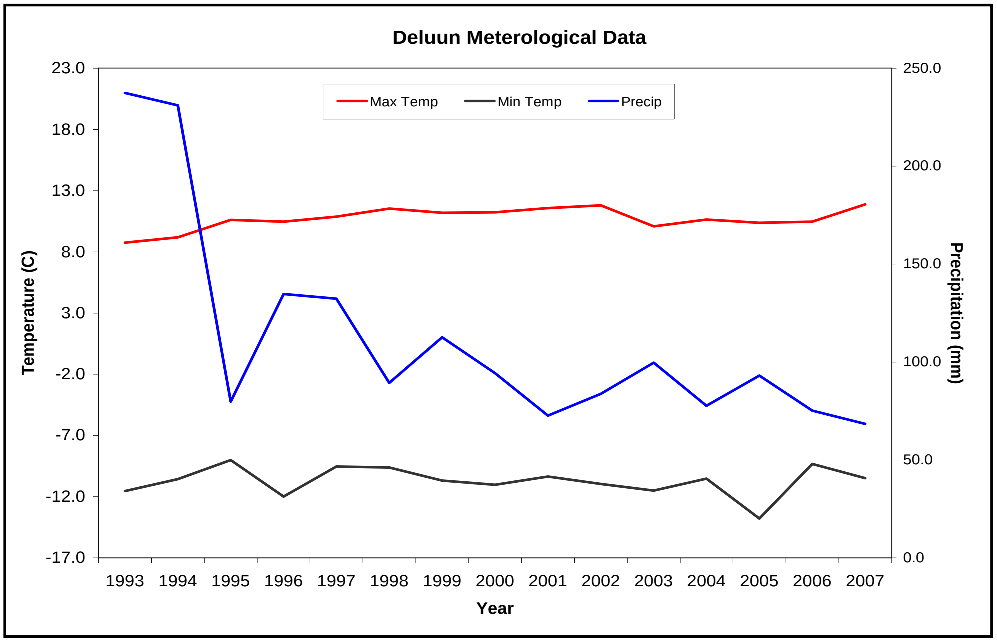
Two Siberian larch stands were sampled in the Altai Mountains of Western Mongolia. The first site is located within Chigertey Gol (CG) Valley (N47º49’59.2”, E90º18’47.6”), a wide, U-shaped glacial valley located about 30 km west of the town of Deluun, Mongolia (Fig 1 & 2). A shallow but wide river runs along the floor of this valley, approximately 100 m below lower tree line. This larch stand occurs on the North-facing slope of the valley on a green phyllite substrate, and contains a minor willow (*Salix)* population. The mean elevation of the stand is 2560 m, with the lower tree line at 2413 m and the upper tree line at 2875 m. The diameter at breast height ranged from 14 cm to 48 cm, with a mean of 29 cm. Trees were approximately 6-10 m in height and had a density population of about 1.5 mature trees per 2 m^2. Trees exhibited significant heart rot at this location which made obtaining a complete core to the pith difficult, though this did not negatively affect sample processing.

Leya Gol Valley

The second sampled larch stand in Leya Gol (LG) Valley (N47º46', E91º02') is also located on the North-facing slope of a narrow valley, suggesting that the trees are less moisture sensitive due to the typically cooler and moister conditions (Fig 1 & 2). The mean elevation of this site is 2590 m, with the lowest cored tree at 2472 m and the upper tree line at 2628 m. Tree diameter at breast height ranged from 29 to 49 cm, with an average of 38 cm. The ecology of this stand is slightly different from the CG site in that the willow (*Salix)* population is much more abundant (even dominant) at the base of the stand which came in contact with the banks of the small river flowing along the valley floor and the larch population density was sparse in comparison to Chigertey Gol Valley at approximately 1 mature tree per 5 m^2 at ~6-10 m in height on average. Heart rot is less significant at this location.

Local Climate

Local temperature and precipitation data is available for the Delüün (N47º, E90º) and Khovd (N48º, E91º) weather stations beginning in 1993 and 1937, respectively (Fig 8 & 9) (IMHM, 2008). The Delüün station is located approximately 30 km from both stands, and Khovd is about 50 and 100 km east of the LG and CG stands, respectively (Fig 1). Temperatures from both locations show a consistent seasonal pattern from year to year. The highs and lows for Khovd and Delüün reach 20º C and 15º C in the summer, and drop to about -30º C and -35º C in the winter. Precipitation varies between the two locations, and from year to year, due in part to the mountainous topography and climatic periodicities. The majority of the total precipitation occurs during the summer months (May to September) but varies annually (Fig 10). Annual temperature variation stays fairly consistent with the hottest months being June through August, and the coolest being December through February (Fig 10).



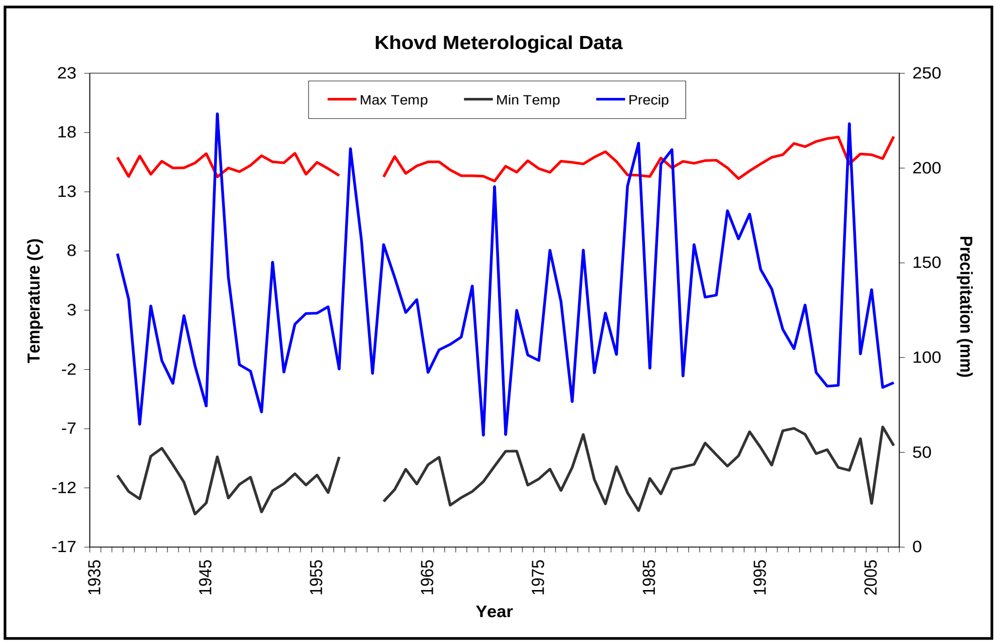


Figure 8 and 9: Graphs of mean annual temperature and precipitation from Deluun (N47º, E90º) and Khovd (N48º, E91º) meteorological stations. Records begin in 1993 and 1937, respectively.

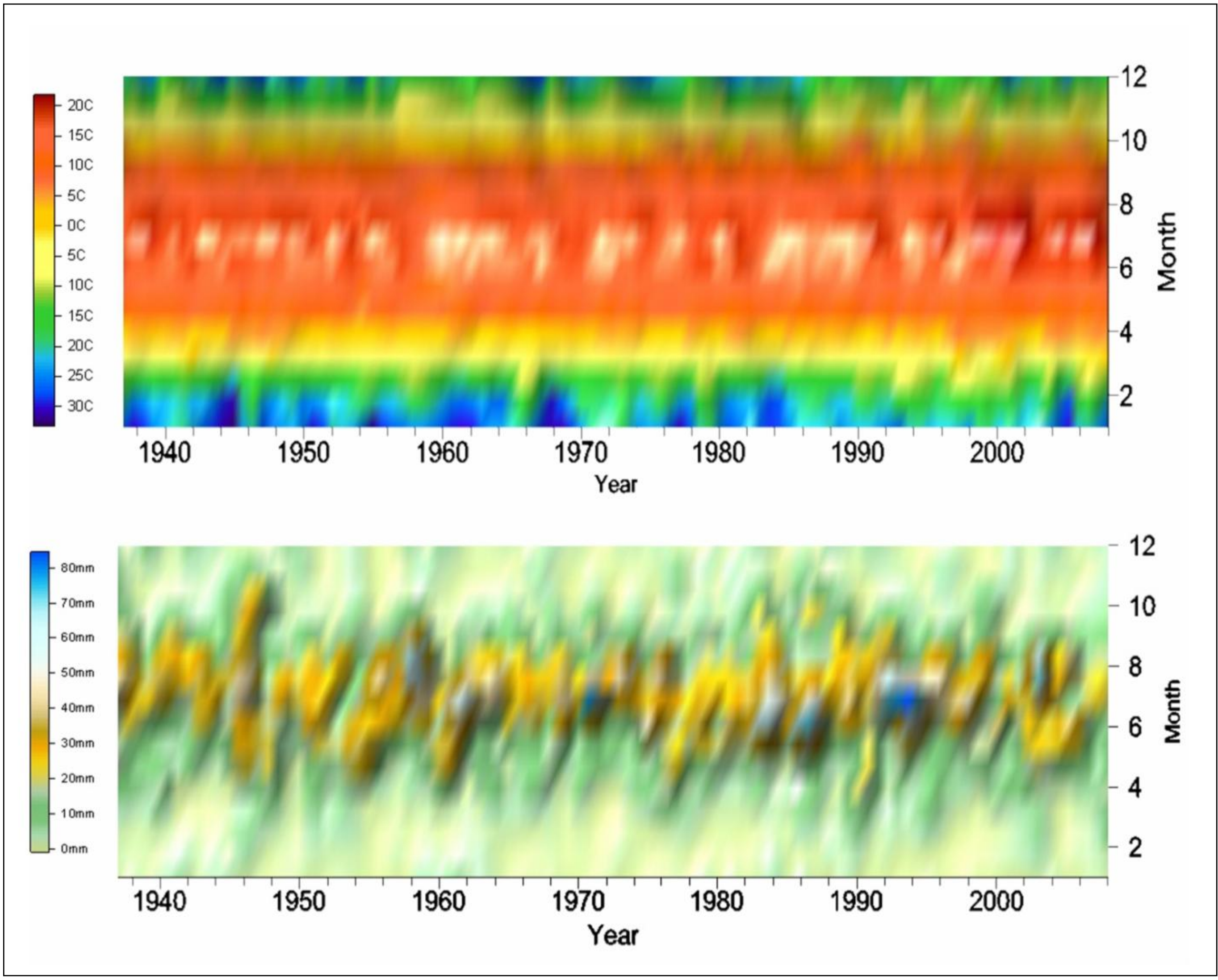


Figure 10: 3-Dimensional representation of seasonal and monthly temperature and precipitation variation from Khovd meteorological station (N48º, E91º). Top graph displays average monthly temperature, bottom graph displays average monthly precipitation.

METHODS

FIELD

Thirty-four increment cores from twenty-three living trees were retrieved from Chigertey and Leya Gol (CG and LG) Valleys in the Altai Mountains of Western Mongolia in July of 2008 (Fig 1). Study sites were selected based on availability and accessibility and within a stand, trees were chosen based on size and lack of growth deformation (multiple heads, evidence of logging). Trees were sampled from lower tree line to upper tree line, and back down again with the use of an increment borer (Fig 11a). Cores were taken approximately 1.5 m up from the base of the tree from the upslope side of the trunk and were stored in plastic straws for transport back to the lab (Fig 11 a & b). At each sampled tree, a GPS waypoint and circumference measurement was taken with a measuring tape.

LAB

Recovered cores were air dried and mounted with Elmer's all-purpose glue onto wooden mounting blocks (with a .5cm grooves) with the cell structures of the cores oriented vertically. The cores were sanded flat (but not flush) with progressively finer-grit sand paper (320 to 1500) according to methods outlined by Stokes and Smiley (1968) and Fritts (1976). The list method, which is essentially careful examination and manual counting of the cores, was employed to mark 10, 50, 100, 1000-year intervals and to locate indictor rings with unique growth patterns within each core (Speer, 2007). Tree-rings for each core are measured with a stereomicroscope mounted above a Velmex Unislide. The Velmex Unislide is a sliding microscope stage that tracks the distance between each annual ring boundary with 0.001 mm precision. These measurements were recorded by MeasureJ2X software on an adjacent computer.

COFECHA

Once measured, raw ring measurements were cross-dated using the Dendrochronology Program Library (DPL) software program, COFECHA, to verify the quality of measurements, isolate anomalous ring patterns, and to determine correlation within and between sites (Grissino-Mayer, 2008; Fritts, 1976; Speer, 2007). COFECHA software creates a master chronology based on the mean ring width of the cores being cross dated, known as a ring index value. The master is derived from the first core listed in the file that is inputted in COFECHA. Care needs to be taken to ensure that a well counted core is not being cross dated to a poorly counted core. For this reason, comparison to already established master chronologies from other studies is essential. Once you have determined which cores are accurately dated, then you can rely upon those cores as the basis for your master chronology.

Well measured and poorly measured cores which either agree or disagree with the master ring width pattern are demarcated by a series intercorrelation number. The series intercorrelation number is a Pearson's correlation coefficient representing the common stand-level signal expressed by each core when compared to a master chronology of standardized ring widths, known as ring indices. The threshold of a positive correlation number within tree-ring cross-dating is 0.3281 (Cofecha, 2008; Speer, 2007). Any number below that is flagged as unable to cross-date with the master, and any number above that number is being positively cross dated at 99% confidence level. Mean sensitivity is a parameter of year-to-year variability, with 0 indicating no variability in annual ring width and 0.4 indicating great variability between annual rings; such as record would be very difficult to cross date. But a record that displays a mean sensitivity of 0.2 or above is considered to have enough sensitivity to be viable for climate reconstruction (Speer, 2007; NOAA, 2009).

Cross dating in COFECHA is accomplished by comparing 50-year segments of the core with a 25-year overlap to other cores. Since trees were cored from living trees, their records all end at the year 2007. All the cores overlap for this first 50-year segment and then begin to drop out as the records goes further back in time until all that is left is the longest core. Each year is assigned a ring index value which is based on how the width of that particular year compares with the width of that year in the master. If the width is above average, it will have a value higher than 1. If the width is below average, it will have a value below 1. Based on the value assigned to that year, you can observe just how far the width of that year deviates or is in agreement with the master chronology. If it is in agreement, it will have a ring index value of 1 and will contribute to a higher intercorrelation number. For this reason, series intercorrelation and ring indices can be utilized to isolate missing rings or identify a poorly measured core.

Sufficient correlations in COFECHA are necessary before proceeding with detrending and statistical climate analysis because it ensures that the tree-rings are correctly dated and anomalous ring patterns have been addressed. Series intercorrelations in cross dating are important within dendroclimatology because it confirms that there is a common stand-level climate signal controlling tree growth rather than ecologically localized conditions. COFECHA is an extremely powerful and absolutely critical tool in dendrochronology, but first-time users be warned, the program has been described as opaque with a steep learning curve (Larry Winship and Karl Wegmann, personal communication). After cross-dating, ring measurements can then be edited using another software program from DPL called EDRM (Grissino-Mayer, 2008). With this program, ring measurements can be inserted, deleted, or re-measured to eliminate tree-specific variation and increase the series intercorrelation.

ARSTAN

Once correlated, raw ring width measurements require further refinement before they can be confidently used in climate reconstructions. One refinement is the removal of age-related growth trends. Early growth rings established at the beginning of a tree's life are often wide because the diameter of the sapling tree is small, so the amount of tissue produced is spread over a smaller area. As the tree ages and the diameter of the tree increases, rings typically become more narrow because the same amount of tissue is meant to covers a larger area (Fritts, 1976; Schweingruber, 1989). For this reason, a detrending curve is fit to a series of cores that removes the natural age-related growth pattern. This is accomplished with the computer program ARSTAN, which aggregates individual cores producing three statistically corrected chronologies that remove high frequency variation associated with biological processes and enhance low frequency variation associated with climatic influences (Fig 13; Grissino-Mayer, 2008).

The ARSTAN program yields three chronologies: the standard, residual, and arstan chronology. The standard chronology is the average of the tree-ring indices determined by the standardization curve, which in this case is a linear regression curve that has been autocorrelated. The residual chronology has no autocorrelation and displays deviations from the mean of the observed sample set. The arstan chronology has a reintroduced stand-level autocorrelation that can be related to climate. The arstan chronology was not actively engaged in order to control the climatic parameters introduced (Speer, 2007).

Climate correlations and reconstructions

Once the raw measurements have been evaluated, correlated, and detrended, the resulting tree-ring composite chronologies can be correlated to existing tree-ring chronologies and climatic data (Bradley, 1999; Schweingruber, 1989). Correlations were made in excel with multiple climatic parameters, such as temperature, precipitation, Kherlen river streamflow, SOI, PDO, and Sunspots using a simple linear regression analysis (Pederson et al., 2001; NOAA: Climate Prediction, NGDC, JISAO). Correlations above an R-value (or Pearson's coefficient) of 0.32 and below -0.32 were highlighted to display positive and negative correlations. Regression analysis was then applied to the positively correlated climatic data and the tree-ring chronologies to determine the statistical significance of the parameter on tree-ring growth, which was interpreted by way of R, r^2, and p-values.

The final steps in tree-ring analysis are calibration and verification of the climatic data with the tree-rings, known as response function analysis, and last but not least, climate reconstruction (Bradley, 1999). Reconstruction is achieved by applying the equation from the regression analysis to the tree-ring measurements not already associated with instrumental data to yield a reconstructed climate proxy time-series. The equation is also applied to the tree-ring measurements already associated with instrumental data to verify the quality of the reconstructed climate data against the actual instrumental data. This is quantified through regression analysis of the reconstructed data with instrumental data to ensure the statistical significance is still intact.

Figure 11: A) Using an increment borer in the upslope side of a Siberian larch in CG Valley, Western Mongolia. B) Extracted core being placed in a plastic straw for protection and transport.

```
****************************************
 *C* Number of dated series        32 *C*
 *O* Master series 1583 2008  426 yrs *O*
 *F* Total rings in all series   5534 *F*
 *E* Total dated rings checked   5534 *E*
 *C* Series intercorrelation     .580 *C*
 *H* Average mean sensitivity    .294 *H*
 *A* Segments, possible problems   14 *A*
 *** Mean length of series      172.9 ***
******************************************
```

Figure 12: Brief number summary of correlations taken from a COFECHA output file for all cores from both Leya Gol and Chigertey Gol Valley. Includes number of cores being cross dated, total number of years and rings, the correlation number, and the mean sensitivity.

```
PART 2:  TIME PLOT OF TREE-RING SERIES:                  10:18  Thu 23 Apr 2009  Page   2
--------------------------------------------------------------------------------------------
1500 1550 1600 1650 1700 1750 1800 1850 1900 1950 2000 2050 Ident     Seq Time-span  Yrs
   :    :    :    :    :    :    :    :    :    :    :    :  -------- --- ---- ---- ----
   .    .    .    .    .    .    .<==================>    .  7240812a   1 1814 2007  194
   .    .    .    .    .    .    .<==================>    .  7240812b   2 1813 2007  195
   .    .    .    .    .    .    .  <================>    .  7240811a   3 1832 2007  176
   .    .    .    .    .    .    .<==================>    .  7240811b   4 1814 2007  194
   .    .    .    .    .    .    .    <==============>    .  7240811c   5 1850 2007  158
   .    .    .    .    .    .    .  <================>    .  72408-6b   6 1828 2008  181
   .    .    .    .    .    .    .    .   <==========>    .  72408-6a   7 1892 2007  116
   .    .    .    .    .    .    .    .    .  <======>    .  72408-1    8 1928 2008   81
   .    .    .    .    .    .    .    .    . <=======>    .  72408-8    9 1924 2007   84
   .    .    .    .    .    .    .    .    <=========>    .  7240813a  10 1900 2007  108
   .    .    .    .    .    .    .    .    <=========>    .  7240813b  11 1902 2007  106
   .    .    .    .    .<============================>    .  7240810b  12 1712 2008  297
   .    .    .    .    .    .    .    .   <==========>    .  72708-9   13 1892 2007  116
   .    .    .    .    .    .    .  <================>    .  7240815A  14 1831 2007  177
   .    .    .    .    .    . <======================>    .  7240815B  15 1768 2007  240
   .    .    .    .    .    .    .    .   <==========>    .  240814aU  16 1891 2007  117
   .    .    .    .    .    .    .    .   <==========>    .  240814aD  17 1891 2007  117
   .    .    .    .    .    .    .    .   <==========>    .  240814bU  18 1889 2008  120
   .    .    .    .    .    .    .    .<=============>    .  7240810a  19 1860 2007  148
   .    .    .    .    <=============>.    .    .    .    .  7240810c  20 1704 1842  139
   .    .    .    .    .    .    .    .   <==========>    .  72708-8   21 1886 2008  123
   .    .    .    .    .    .    .    .   <==========>    .  72708-7a  22 1887 2008  122
   .    .    .    .    .    .    .    .    <=========>    .  72708-7b  23 1902 2008  107
   .    .    .    .    .    .    .    .    .  <======>    .  72708-6   24 1928 2008   81
   .    .    .    .    .    .    .    .    .   <=====>    .  72708-5   25 1943 2008   66
   .    .    .    .    .    .    .    .    .  <======>    .  72708-4   26 1930 2008   79
   .    .    .    .    .    .    .    <==============>    .  72708-3U  27 1847 2008  162
   .    .    .    .    .    .    .    <==============>    .  72708-3D  28 1847 2007  161
   .    .  <=========================================>    .  72708-2U  29 1583 2007  425
   .    .  <=========================================>    .  72708_2D  30 1583 2007  425
   .    .    .    . <================================>    .  72708-1b  31 1671 2007  337
   .    .    .  <====================================>    .  72708-1a  32 1626 2007  382
```

Figure 13: Time plot from COFECHA output file with all cores from CG and LG Valley being cross dated. The core id# is listed, the years that particular cores spans, and the total number of years within each core. All cores start at the year 2007 (because they were taken from living trees) and extend variously back in time.

```
240814aD  1891 to  2007     117 years                                                       Series  17

[A] Segment   High  -8    -7    -6    -5    -4    -3    -2    -1    +0    +1    +2    +3    +4    +5    +6    +7    +8
   ---------  ----  ---   ---   ---   ---   ---   ---   ---   ---   ---   ---   ---   ---   ---   ---   ---   ---   ---
   1950 1999    0  -.05   .05 -.21 -.11   .10   .04   .01 -.25   .30*-.20   .08 -.04   .11   .09   .02 -.03   .02
   1958 2007    0   .01   .10 -.29 -.13   .05   .07 -.08 -.25   .31*-.18    -     -     -     -     -     -     -

[B] Entire series, effect on correlation (  .546) is:
      Lower   1995< -.027   1994> -.019   1900< -.019   1969> -.009   1927< -.009   1897< -.008
      Higher  1933  .125   1898  .014
    1950 to 1999 segment:
      Lower   1995< -.039   1994> -.021   1969> -.019   1955< -.016   1996< -.013   1973> -.012
      Higher  1959  .053   1965  .033
    1958 to 2007 segment:
      Lower   1995< -.046   1994> -.026   1969> -.020   2004< -.017   1973> -.013   1970> -.013
      Higher   1959  .055   1965  .032

[C] Year-to-year changes diverging by over 4.0 std deviations:
      1932 1933  -4.6 SD

[E] Outliers     1   3.0 SD above or -4.5 SD below mean for year
      1994 +5.0 SD
```

Figure 14: Cross dating information for individual core from a COFECHA output file. Sample number is in upper left hand corner. Segment lengths are 50-years with 25-year overlap. The numbers in the column are the correlation numbers. An asterisk next to a number higher than 0.32 (the approved intercorrelation number) indicates the highest possible correlation. If the 0.32 is at 0, it is cross dating well. If it falls in the negative section, rings need to be added; in the positive field, rings need to be taken away.

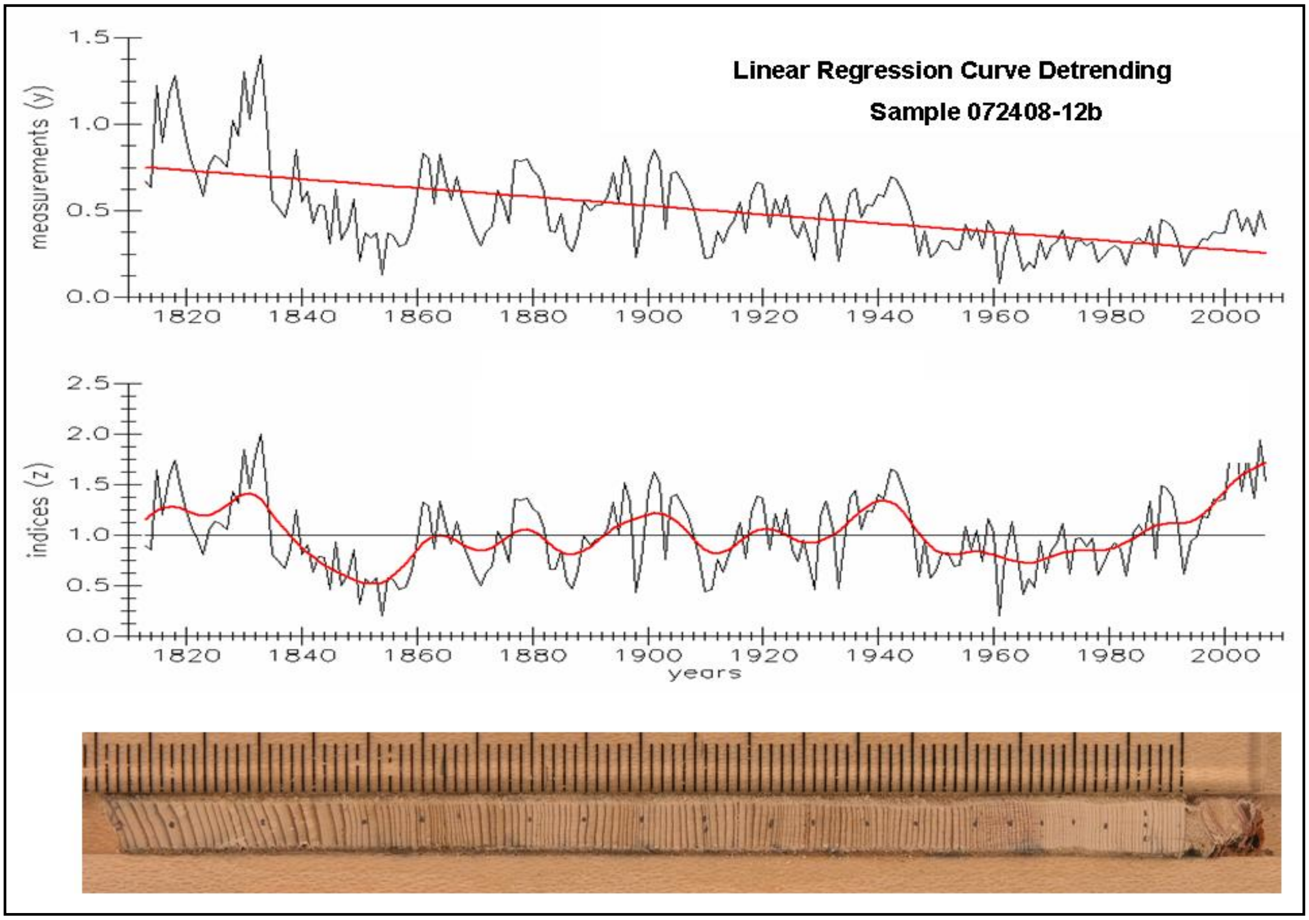


Figure 15: Example of linear regression detrending in ARSTAN on sample 072408-12b (pictured below) from Chigertey Gol Valley. Top graph plots raw ring width measurements with linear regression line. Bottom graph plots detrended ring width indices with running curve. Sample 072408-12aU below with cm ruler for scale. Core is approximately 10 cm long, with bark end is on the right. Black pencil marks delineate each decade.

RESULTS

Cross dating with COFECHA

Chigertey Gol stand produced a 296-year chronology containing 20 cores (series) from 11 trees (Fig 20). Leya Gol stand produced a 425-year chronology from 12 series and 8 trees (Figs 16). Series intercorrelation for the LG stand is 0.618 with a mean sensitivity of 0.300. The CG cores have a series intercorrelation of 0.601 and a mean sensitivity of 0.290. Combined, these sites correlate at 0.573 with a mean sensitivity of 0.296. Both of these larch stands also positively correlate with chronologies from previous studies conducted in Mongolia, some of which are: Khlazan Khama (N49º, E91º), Horin Bugatyin Davaa (N49º, E94º), and Hovsgol Nuur (N50º, E100º) (Jacoby et al., 1999; D'Arrigo et al., 2000, respectively). The series correlations and mean sensitivity for each of these sites with trees from this study are 0.633, 0.527, 0.516 and 0.326, 0.298, 0.245, respectively.

Growth detrending in ARSTAN

The cross dated chronologies produced from CG and LG valleys were individually input into the DPL program ARSTAN. Each chronology was fit with a conservative linear regression detrending line. The runs for each chronology yielded a raw, standard, residual, and arstan chronology. Each chronology has a 20-year running mean. The CG and LG chronologies were also combined into one chronology since they also positively correlated with each other in

COFECHA . Aggregating the two chronologies into one provides a higher sample depth of cores meaning higher number of overlapping cores and attempts to give the data a more regional, less localized character to the data (Fig 24).

<u>*Leya Gol Valley*</u>

The raw ring width chronology for the LG site begins in 1583 and shows above average growth between 1720 and 1800, after which growth drops below the average for the 1800's except for a little respite in the 1830's (Fig 16). Beginning in the 1900's, ring indices increase progressively above average for the duration of the record (until 2007). The standardized chronology (which averages all the growth measurements of each core for a particular year) alters the original growth pattern found in the raw chronology (Fig 16). Rather than below average growth until the 1900's, growth fluctuates above and below the average for the earliest 200 years of the record and generally runs along the mean for the later 200 years of the record. The only major anomaly is a decrease in growth around 1884 and 1866. Notice that sample depth is most likely a factor with the values in these chronologies, with sample depth decreasing dramatically around 1800 and 1850.

The residual chronology, which documents sample deviation from the observed sample mean, shows no obvious outliers (Fig 17). There is some minor deviation in the beginning of the record, above and below the average, as well as the end of the record with above average growth. However, none of these exceed

.25 mm. This confirms that the chronologies are not being significantly skewed in any particular direction based on outlier measurements for a particular core. The arstan chronology is a chronology that has a reintroduced autocorrelation associated with climate. This chronology will not be actively considered because of lack of control of the climatic parameters.

The running Rbar and Expressed Population Signal (EPS) examine the signal strength and the common variability within a chronology (Fig 18). The Rbar averages correlations with 100-year windows with 50-year overlaps and is a measure of common signal strength of the aggregated cores (Speer, 2007). EPS measures common variability or variation in signal within a chronology in relation to sample depth. A predetermined EPS value of 0.85 is the cutoff for chronology confidence (Speer, 2007; Davi et al. 2002). If a chronology drops below this level, sources suggest truncating the record. However, this value should be interpreted loosely since it is dependent on sample depth.

The error bars in the Rbar graph show that the average correlation in both the raw and the residual chronology contain much variation, suggesting that a weak common signal may exist between the trees within the LG stand (Fig 18 & 19). The EPS value is also struggling to stay above the predetermined coherency level in the raw series, and fluctuates above and below the level in the residual series (Fig 18 & 19).

Chigertey Gol Valley

The CG chronology begins in the year A.D.1704 (Fig 20). The raw CG chronology shows a spike in above average growth at the beginning of the record until about 1765, after which growth is consistently below average until the 1900's. The final noticeable change in growth pattern is around 1950's, when growth begins to increase above the average. Unlike the standard chronology for the LG stand, the CG standard retains the same basic growth patterns throughout the record, only with less deviation from the mean throughout the 1800 and 1900's (Fig 20). Again, note that the sample depth for CG stand is minimal for the years prior to 1800 (Fig 20).

There are no major deviations in the residual chronology, again indicating that there are no anomalous cores negatively influencing the final chronologies (Fig 21). The EPS value for raw and residual data for CG Valley is above the predetermined 0.85 value until about 1860, with some variation after this point as a result of decreased sample depth (Fig 22 & 23). The Rbar graphs show the variability in common signal strength with error bars, which has a much smaller range than the LG stand indicating a stronger common signal (Fig 22 & 23).

Combined Chronologies

The combined chronology of these two sites produces, as expected, a chronology with a combination of growth patterns found in each of the independent chronologies (Fig 24). In the raw chronology, the 1600's and early

1700's show below average growth levels, with ring indices of about 0.3 mm. Growth in the late 1700's and 1800's is around average, and increases to above average beginning around 1890. The first 200 years in the standardized chronology shows larger growth fluctuations that deviate above and below average (Fig 24). The latter 200 years of the growth record stays consistently at average growth (Fig 24). This is most likely a function of sample depth, in that many more cores are being averaged in the latter 200 years. The residual chronology for both the LG and CG sites show some minor variation in growth from the mean in the early portion of the record (Fig 25). The Rbar graphs show most variation in signal strength in the 1700's and early 1800's (Fig 26 & 27). And consistent with the sample depth, the EPS is strong in the later portion of the record (1850 to present) but diminishes in the early part of the record (Fig 26 & 27).

Correlations with Climate

The standard chronology from the combined LG and CG run showed correlation with June and August temperatures from Delüün meteorological station (R=0.383, 0.412) (Fig 28) and July temperatures from Khovd meteorological station (R=0.35) (Fig 29). Tree-rings also correlated with October and November temperatures from Khovd and Deluun (R=0.325, 0.418).

Precipitation had less consistent correlations between the two weather station locations. There were no significant correlations of the standard chronology with current or lag year precipitation for Khovd weather station. The Deluun precipitation records correlated with the CG standard chronology for July (R=0.476), and with the previous year's July precipitation (R=0.465). The combined standard chronology also correlates with previous year's May and August precipitation (R=0.384 and 0.471).

Among the climatic data, the standard chronology correlated with standardized anomalies in sea-level pressure (SLP) from Indonesia of the Equatorial Pacific Southern Oscillation (EQSOI) from September through November (R=0.370 to 0.384) (NOAA, Climate Prediction Center) (Fig 30).

<u>Regression Analysis with Climate</u>

Regression analysis of climate with the standardized chronology measures the statistical significance of the correlations found above. It quantifies the degree to which tree growth is controlled by any particular parameter, as well as the amount of variance in ring width explained by that parameter. The R-value is a correlation coefficient of linear dependence of the ring widths on the climate data in question. R^2 is a coefficient of determination that determines the "goodness of fit" and the amount of variance explained by the climatic parameter in question. The p-value represents the statistical significance of correlation between the two parameters, and n is the number of observations in the data set.

Regression of various climate parameters showed positive correlations of mixed statistical significance. The regression values for June through August temperatures from Deluun weather station and July temperatures from Khovd weather station are $R=0.437$ $r^2= 0.19$ $p<0.1$ $n=15$, and $R=0.35$ $r^2= 0.12$ $p<0.003$ $n=68$, respectively (Figs 28 & 29). Regression with previous year's precipitation from Deluun for the months of May and August show the following statistical values: $R=0.384$ $r^2=0.14$ $p<0.174$ $n=14$, $R= 0.099$ $r^2=0.009$ $p< 0.735$ $n= 14$, respectively. Regression values of Equatorial SOI Anomalies with tree-ring are: $R=0.42$ $r^2= 0.18$ $p<0.001$ $n=57$ (Fig 30).

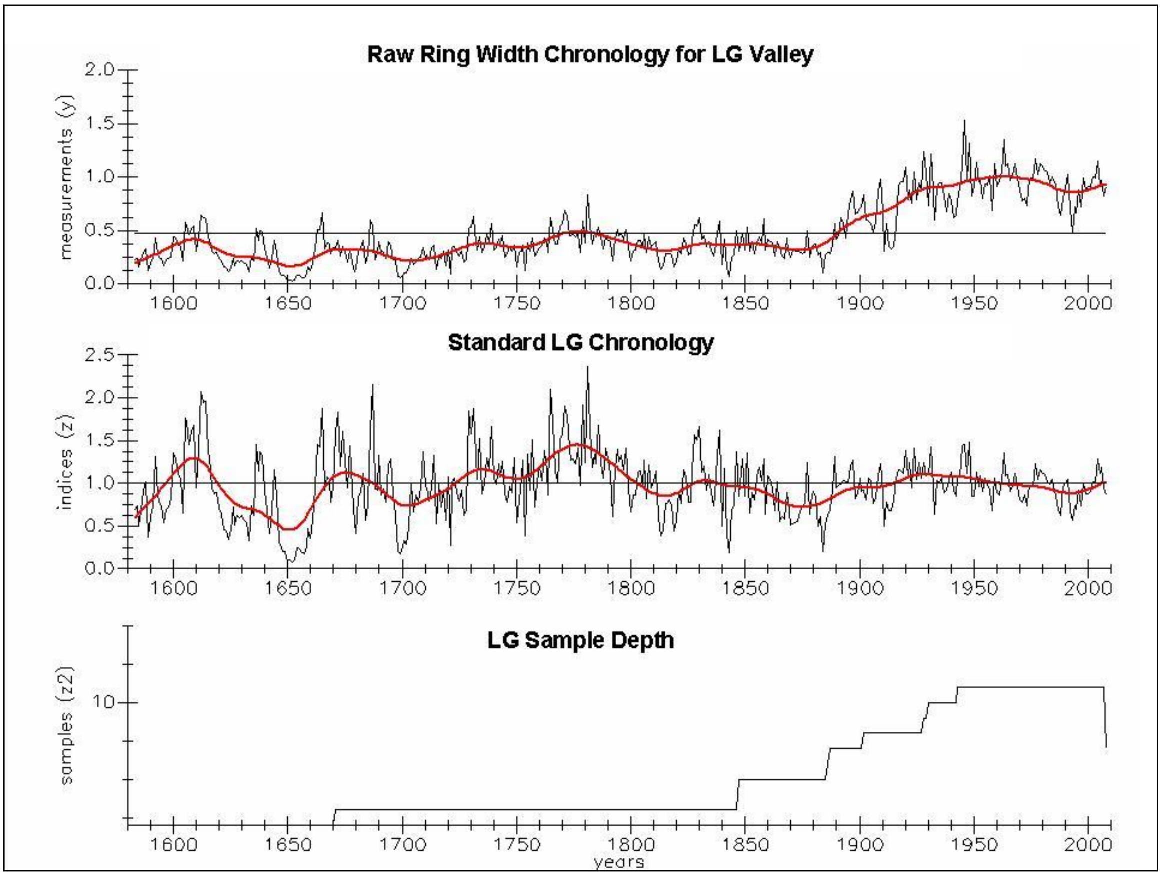


Figure 16: ARSTAN graphs of raw ring-width and standard chronology fit with a linear regression curve for Leya Gol (LG)Valley, Western Mongolia. Sample depth is the number of cores being averaged. Ring width and ring indices are in mm and sample depth is in numbers. The solid line is a 20-year running mean.

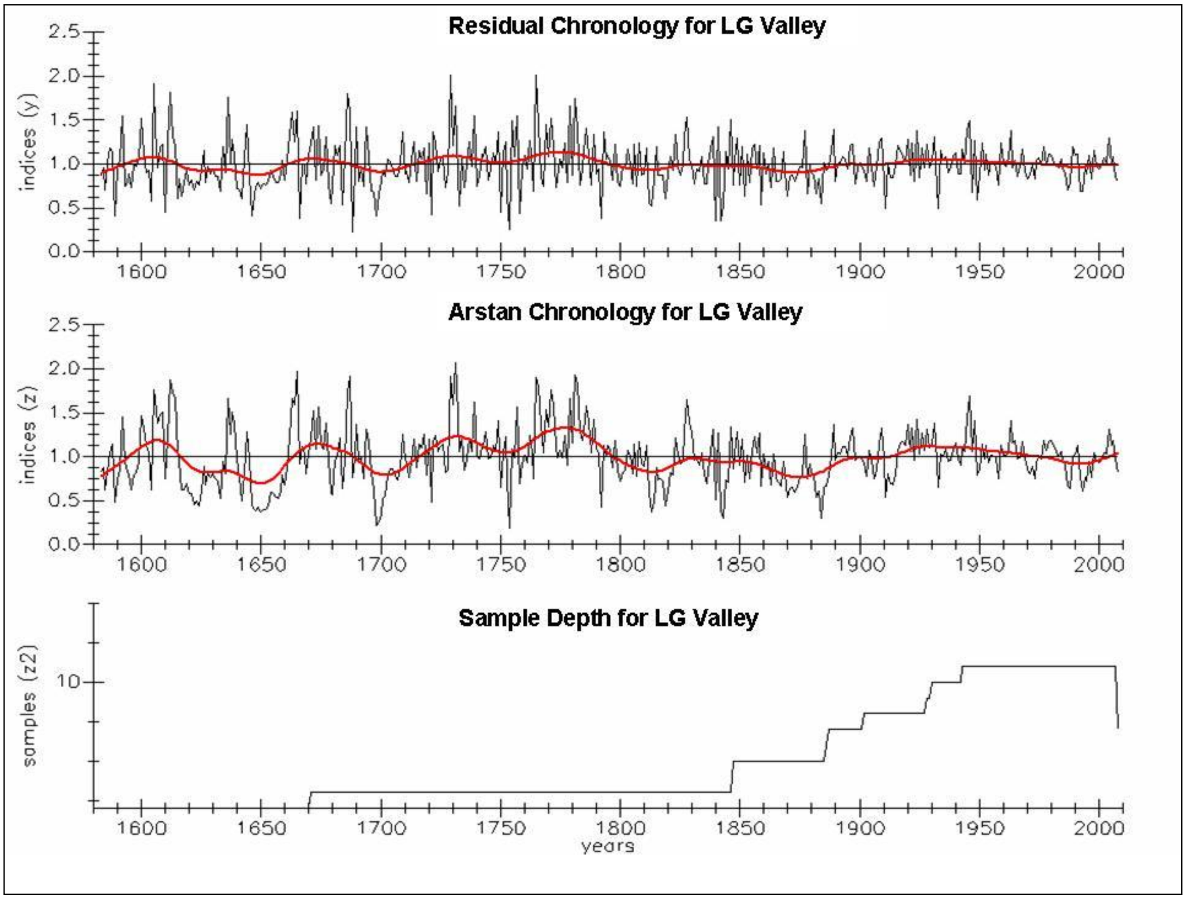


Figure 17: Residual and Arstan chronology graphs for Leya Gol (LG) Valley. Ring indices are all in mm and sample depth is in number of correlated tree cores. Red line is a 20-year running mean. Residual chronology is making sure there are no anomalous cores skewing the data and the arstan graph has reintroduced autocorrelation, but will not be considered here.

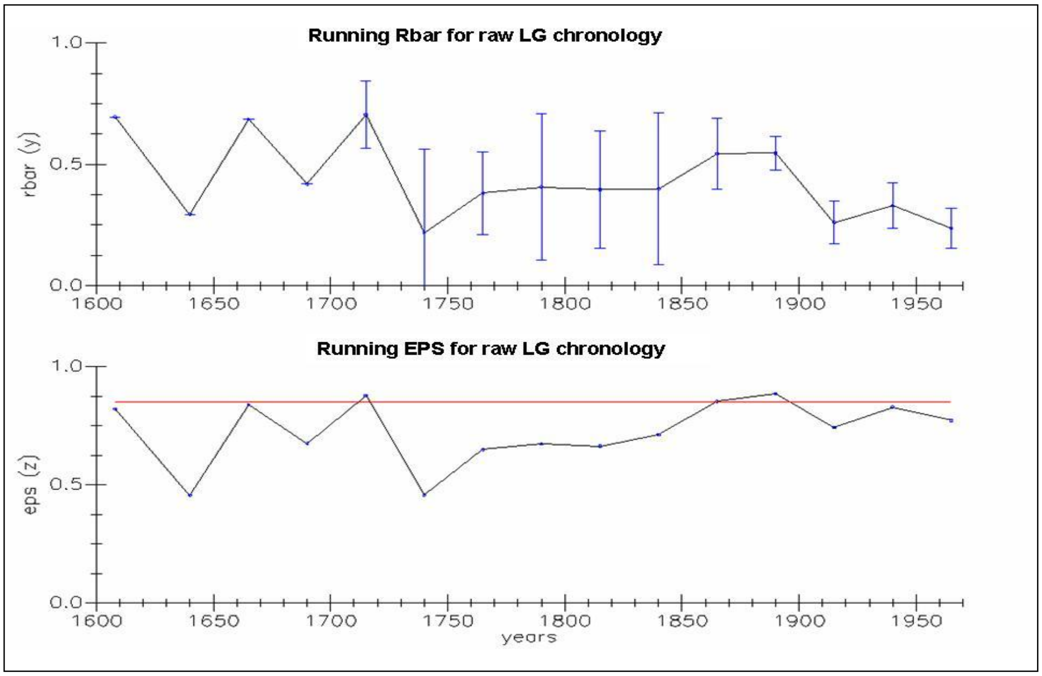


Figure 18: Rbar and EPS values for the raw LG chronology. Rbar shows the variation in limits of averaged correlation, represents the strength of a stand level climate signal expressed in the data. EPS is another measure variation based on a common signal within the chronology that is dependent on sample depth. The solid straight line at 0.8 is the "predetermined" value of a coherent signal.

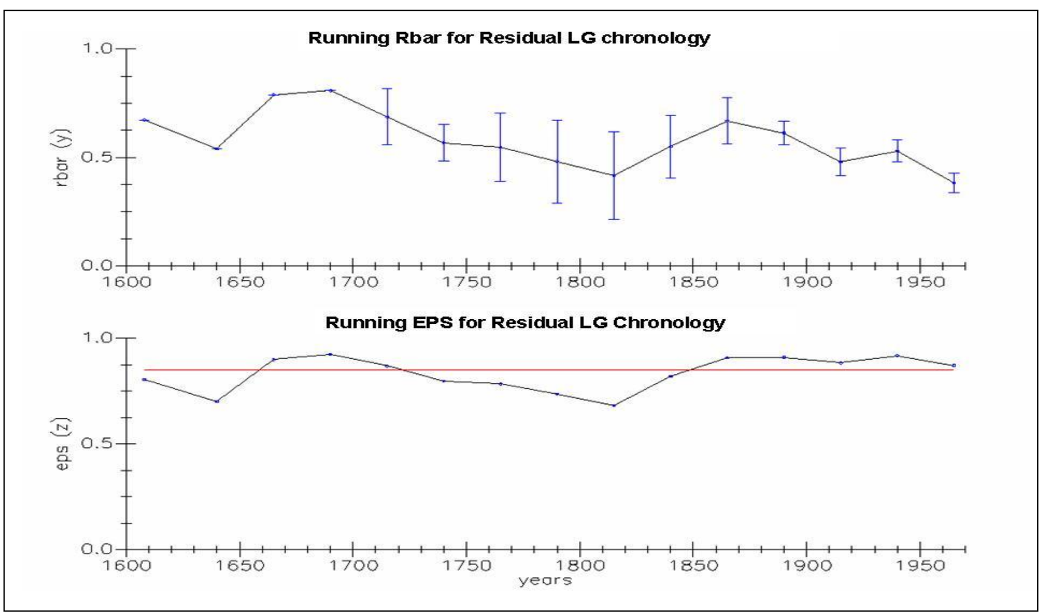


Figure 19: Rbar and EPS values for the residual chronology for LG Valley.

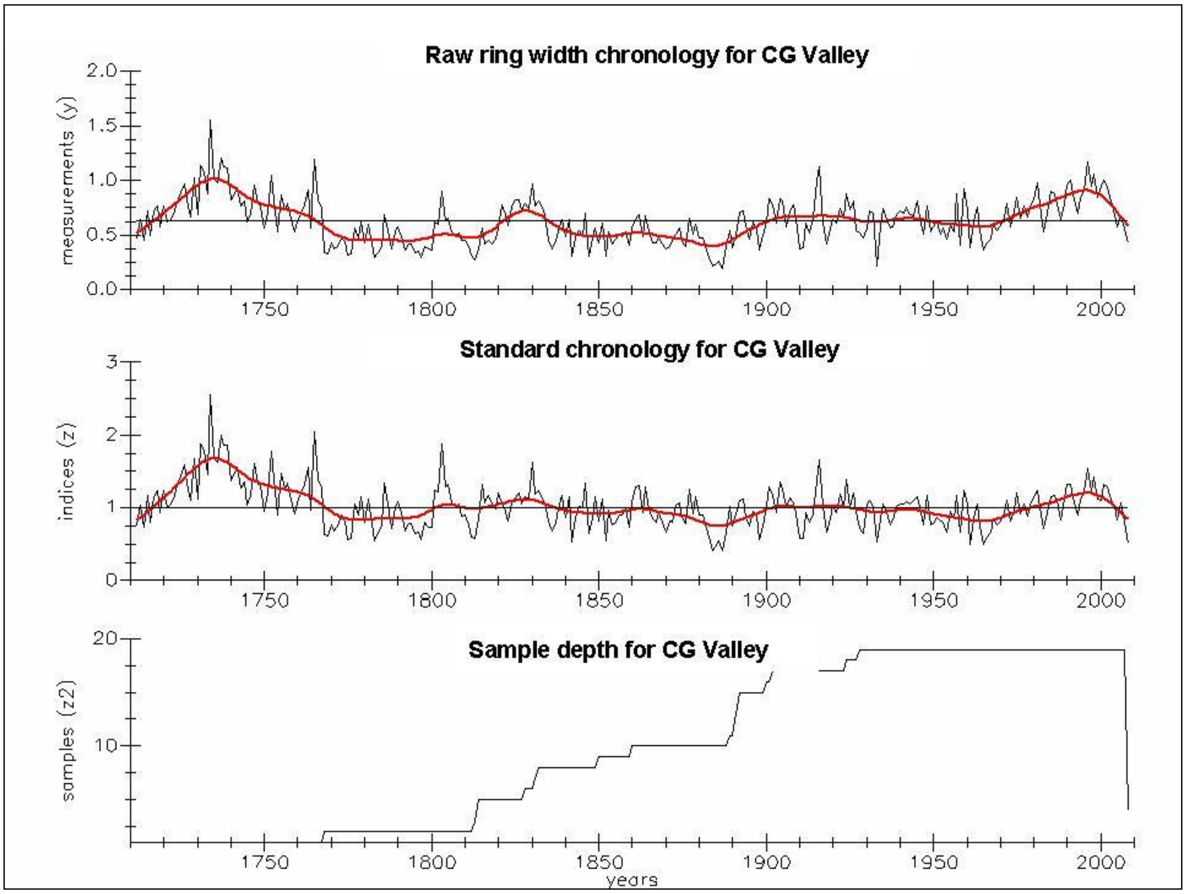


Figure 20: ARSTAN graphs of raw ring-width and standard chronology fit with a linear regression for Chigertey Gol Valley, Western Mongolia. Measurements and indices are in mm and sample depth is in numbers. The solid line is a 20-year running mean.

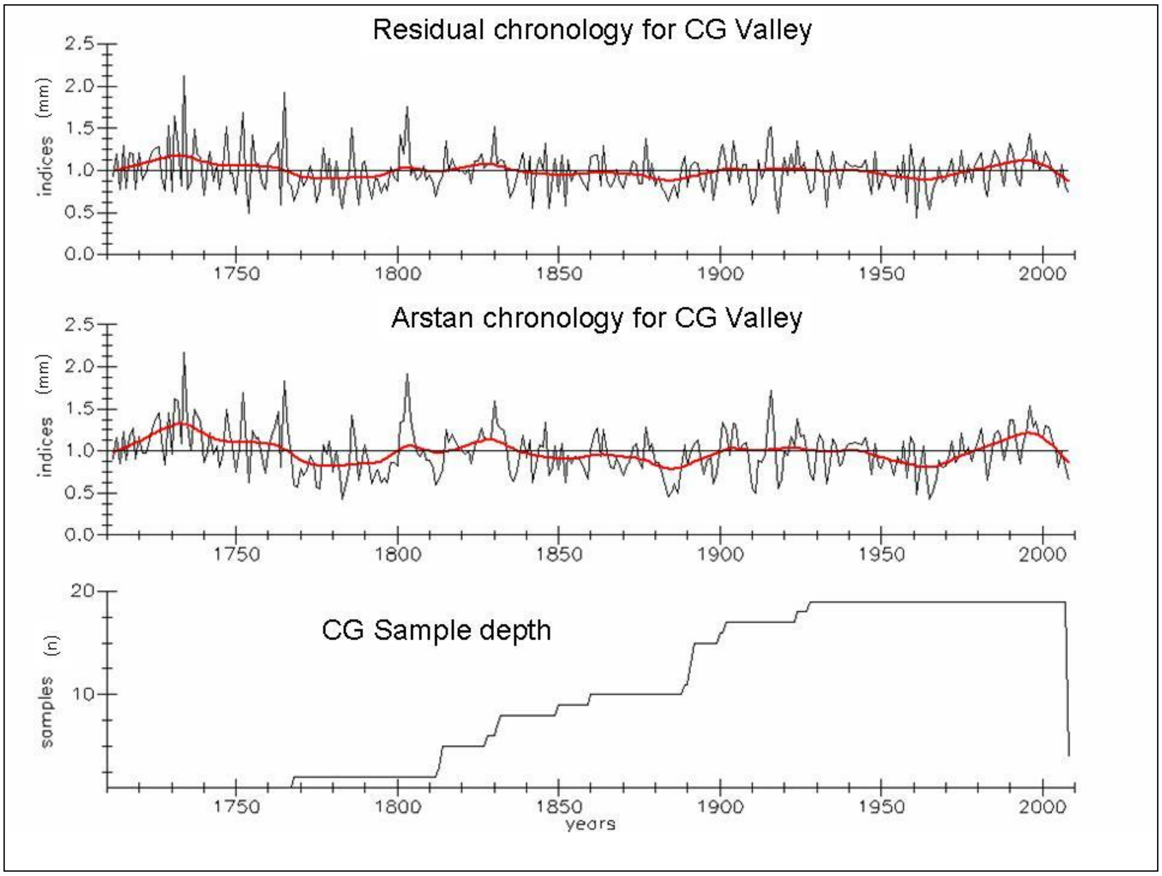


Figure 21: Graph of residual and arstan chronologies, as well as sample depth for Chigerety Gol Valley (CG). The residual chronology show how much ring indices deviate from a mean value of a 25-year segment. Arstan is not being actively considered because its reintroduced autocorrelation was not a function of climatic parameters from Mongolian meteorological data.

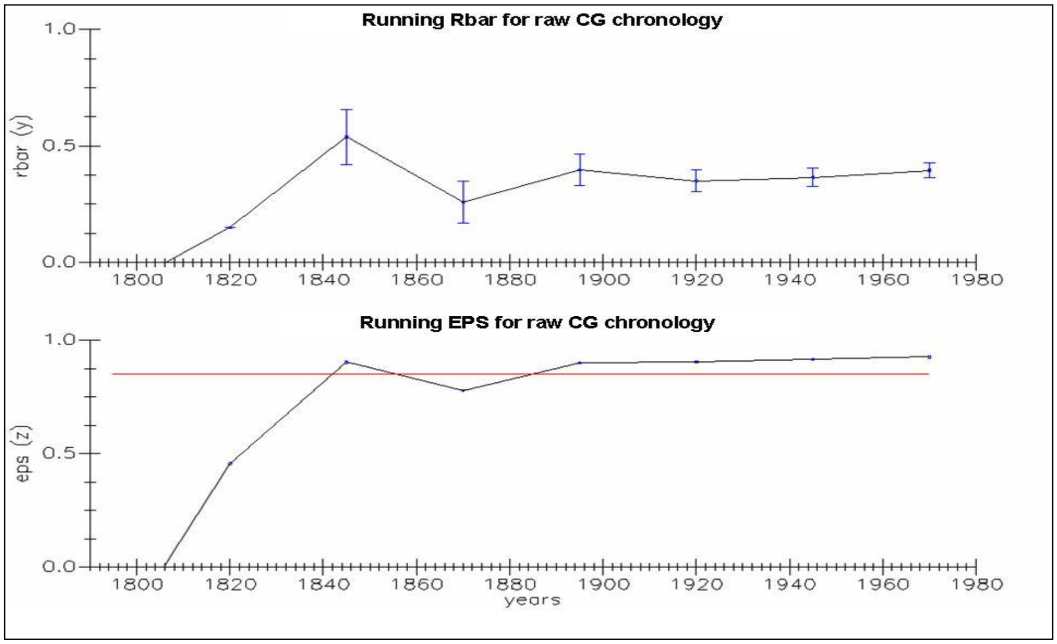


Figure 22: Running rbar and EPS for the raw CG chronology. Rbar displays the variation in signal strength, or upper and lower limits of averaged correlations in a 100-year window with 50-year overlap. EPS show common variability between cores, but is heavily dependent on sample depth.

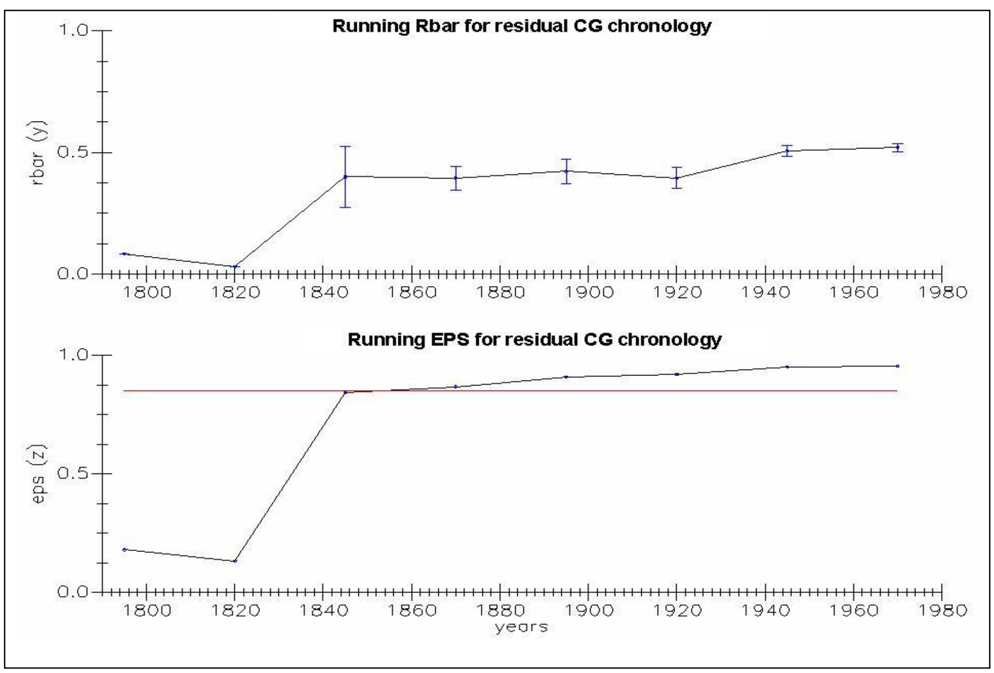


Figure 23: Rbar and EPS graphs for residual chronology for CG Valley.

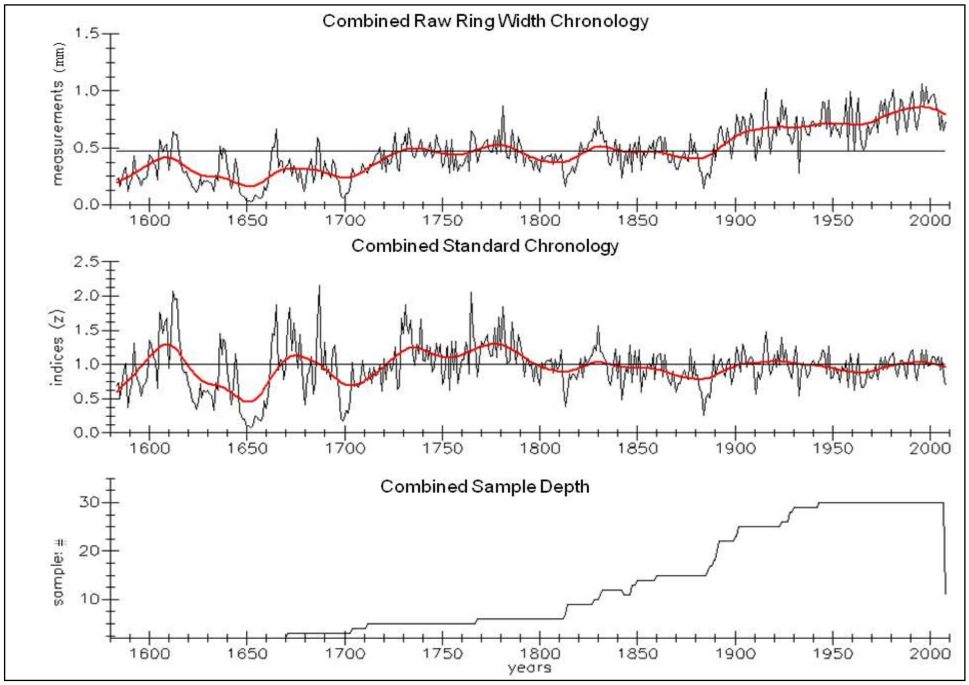


Figure 24: ARSTAN graphs of raw ring-width and standard chronology for both Chigertey Gol Valley and Leya Gol Valley combined. Measurements and indices are in mm and sample depth is the number of overlapping cores.

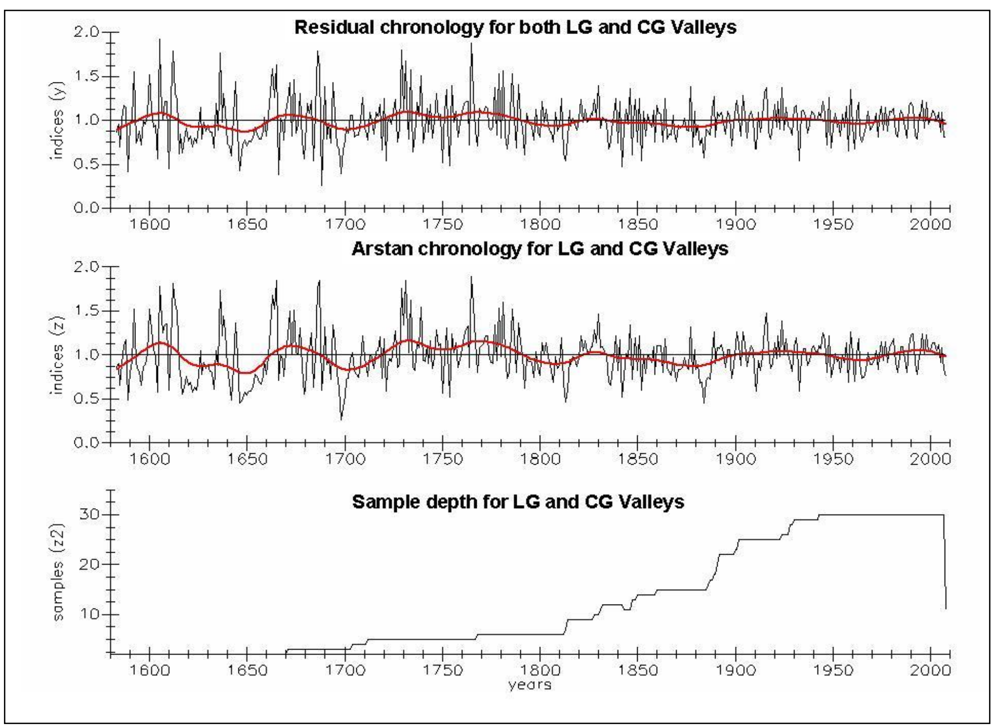


Figure 25: Residual and Arstan graphs for LG and CG Valleys combined.

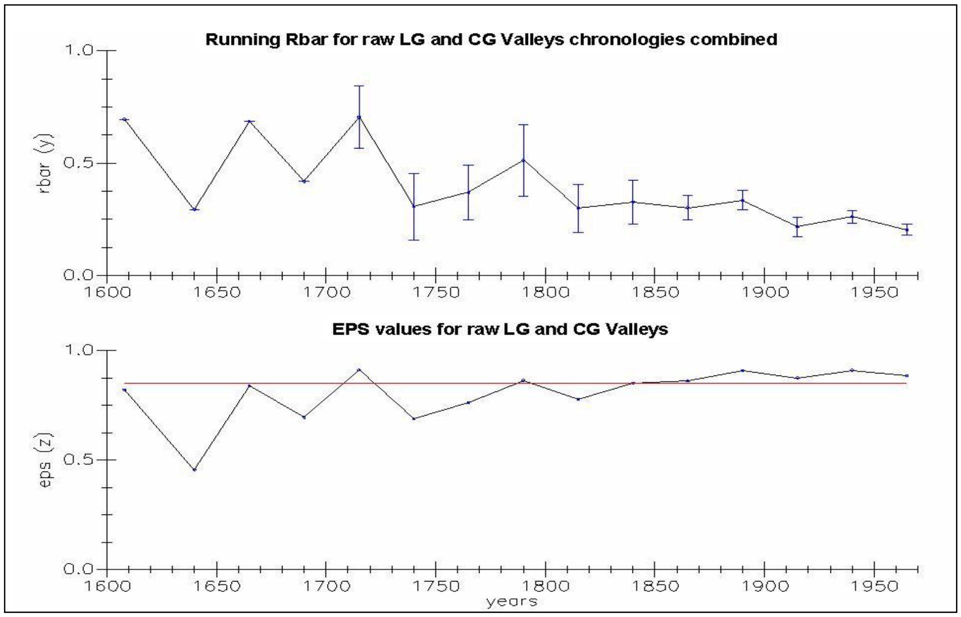


Figure 26: Rbar and EPS for the raw chronology of both LG and CG cores. Rbar show the upper and lower limits of the signal strength of averaged correlations in a 100-year window with 50-year overlap. EPS is the common variation. The straight line is the "predetermined" level of sufficient stand level signal.

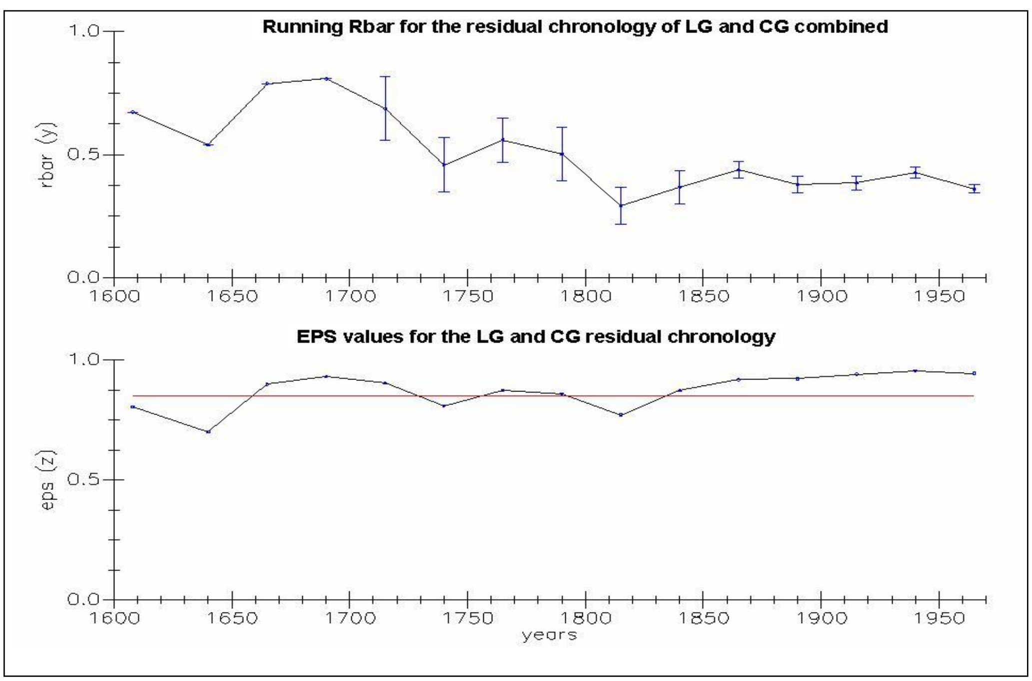


Figure 27: Rbar and EPS for residual chronology of LG and CG Valleys combined.

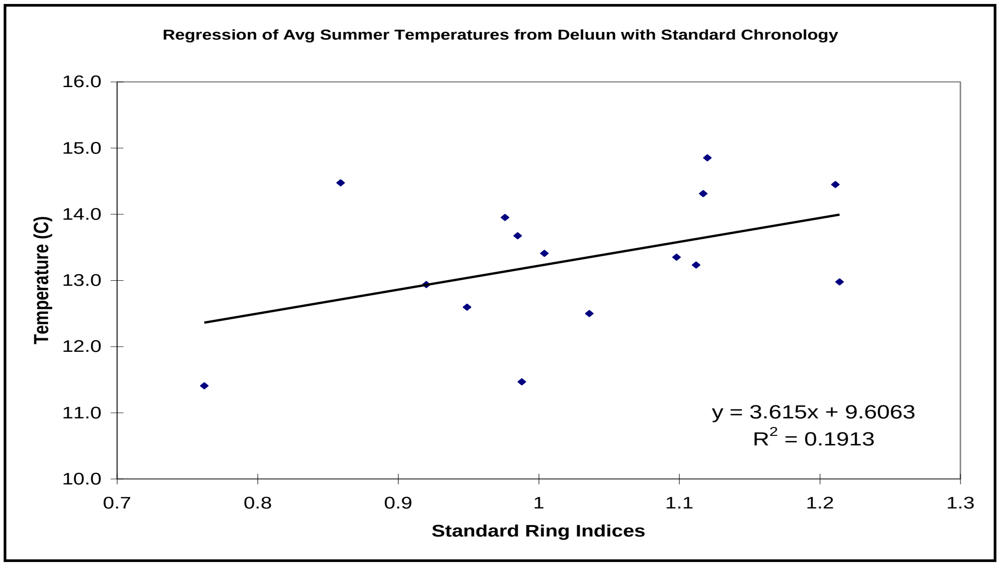


Figure 28: Regression scatter plot of the combined standard chronology against averaged Deluun Summer temperature. R^2 value is 0.19, explaining 19% of variance. However, number of observations (15) makes this climate parameter unreliable for reconstruction.

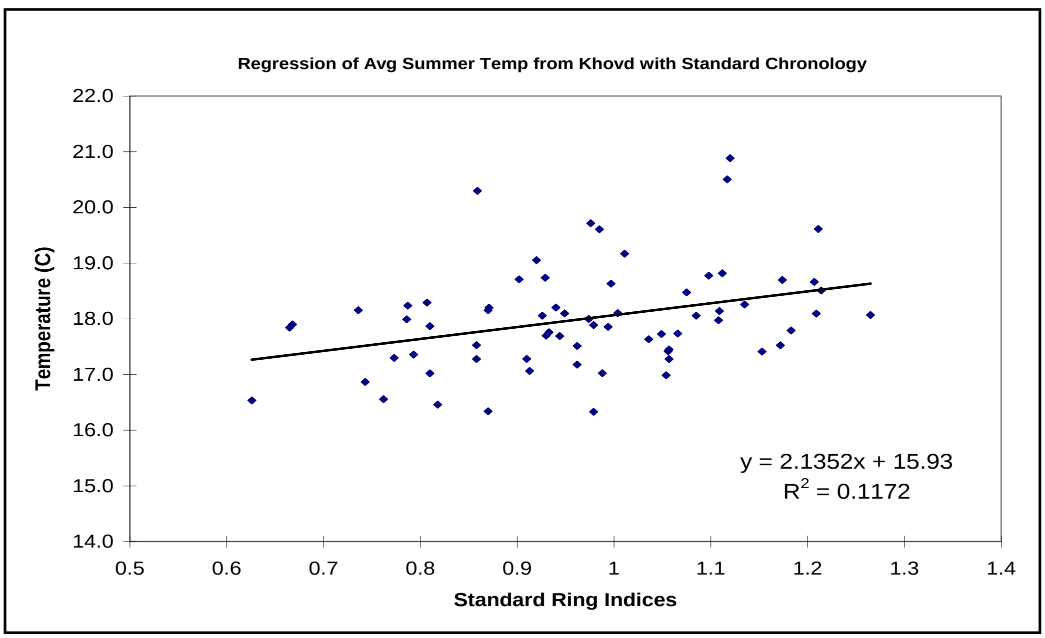


Figure29: Regression scatter plot of the combined standard chronology with averaged summer temperatures from Khovd weather station. The R^2 value is 0.12, explaining 12% variance. Even though this weather station is farther from the sampled trees, the more extensive data set makes reconstructed temperatures more reliable.

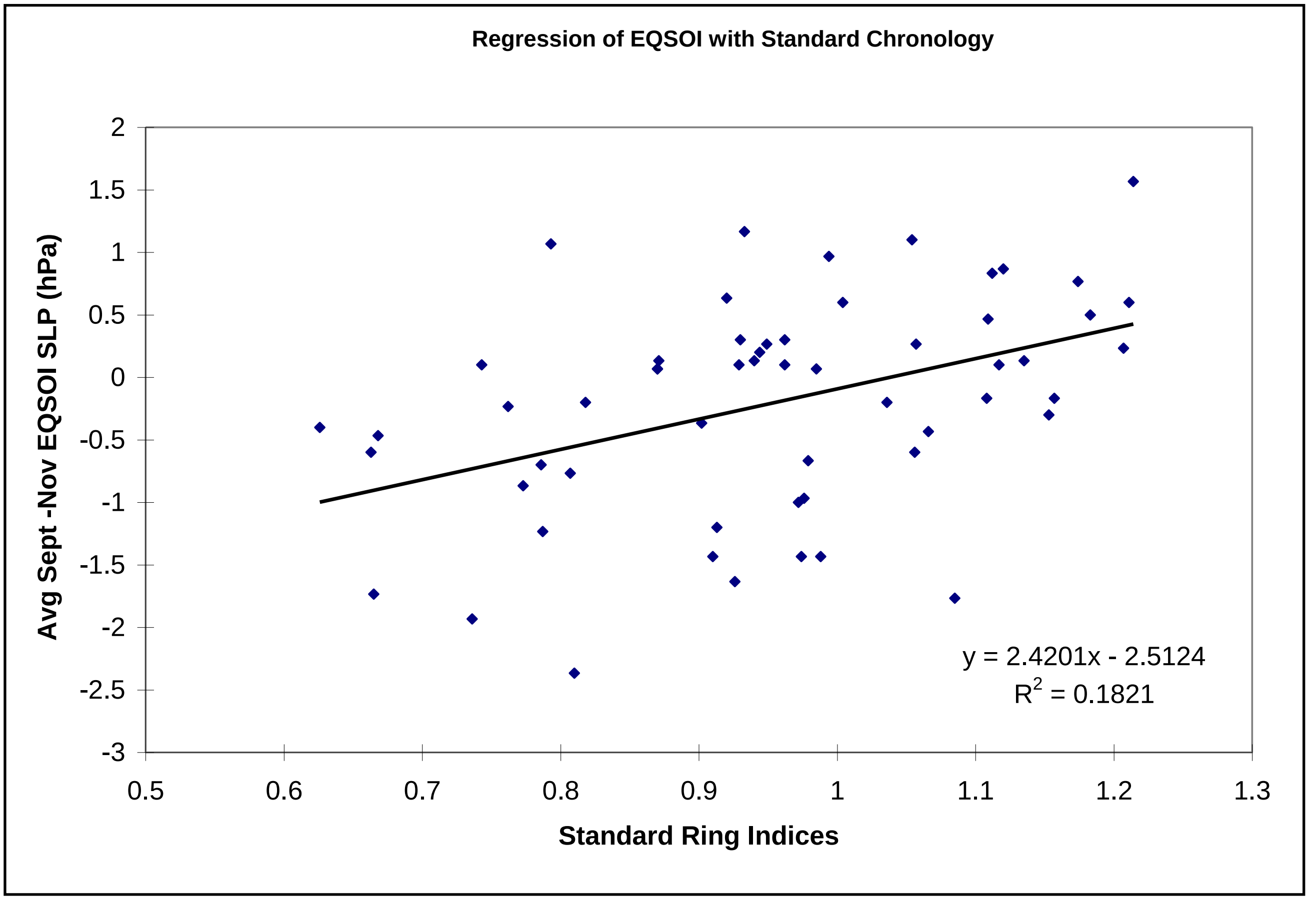


Figure 30: Regression scatter plot of the combined standard chronology with EQSOI data. R^2 value is 0.18, showing significant explanation of variance.

INTERPRETATION

Determination of climate control

Correlation and regression analysis of tree-ring indices with climatic data revealed positive correlation between summer temperatures (June, July, August) from Khovd weather station. With the r^2-value representing the amount of variation explained by any particular climatic parameter, averaged summer temperatures from Khovd weather station explains approximately 12% (r^2=0.12) of the variation in interannual ring width. The r^2-value for Deluun summer temperature was slightly more significant (r^2=0.19, 19%), most likely due to its more proximal location to the tree stands and perhaps fewer year to correlate. Correlation with previous year's July precipitation recorded at Deluun were positive (R=0.465) yet the p-value (which determines the significance of the correlation) exhibits less statistical significance ($p<0.735$). In addition, the limited data set (n=15) makes use of these positive correlations difficult since the recorded values are not necessarily representative of all temperature and precipitation ranges, thus constraining the reconstructed values. For this reason, reconstructed summer temperatures will be based off of averaged summer temperatures recorded at Khovd meteorological station.

Comparison of measured and reconstructed summer temperatures

Reconstructed temperatures were derived from application of the regression equation to tree-ring measurements. Overlapping reconstructed and measured temperatures for the years 1937 to 2007 were compared to analyze the validity of the reconstruction (Fig 31). Standard deviation of each parameter shows that the measured data has much more natural fluctuation than the reconstructed (0.928 and 0.318, respectively), suggesting that this tree-ring based reconstruction of summer temperatures is largely representative of low frequency rather than high frequency climatic variation. With that said, the trends of June through August temperatures from the reconstructed and instrumental temperatures show similar patterns (Fig 31). The reconstructed data is fairly representative of the measured climate data from 1937 to approximately 1970. In the latter portion of the record, however, large summer temperature variations around 1982, 1990, and 1997 until 2007 are not being accurately represented in the reconstructed data set. The 5-year 2nd order polynomial trend lines (Fig 31) accentuate this feature.

Analysis of summer temperature reconstruction

Looking at the complete record of reconstructed summer temperatures, we can see some general trends within the 425-year record (Fig 32). Throughout all the 1600's, cold temperatures prevail, after which warmer temperatures dominate for the duration of the 1700's and into the early 1800's. Temperatures drop again for the latter half of the 1800's, and into the early 1900's. Around 1962, temperatures begin on an upward trend that persists until the present.

In an attempt to quantify some of the error contained within the reconstruction, two standard deviations were plotted above and below the 30-year mean at a 95% confidence level, meaning that 95% of the points within that 30-year interval falls within this envelope of error (Fig 32). From this representation, the variation in possible summer temperatures is much greater in the early part of the record than in the later. Possible summer temperatures in the 1600's could be within a range of 4º C, whereas the more recent part of the record is ± 2º C. It is important to note that this envelope of error is referring to the variation in data points as they are plotted on this graph. It does not account for other errors that occur within ARSTAN or COFECHA, or those that result from lack of accommodation of multiple factors that might be controlling growth, such as physiological processes and localized ecology.

EQSOI Reconstruction

Large scale atmospheric circulation patterns that could be affecting summer temperatures in the western Altai Mountains include the El Nino-Southern Oscillation. The Equatorial Southern Oscillation Index (EQSOI) is a measure of standardized anomalies of sea-level pressure in Indonesia (NOAA). The EQSOI is a measurement of the El Nino/La Nina cycles (which span 2 to 7 years) by way of air and sea level pressure (NOAA; Yatagai and Yasumari, 1994). Positive values correspond to increased warming and a reduction in rainfall and trade winds, while negative values indicate periods of lower temperature, stronger winds, and increased rainfall (Morinaga,). EQSOI positively correlated with tree-ring widths for the months of September to November (R=0.426). The R^2 value of 0.18, meaning that 18% of the variance in interannual ring widths is explained by EQSOI parameter.

Comparison of measured and reconstructed EQSOI

The EQSOI sea-level pressure values begin in 1949 and extend to 2005 (Fig 33) (NOAA, Climate Prediction). High and low sea level pressure generally cycle within the 2 to 7 year range typical of El Nino. The highs correspond to hot dry periods while the lows correspond to cold wet periods. The reconstructed EQSOI follows the general trend of the original data fairly closely. As was the case in the temperature reconstruction, the reconstructed EQSOI exhibits less subdued fluctuations from the mean than the measured data, with standard deviations over a moving 30-year window of 0.866 and 0.369, respectively. Even though the reconstructed EQSOI does not accurately display the intensity of the measured data, the overall trend is better preserved in this reconstruction than in the summer temperature reconstruction. The 5-year 2^{nd} order polynomial trend line plot (Fig 33) indicates that within the recorded data, there is an increasing trend indicating more intense El Nino conditions that would result in hotter and drier conditions in the early fall.

Analysis of reconstructed EQSOI

The reconstructed EQSOI shows similar overall pattern in sea level pressure as did the summer temperature reconstruction, indicating that the EQSOI is a major contributing factor in summer temperature conditions (Fig 32 & 34). The 1600's were a period of cold, wet conditions. The 1700's was a century of warming, as was the early 1800's. The late 1800's and early 1900's were cool, and beginning in the 1960's temperatures began to rise and droughts presumably became more frequent. Error was again quantified with by plotting two standard deviations above and below the 30-year running mean value at 95% confidence level (Fig 34).

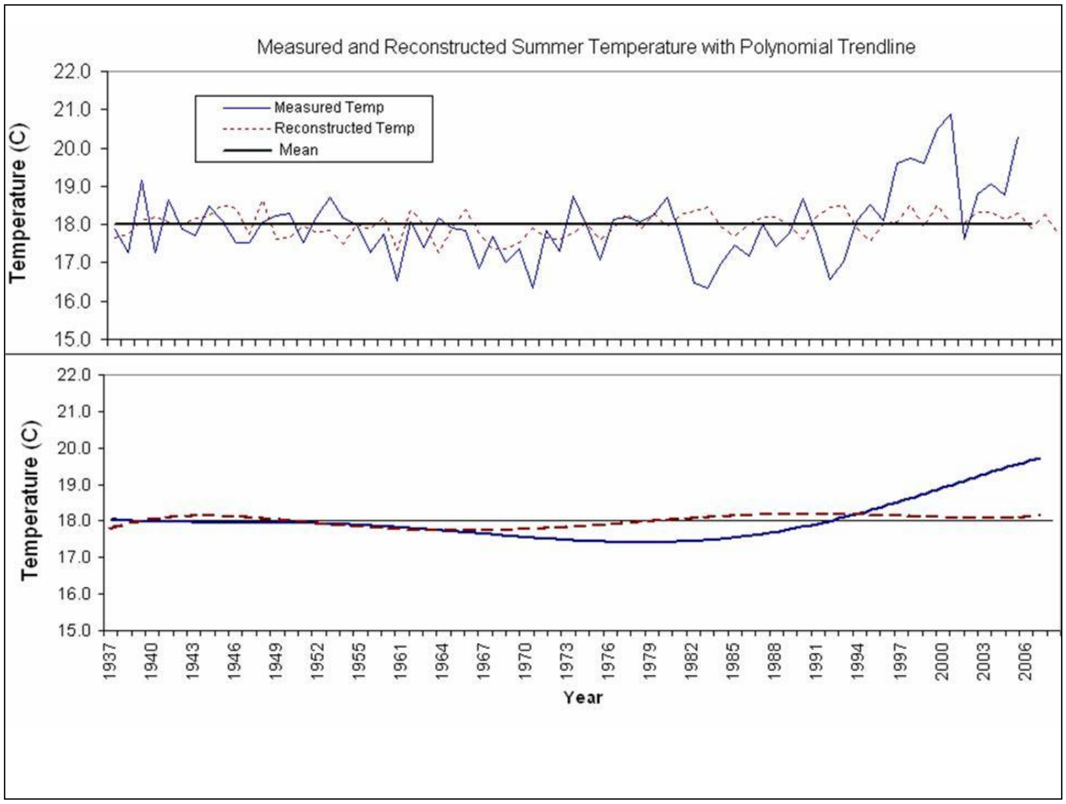


Figure 31: Comparison line graph of measured instrumental data (averaged June through August temperatures) from Khovd meteorological station and reconstructed temperatures for the same period derived from regression equation applied to standardized tree-ring indices. 5-year 2^{nd} order polynomial trend line smooths out interannual variation to show overall trend between the two data sets.

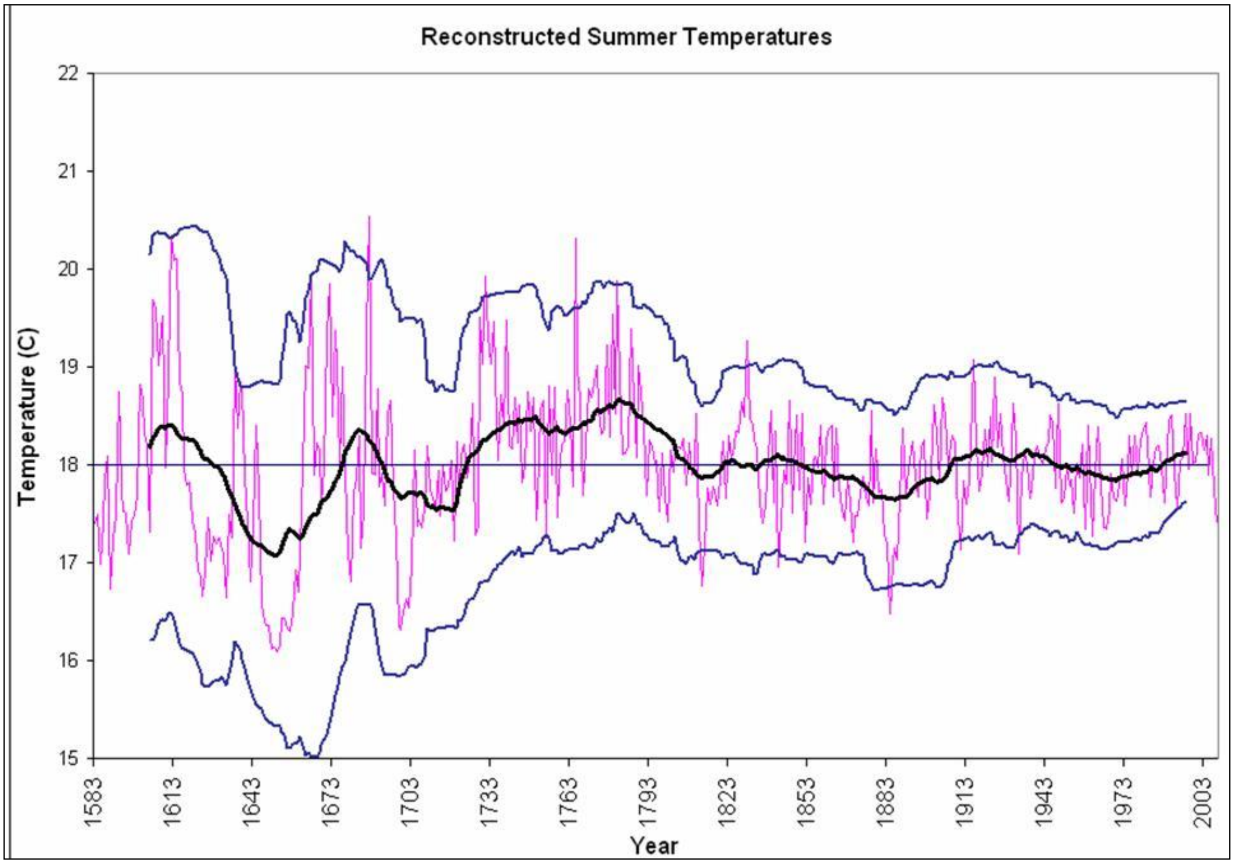


Figure 32: Reconstructed summer (June through August) temperatures derived from standardized (averaged) tree-ring measurements from 32 cores Chigertey Gol and Leya Gol Valleys in the Altai Mountains, Western Mongolia. Black solid line in the middle is a 30-year running mean for ring indices. The lines above and below are 2 standard deviations above and below the mean, at a 95% confidence interval.

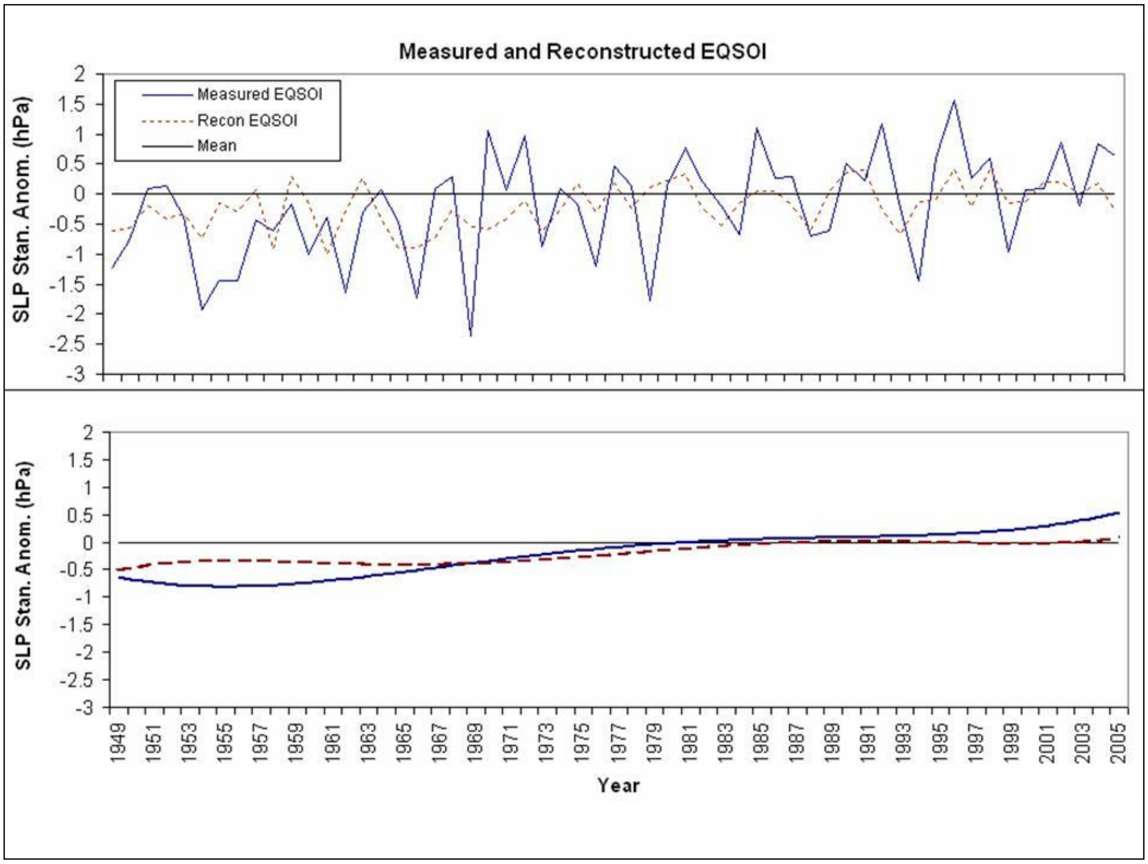


Figure 33: Comparison line graph of measured Equatorial Southern Oscillation Index (EQSOI) measurements with reconstructed EQSOI values derived from tree-ring indices by way of regression equation application. The bottom graph is a 5-year 2nd order polynomial trend line of each data set to compare the overall trend between measured and tree-ring derived EQSOI.

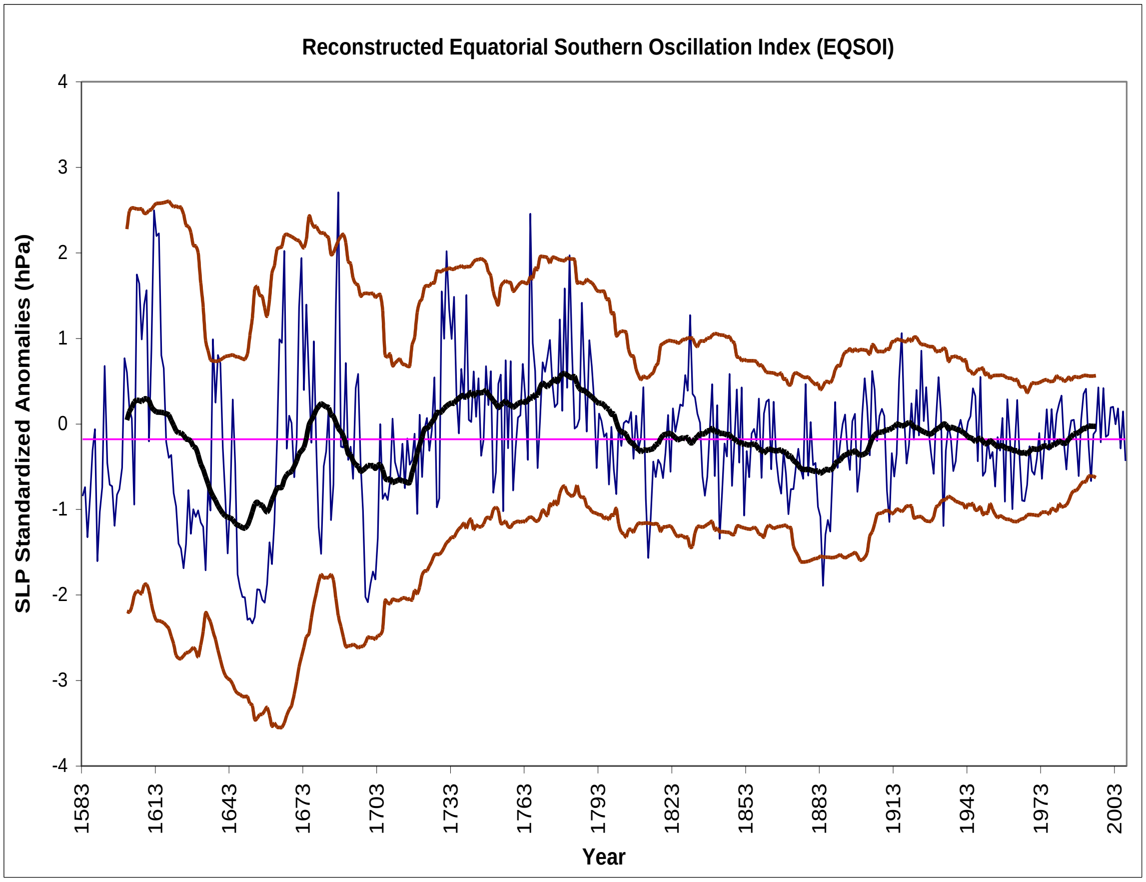


Figure 34: Reconstructed EQSOI values based on standardized chronology of averaged tree-ring chronology of 32 total cores from Chigertey Gol and Leya Gol Valley stands. Negative values indicate cool wet conditions, while positive values represent warmer and drier conditions. The solid middle line is a 30-year running mean of the data, and the two lines above and below the mean are the upper and lower limits of the data, each plotted at two standard deviations above and below the mean.

DISCUSSION

Influence of summer temperature

Due to Mongolia's extreme continental location and mountainous topography, it is likely that multiple climactic and biologic variables influence tree growth. Observations of the LG and CG chronology indicate that in this region, growth variation in Siberian larches is partially dependent on summer temperatures and is therefore a potential summer temperature paleoclimate proxy. This is a tentative rather than definite proxy record because the amount of variation explained by summer temperatures is only a fraction of total variability. There is also a compounding error factor that makes definite conclusions about past climate difficult. For example, actual meteorological data points are limited and spatially distant from the tree stands, sample depth is not extensive in the early part of the record, and there are most likely many more factors that are influencing growth that have not been considered either because they have not been measured or are poorly understood. Such factors include local weather conditions, soil moisture, pest and disease stress, and physiological processes. As such, the climate reconstructions based on the tree-ring record presented in this study is probably best viewed as a semi-quantified reconstruction that provides a qualitative perspective of past temperature change.

With the available information and with acknowledgment of the potential uncertainties, I conclude from this record that periods of above average and below average growth correlate to periods of low and high temperature, with June through August temperatures explaining approximately 20% of the variance. Periods of growth that exceed average levels are interpreted as being periods of higher than average summer temperatures in the current growing season while below average growth is interpreted as a response to lower summer temperatures. This growth response is most likely due to the tree's North-facing aspect, which is normally cooler and shadier, allowing for increased soil moisture retention and lower moisture sensitivity. Local seeps within the CG stand and a nearby river in LG Valley further supports the notion of lower dependency of moisture sensitivity.

However, as mentioned previously, explanation of 20% growth variation is a small fraction of annual tree growth. Other physiologic and environmental that are definitely active growth factors are not taken into account in this reconstruction. For example, though the significance of precipitation did not strongly correlate with the ring width indices due to limited weather records, regression analysis nevertheless suggests that precipitation accounts for approximately 10% of the growth variation ($R=0.300$, $R^2=0.09$). Together, precipitation and temperatures explain only 30% of the growth variation, leaving the remaining 70% of the annual growth variance due to 'other' factors including soil moisture and population density, as well as biological processes that as of yet are not well understood (Fritts, 1976; Kagawa et al., 2003; Kirdyanov et al., 2008). The mountainous topography of the region also has an effect on growth patterns by creating highly localized and site-specific microclimates through alteration of atmospheric convection (Gunin, 1999; Batima, 2005). Because these trees occupy such a limited ecological belt, the effects of unmeasured localized microclimates could play a large role in rates of tree growth.

EQSOI

Correlations with the EQSOI indicate that the El Nino/La Nina oscillation is a factor in tree-ring growth within the Altai Mountains ($R=0.42$, $R^2= 0.18$, 18%). In addition to being the least populated country in the world, it is also one of the most land locked and furthest removed from a regulating body of water. This geographic location has a major influence in the atmospheric circulation patterns controlling Mongolia's climate. As Pederson et al. (2001) noted, many climatic systems are in operation in Mongolia, such as ENSO, PDO, NAO, and the Asian monsoons. But none of these dominate the climate system because Mongolia experiences only the margins of those systems due to its distance from any regulating bodies of water. Despite this remoteness ENSO appears to have influenced tree growth in this study a result (Davi et al., 2006; Morinaga et al. 2003; Yatagai and Yasunari, 1994; Stratton, 2007).

Though utilized to reconstruct drought conditions, the Hovs Gol Nuur tree-ring chronology produced by Davi et al. (2006) from central Mongolia yielded a strong cross dating correlation with the LG and CG sites in COFECHA. This study also reported observation of ENSO periodicity within this record, indicating a similar and persistent climatic growth control for all trees in question.

Positive correlation and a high R and p-value indicate that there is indeed a common atmospheric circulation system (ENSO) that is operating over the country that can not only be observed in precipitation models, but temperature models as well. Other Mongolian tree-ring chronologies from different regions that correlated with trees from CG and LG valleys are: (Khlazan Khama [N49º, E91º], Horin Bugatyin Davaa [N49º, E94º], and Hovsgol Nuur [N50º, E100º]) (Jacoby et al., 1999; Pederson et al., 2001; Davi et al., 2006). With series intercorrelations of 0.494, 0.704, 0.659 (respectively), there must be some common signal that is being expressed by tree stands in various locations, and that the width pattern in the LG and CG chronologies is not entirely the result of local conditions.

Reconstructed Climate Analysis

Several tree-ring studies in various regions have also found temperature to be a significant influence on the development of tree-ring growth (Jacoby et al., 1999; D'Arrigo et al., 2001; Davi et al., 2003; Kirdyanov, 2008; Fan et. al, 2008). Some of these studies reported similar climate patterns those found within this study, such as higher temperatures in the late 1700's and early 1900's and lower temperatures in the 1600's, early 1700's, and all of the 1800's. The 1,738-year chronology produced from Siberian pines in the Tarvargatay Mountains is especially useful in comparison for the insight it provides into long term variation (D'Arrigo et al. 2001). The prolonged cold period found in that record from 1500 to 1750 A.D is consistent with the cold period observed within this study during the 1600's, which is thought to represent the Little Ice Age Maximum (LIA). If the cold period indeed represents the LIA, and not an anomaly of local cooler summer temperatures, it would suggest that the spatial extent of the LIA reached into the Altai, supporting the theory the LIA was a globally experienced climate phenomena (Grove, 1988).

The late 1700's appears to be a period of warmth as measured in this study and in previous works such as D'Arrigo et al.'s (2000) 1,738-year record and others (Jacoby et al., 1999; D'Arrigo et al., 2001; Davi et al., 2003; Kirdyanov, 2008; Fan et. al, 2008). Twentieth century warming, on the other hand is not quite as consistently represented. The raw tree-ring record for CG and LG Valleys both show marked increases in tree-ring width, indicating warmer summer temperatures (Fig 16, 20, 24). However, the standard chronology does not show the same increase in ring indices at the end of the record (Fig 16, 20, 24). This divergence in growth pattern of the same samples but with different statistical application is another error that should be considered in assessing the validity of this record. Though conventions of tree-ring processing were followed, this erasure of natural growth pattern from the raw record to the standard chronology is an artifact of statistical analysis that perhaps leads to faulty conclusions.

Reconstructed temperatures and EQSOI only display slightly above average values (Fig 29 & 31). However, as mentioned previously, averaging multiple tree core measurements together to create the standard chronology removes much of the high frequency variation preserved in tree-ring records. Warming in the 18th century was also observed in several chronologies from various locations, though with some differences most likely as a result of regional topography variation or localized ecological settings (Jacoby et al., 1999; D'Arrigo et al., 2000; Jacoby et al., 2003; Davi et al., 2003; Fan et al., 2008).

In terms of patterns in past climate, the standardized chronology for the LG and CG stands suggests that the late 1700's were a period of warming, followed by cooling in the 1800's, and warming again in the 1900's. The raw-ring width chronology indicates significantly lower summer temperatures in the 1600's, fairly consistent temperatures in the 1700's and 1800's, and a marked increase in temperature beginning in the 1900's (Fig 24). This recent warming is consistent with measured temperature records and suggests even this remote region of the world is responding to human induced climate change

CONCLUSION

Information on the past climate of Mongolia (prior to 1940) is spatially and temporally limited making interpretation of recent climate changes (as either anomalous or within normal periodicity) difficult. In an attempt to put recent climate changes in context of larger climate patterns, this study utilized Siberian larch tree-rings to reconstruct past summer temperatures in the Altai Mountains of western Mongolia. The sampled trees, which were anomalous in this steppe dominated landscape, were sampled from two out of two possible tree stands. These trees exist in a very narrow ecological zone, making them theoretically sensitive to environmental change.

The sample cores from these larches were analyzed by counting and measuring their annual ring widths, producing a 425-year chronology. Measurements were then statistically analyzed using various software programs to determine the presence and strength of a common climatic signal responsible for interannual ring width variation. Results suggest that there is a common climatic signal (summer temperature) and that the signal add the most significant effect on growth (0.35 r^2= 0.12). Despite this low correlation coefficient, the tree-rings in this study were utilized as a summer temperature paleoclimate proxy. However, even though the strongest climate correlation was related to summer temperatures, this parameter only explains approximately 20% of the growth variance. What this means is that there are still many factors that are influencing the growth of these trees that are not being accounted for within the summer temperature reconstruction, and that measurements are perhaps reflecting (in addition to summer temperatures) other parameters that control growth.

ENSO is positively correlated with the standard chronology and is a possible mechanism for variation in temperature and precipitation, but also provides more information on atmospheric circulation patterns that are operating in Mongolia. The climate of Mongolia has not been extensively studied, so to contribute and support findings of ENSO as a climatic system that has been consistently found to be a factor in past and present climate systems in Mongolia is one step closer to understanding the behavior of different climate systems in Mongolia and other extreme continental locations.

In terms of reconstructed summer temperatures, it was found that the 1600's and 1800's were a period of cooling and perhaps reflect the presence of the LIA. Warmer summer temperatures were also found in the late 1750's, as well as in the 1900's. The final burning question is whether (and how) Mongolia is experiencing recent climate change. It seems, based on this chronology and others produced in various regions, that yes, Mongolia is experiencing a changing in climate. But due to the vast expanse of the country, its mountainous topography, localized ecologies, and the various operating atmospheric systems, climate change is being experienced differently by different regions in the country.

There is much to be learned about Mongolia's current and past climate that more data would of course be valuable to fill in the local and regional gaps. The findings within this study reflect the growth patterns of just a handful of trees in a remote and isolated location. Even though Mongolia is sparsely populated, understanding how this country is experiencing climate change is important. Mongolia's continental location and complicated atmospheric circulation system makes it especially susceptible to a fluctuating climate. This could potentially have drastic effects on the nomadic culture and the agrarian economy of the region. For further study, I would recommend extending this chronology temporally by utilizing relict wood, and spatially by sampling in other locations in the Altai. In addition, other paleoclimate proxies, such as glacial lake sediment and pollen, should also be utilized more extensively to reconstruct past climates in order to understand the present.

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Appendix A: Raw Measurements of individual cores in decadal format.
Decimal is three digits from the right. Measurements are in mm.

ID#	Year	0	1	2	3	4	5	6	7	8	9
7240812a	1814	668	956	927	1020	995	865				
7240812a	1820	738	654	594	434	753	735	848	716	784	733
7240812a	1830	1163	766	1005	1002	811	555	372	428	599	937
7240812a	1840	566	503	351	311	396	318	526	270	391	520
7240812a	1850	337	373	323	362	132	328	377	346	312	405
7240812a	1860	514	821	910	573	786	699	580	490	559	568
7240812a	1870	396	386	402	435	610	666	563	987	723	1022
7240812a	1880	714	636	556	380	471	562	411	286	594	741
7240812a	1890	449	710	852	1071	1215	836	1157	946	315	400
7240812a	1900	838	936	881	699	1010	888	661	642	559	500
7240812a	1910	262	294	450	394	356	531	584	347	555	644
7240812a	1920	670	492	668	453	678	460	529	591	407	281
7240812a	1930	459	562	598	287	502	764	811	567	536	606
7240812a	1940	580	537	665	690	652	663	675	318	536	283
7240812a	1950	303	381	346	330	256	334	327	369	308	431
7240812a	1960	325	53	298	358	278	144	192	222	310	275
7240812a	1970	261	334	352	266	277	253	251	294	181	211
7240812a	1980	231	273	256	192	301	324	337	355	240	418
7240812a	1990	469	383	243	149	293	343	387	291	339	324
7240812a	2000	273	421	347	344	403	387	381	318	-9999	
7240812b	1813	672	637	1224	895	1182	1283	1073			
7240812b	1820	911	777	698	587	759	819	797	756	1023	934
7240812b	1830	1303	1027	1256	1401	1026	559	521	462	593	856
7240812b	1840	553	611	430	533	526	312	624	331	410	567
7240812b	1850	208	372	341	374	132	374	356	294	310	406
7240812b	1860	602	831	806	541	829	676	561	695	561	458
7240812b	1870	366	301	380	411	617	548	429	794	788	796
7240812b	1880	730	704	615	382	378	481	310	263	365	556

7240812b	1890	502	533	536	582	720	547	817	711	230	392
7240812b	1900	758	856	790	396	713	727	668	608	510	394
7240812b	1910	225	231	380	313	400	452	550	372	589	665
7240812b	1920	651	406	571	471	590	399	342	438	330	212
7240812b	1930	533	603	474	208	414	599	630	461	537	527
7240812b	1940	598	577	699	682	619	548	428	240	383	232
7240812b	1950	259	327	321	274	276	422	331	401	282	442
7240812b	1960	386	77	287	417	289	150	203	172	334	221
7240812b	1970	301	320	386	212	328	328	296	322	201	237
7240812b	1980	276	296	278	188	322	344	312	410	233	449
7240812b	1990	436	408	316	179	273	282	337	331	377	369
7240812b	2000	371	497	508	381	463	356	503	391	-9999	
7240811a	1832	1249	1119	1013	446	414	445	440	461		
7240811a	1840	377	580	199	340	378	490	530	270	329	478
7240811a	1850	332	490	253	364	173	232	253	390	587	335
7240811a	1860	602	443	534	236	510	249	294	310	368	235
7240811a	1870	245	331	257	407	343	246	266	373	218	275
7240811a	1880	186	239	134	168	76	34	118	105	228	140
7240811a	1890	325	387	359	459	318	180	373	395	222	175
7240811a	1900	744	592	510	427	661	510	244	510	293	393
7240811a	1910	406	413	648	503	446	741	928	574	454	604
7240811a	1920	619	495	692	487	734	463	781	502	366	349
7240811a	1930	413	445	363	242	394	443	357	285	334	416
7240811a	1940	383	370	328	396	442	815	593	350	783	477
7240811a	1950	502	510	519	534	430	658	507	452	407	780
7240811a	1960	658	208	524	522	492	350	372	397	526	550
7240811a	1970	575	624	771	594	692	813	601	796	769	825
7240811a	1980	677	795	576	533	516	807	960	675	576	766
7240811a	1990	901	924	735	584	686	991	1763	1430	1435	919
7240811a	2000	925	1039	840	822	934	750	889	765	-9999	
7240811b	1814	367	565	415	456	417	308				
7240811b	1820	519	868	687	837	604	889	824	727	562	493

7240811b	1830	693	418	271	379	387	249	341	426	396	452
7240811b	1840	277	634	185	337	372	302	582	272	370	635
7240811b	1850	507	633	0	350	546	272	366	375	359	435
7240811b	1860	335	480	502	525	304	673	395	315	356	542
7240811b	1870	215	256	355	578	565	324	345	665	365	567
7240811b	1880	388	319	159	243	71	86	182	117	317	341
7240811b	1890	290	405	449	619	528	379	616	604	467	611
7240811b	1900	1097	960	847	597	838	902	516	721	1127	971
7240811b	1910	543	347	542	443	399	744	533	487	360	409
7240811b	1920	640	511	454	499	588	474	597	531	464	369
7240811b	1930	548	716	548	469	393	538	491	602	562	674
7240811b	1940	622	654	619	514	611	851	764	557	666	454
7240811b	1950	239	422	374	466	330	394	349	448	267	567
7240811b	1960	327	214	350	416	415	235	397	359	472	548
7240811b	1970	540	565	689	512	485	729	674	660	642	821
7240811b	1980	727	936	721	551	496	520	805	804	598	669
7240811b	1990	852	950	910	607	643	846	998	969	1135	862
7240811b	2000	843	920	861	753	818	819	977	930	-9999	

7240811c	1850	766	1227	586	994	632	714	769	943	1032	820
7240811c	1860	1110	970	1024	537	987	629	710	595	580	398
7240811c	1870	446	748	593	1025	753	594	647	947	566	534
7240811c	1880	479	395	188	256	94	92	235	159	327	328
7240811c	1890	366	533	540	480	440	195	331	601	335	434
7240811c	1900	972	904	728	542	788	657	370	555	331	297
7240811c	1910	394	449	863	544	834	1518	1611	845	572	503
7240811c	1920	758	533	589	494	773	464	627	463	333	336
7240811c	1930	441	482	360	199	394	398	373	257	181	330
7240811c	1940	352	335	349	305	368	835	622	441	735	523
7240811c	1950	470	446	429	523	422	787	679	700	607	973
7240811c	1960	774	462	751	538	447	437	508	520	808	788
7240811c	1970	708	684	767	707	947	1034	764	951	943	978
7240811c	1980	977	1048	902	726	768	1036	1118	910	691	739
7240811c	1990	767	848	703	607	699	1034	1774	1246	1252	678

7240811c	2000	884	1008	820	897	890	544	627	804	-9999	
72408-6b	1828	741	774								
72408-6b	1830	843	817	1077	1019	917	725	763	731	757	749
72408-6b	1840	704	724	262	656	988	827	862	342	686	715
72408-6b	1850	538	747	366	664	527	643	663	692	634	507
72408-6b	1860	816	988	786	781	884	489	426	490	575	383
72408-6b	1870	572	380	530	656	616	331	277	586	681	798
72408-6b	1880	789	903	1040	727	440	498	657	607	1069	633
72408-6b	1890	375	567	681	377	423	325	343	348	284	472
72408-6b	1900	625	656	632	601	893	764	450	495	719	794
72408-6b	1910	668	534	891	819	1242	1852	1790	1180	484	744
72408-6b	1920	958	853	1031	1030	1473	1589	1235	1167	695	853
72408-6b	1930	1566	1254	1554	1173	1031	1307	1026	544	560	741
72408-6b	1940	768	930	1039	565	1199	1042	736	482	845	707
72408-6b	1950	849	886	994	782	516	892	573	1135	583	832
72408-6b	1960	770	407	529	909	412	436	563	301	1023	704
72408-6b	1970	658	752	838	460	646	859	701	967	667	736
72408-6b	1980	1154	1312	928	645	922	1132	966	1020	884	1072
72408-6b	1990	1247	1224	970	847	1016	887	928	740	713	518
72408-6b	2000	521	653	497	404	430	387	489	220	238	-9999
72408-6a	1892	470	434	526	369	515	597	359	661		
72408-6a	1900	654	757	790	573	559	1108	665	642	910	1112
72408-6a	1910	1287	697	922	654	1358	1629	1570	1266	607	715
72408-6a	1920	1154	859	1238	896	1140	1610	1436	1286	987	982
72408-6a	1930	1643	977	1301	936	893	1175	200	192	286	294
72408-6a	1940	730	870	778	744	826	646	611	433	719	524
72408-6a	1950	472	634	762	720	526	712	558	804	447	904
72408-6a	1960	816	380	552	953	742	528	614	607	790	587
72408-6a	1970	623	686	511	422	1116	1529	1084	1780	1168	979
72408-6a	1980	1350	1482	782	589	770	827	778	788	542	593
72408-6a	1990	1013	1190	974	767	885	865	878	832	733	709
72408-6a	2000	812	729	615	408	481	412	512	342	-9999	

72408-1	1928	886	336								
72408-1	1930	236	483	572	1264	1553	1069	555	1370	1895	2197
72408-1	1940	2057	2794	2099	2523	1985	2198	2867	3388	2700	432
72408-1	1950	1284	1196	1314	1477	1551	2217	1725	2565	1691	2591
72408-1	1960	2434	868	1374	2359	3097	1361	1361	2046	2460	2451
72408-1	1970	3196	3015	3159	2932	2967	3393	2304	2834	2173	2267
72408-1	1980	2929	1944	858	486	1088	1709	2161	2439	1646	2626
72408-1	1990	3620	2878	2110	2094	2605	2470	3001	1855	2751	2441
72408-1	2000	1979	1375	1554	432	474	397	766	595	305	-9999

72408-8	1924	154	379	330	594	410	399				
72408-8	1930	399	526	622	229	517	473	769	850	1010	1504
72408-8	1940	1298	1633	1243	594	646	1134	1670	1264	2935	2308
72408-8	1950	2226	2479	2253	2858	2177	2106	1575	1973	1235	1477
72408-8	1960	1224	986	1260	1573	974	639	819	1043	1009	800
72408-8	1970	1219	1461	1146	1234	1269	1727	1375	1036	961	1253
72408-8	1980	1486	1376	834	871	1158	1432	836	838	934	1095
72408-8	1990	1380	1389	1045	1084	1145	1197	1081	667	863	1025
72408-8	2000	1227	1046	1128	856	448	302	442	192	-9999	

7240813a	1900	299	873	839	573	734	705	525	652	855	578
7240813a	1910	418	378	882	608	681	982	1049	718	474	635
7240813a	1920	695	763	920	888	1084	831	986	988	863	736
7240813a	1930	1292	1078	1148	710	981	1179	1194	1156	1113	1194
7240813a	1940	1258	1285	1436	1473	1528	1381	1171	963	1354	1069
7240813a	1950	1245	1139	1180	1003	820	689	443	828	393	797
7240813a	1960	754	530	760	978	700	496	622	781	921	838
7240813a	1970	983	792	953	590	1070	1165	857	1205	856	1198
7240813a	1980	1048	1412	1192	847	730	1213	1438	1153	1017	886
7240813a	1990	1485	1391	1295	949	1181	979	1462	1196	1617	1346
7240813a	2000	1366	1505	2187	1176	1727	909	1925	1408	-9999	

7240813b	1902	773	490	735	558	465	505	729	575		

7240813b	1910	479	495	672	674	713	988	983	741	588	688
7240813b	1920	747	825	855	763	996	918	1008	1114	969	675
7240813b	1930	1199	1076	1121	645	876	1084	1246	1067	1240	1035
7240813b	1940	959	967	1090	1145	1060	1239	833	945	1049	873
7240813b	1950	1237	906	1064	1168	1437	1418	1749	2039	1137	1792
7240813b	1960	1293	631	628	1089	983	707	574	703	792	572
7240813b	1970	594	882	942	815	911	906	737	971	917	1162
7240813b	1980	1231	1238	849	741	1016	1109	1030	846	930	991
7240813b	1990	1307	1285	1305	1065	1034	1158	1374	867	1068	731
7240813b	2000	1146	1256	1113	993	1009	1044	1555	971	-9999	

7240810b	1712	473	641	451	723	495	717	760	578		
7240810b	1720	764	616	644	682	796	885	971	820	669	1021
7240810b	1730	682	1142	1083	877	1548	1020	981	1201	1123	1116
7240810b	1740	820	879	932	762	814	620	693	958	783	769
7240810b	1750	564	708	1047	821	530	865	737	787	645	535
7240810b	1760	624	700	774	911	561	1192	809	749	503	538
7240810b	1770	775	598	598	662	711	563	605	939	700	962
7240810b	1780	705	963	666	479	502	537	798	735	511	780
7240810b	1790	855	732	538	694	700	466	516	416	396	442
7240810b	1800	340	613	532	550	535	625	465	442	457	502
7240810b	1810	421	632	512	0	212	241	360	250	251	318
7240810b	1820	356	363	487	326	344	411	361	379	378	472
7240810b	1830	449	449	425	250	211	326	204	98	198	251
7240810b	1840	218	177	127	191	227	160	305	72	151	257
7240810b	1850	197	188	80	165	136	224	174	188	170	137
7240810b	1860	165	162	157	69	164	176	85	148	113	112
7240810b	1870	196	209	169	129	220	155	107	311	126	183
7240810b	1880	152	181	129	129	122	282	387	237	543	594
7240810b	1890	382	352	259	313	262	272	297	314	208	224
7240810b	1900	204	312	423	366	593	425	438	455	354	188
7240810b	1910	177	203	264	327	422	587	763	574	371	393
7240810b	1920	489	506	584	542	729	556	531	524	386	267
7240810b	1930	614	658	467	225	307	528	548	404	579	540

7240810b	1940	498	412	496	407	615	436	357	471	694	444
7240810b	1950	502	647	588	568	564	681	591	591	387	541
7240810b	1960	602	339	637	660	471	161	334	387	532	398
7240810b	1970	352	418	444	352	265	509	377	453	278	375
7240810b	1980	545	679	491	247	393	392	541	669	546	677
7240810b	1990	850	879	745	669	716	666	868	891	944	994
7240810b	2000	995	663	802	939	1037	861	826	872	730	-9999
72708-9	1892	1590	1677	2132	1834	1050	606	962	679		
72708-9	1900	340	571	320	821	993	1062	1580	1923	1727	1314
72708-9	1910	701	306	128	280	743	787	1081	1358	1680	1215
72708-9	1920	434	470	395	595	1157	1232	888	780	186	103
72708-9	1930	218	252	129	53	190	330	257	211	211	253
72708-9	1940	337	253	359	317	236	610	514	243	611	472
72708-9	1950	339	489	402	340	268	748	894	1087	378	922
72708-9	1960	607	404	1109	1018	551	418	462	679	697	463
72708-9	1970	394	540	916	829	967	885	530	913	751	906
72708-9	1980	900	1067	826	826	590	1011	1472	1505	579	1116
72708-9	1990	1465	1330	1031	788	1017	1035	748	703	678	783
72708-9	2000	559	1042	1193	1413	1049	849	1000	748	-9999	
7240815A	1831	866	533	463	406	363	373	464	574	538	
7240815A	1840	495	675	392	799	895	1206	1295	848	881	1196
7240815A	1850	850	838	607	1037	886	1333	995	813	659	468
7240815A	1860	676	896	1287	1106	1470	1016	317	344	569	535
7240815A	1870	838	778	811	604	718	762	468	809	563	850
7240815A	1880	481	561	363	410	156	133	152	229	515	753
7240815A	1890	647	621	889	939	627	448	496	547	408	568
7240815A	1900	1114	1033	842	716	803	776	655	1109	694	705
7240815A	1910	352	330	534	463	659	835	891	681	350	403
7240815A	1920	725	594	637	593	676	651	796	645	309	400
7240815A	1930	584	621	512	286	682	656	524	274	484	676
7240815A	1940	771	583	612	624	691	869	745	575	919	621
7240815A	1950	611	447	441	621	467	660	654	813	377	928

7240815A	1960	951	525	1136	959	582	535	364	615	358	294
7240815A	1970	421	842	983	700	873	898	537	618	849	775
7240815A	1980	717	895	564	647	1002	1217	1415	1247	754	881
7240815A	1990	786	923	635	623	983	1236	1408	817	1122	714
7240815A	2000	665	835	642	778	655	676	813	658	-9999	

7240815B	1768	172	123								
7240815B	1770	83	138	193	287	167	67	40	194	255	267
7240815B	1780	154	237	175	102	184	258	565	349	236	268
7240815B	1790	283	245	186	149	145	202	187	177	404	305
7240815B	1800	378	615	667	1260	731	685	591	560	581	393
7240815B	1810	472	167	114	266	106	227	248	410	401	461
7240815B	1820	564	955	928	825	1229	995	1168	831	1234	1052
7240815B	1830	1318	976	686	455	682	419	280	372	644	837
7240815B	1840	620	885	491	602	687	725	1065	481	623	641
7240815B	1850	283	706	252	582	599	866	664	526	762	405
7240815B	1860	650	623	632	501	761	498	616	713	812	595
7240815B	1870	426	584	784	616	726	516	548	606	438	629
7240815B	1880	342	443	418	337	197	131	142	194	268	515
7240815B	1890	334	495	650	659	486	372	503	517	331	395
7240815B	1900	901	910	814	724	881	695	515	1063	417	705
7240815B	1910	341	255	626	460	617	886	748	487	239	241
7240815B	1920	530	309	644	536	797	603	686	541	235	452
7240815B	1930	501	475	425	166	384	372	423	203	234	457
7240815B	1940	477	390	467	502	567	683	627	416	682	465
7240815B	1950	373	704	270	460	368	563	655	740	243	688
7240815B	1960	565	344	542	514	337	366	289	353	299	251
7240815B	1970	311	584	760	561	505	866	499	586	505	608
7240815B	1980	564	774	414	386	700	1076	709	581	521	645
7240815B	1990	562	522	481	379	630	733	1238	677	765	664
7240815B	2000	673	707	519	648	521	563	704	460	-9999	

240814aU	1891	1799	1480	1249	718	815	970	671	702	875	
240814aU	1900	335	1203	923	785	1385	1137	1192	1055	1304	870

240814aU	1910	390	476	758	651	819	1343	1807	526	255	455
240814aU	1920	603	618	852	745	1176	961	956	385	575	649
240814aU	1930	804	1059	955	150	653	890	700	583	524	703
240814aU	1940	703	797	831	871	737	484	470	327	554	351
240814aU	1950	356	279	366	377	219	246	253	556	308	947
240814aU	1960	875	217	661	785	677	319	410	446	663	838
240814aU	1970	920	786	978	530	613	973	654	737	501	663
240814aU	1980	721	859	669	273	517	794	892	936	868	975
240814aU	1990	970	1125	1014	816	986	944	1325	1182	1491	1164
240814aU	2000	1192	1443	1246	1009	500	344	656	211	-9999	

240814aD	1891	1566	1431	1224	1016	950	946	656	383	604	
240814aD	1900	343	932	978	857	1256	1281	1065	1206	1231	864
240814aD	1910	340	490	767	707	868	1387	2071	596	263	543
240814aD	1920	672	961	1617	1174	1597	1356	1606	453	775	859
240814aD	1930	1382	1478	1196	187	810	919	1012	927	998	1317
240814aD	1940	1396	1514	1008	1330	1171	1091	947	969	1493	856
240814aD	1950	1175	816	712	616	683	571	713	1234	669	1437
240814aD	1960	1061	610	840	888	744	295	436	487	676	941
240814aD	1970	1016	974	1153	850	798	990	954	845	718	717
240814aD	1980	821	1141	636	467	646	756	720	653	685	1050
240814aD	1990	1626	1652	1013	1053	986	1350	1709	1679	1972	1505
240814aD	2000	1957	1827	1799	1374	623	515	650	275	-9999	

240814bU	1889	1454									
240814bU	1890	1119	1300	998	879	839	767	778	602	686	871
240814bU	1900	374	1087	1022	895	1356	1552	1266	1145	1264	747
240814bU	1910	337	499	600	622	774	1335	1974	680	337	690
240814bU	1920	690	881	1252	848	1051	851	1151	405	610	678
240814bU	1930	946	1139	1195	185	776	1010	1000	696	602	739
240814bU	1940	918	746	885	1085	787	452	718	621	996	765
240814bU	1950	708	637	463	459	511	663	693	1233	615	1268
240814bU	1960	883	157	642	692	496	168	384	314	423	461
240814bU	1970	668	793	998	711	747	958	877	782	585	774

240814bU	1980	886	811	833	535	802	821	542	521	519	656
240814bU	1990	581	703	699	754	989	1060	1480	1333	1319	1492
240814bU	2000	1661	1544	1370	1146	495	373	512	317	546	-9999
7240810a	1860	213	162	182	162	227	191	267	169	273	249
7240810a	1870	105	239	216	438	281	293	299	441	520	338
7240810a	1880	518	448	294	224	220	241	242	135	109	409
7240810a	1890	188	96	169	235	254	213	274	360	140	182
7240810a	1900	290	367	366	257	430	368	383	309	336	224
7240810a	1910	136	195	252	304	308	412	494	321	198	181
7240810a	1920	288	296	389	398	547	292	382	281	239	146
7240810a	1930	420	442	453	264	381	538	314	278	279	403
7240810a	1940	397	387	429	546	569	404	324	289	392	182
7240810a	1950	233	415	341	308	225	265	248	406	56	451
7240810a	1960	307	214	380	400	246	110	159	134	310	230
7240810a	1970	170	315	311	279	266	377	329	509	340	469
7240810a	1980	547	488	351	388	552	603	570	495	348	425
7240810a	1990	543	491	296	344	524	409	603	524	673	530
7240810a	2000	489	579	691	700	870	548	533	475	-9999	
7240810c	1704	586	371	293	299	306	396				
7240810c	1710	390	348	283	432	296	503	436	446	510	310
7240810c	1720	554	512	410	341	376	507	634	318	293	528
7240810c	1730	491	534	483	827	968	575	418	527	513	570
7240810c	1740	496	501	708	470	552	411	452	616	527	495
7240810c	1750	327	371	567	492	282	577	298	334	297	357
7240810c	1760	307	481	425	516	351	652	625	591	345	390
7240810c	1770	507	489	659	853	708	595	682	902	624	822
7240810c	1780	589	890	517	390	384	491	772	552	402	726
7240810c	1790	646	467	537	488	423	353	336	212	280	235
7240810c	1800	260	558	356	402	362	397	342	248	352	349
7240810c	1810	360	490	358	171	157	181	160	166	193	281
7240810c	1820	295	460	261	316	289	291	301	312	349	228
7240810c	1830	414	378	296	282	239	103	65	96	193	331
7240810c	1840	248	232	159	-9999						

72708-8	1886	985	1237	1545	1885						
72708-8	1890	1042	1299	1453	1458	1826	1476	1335	1286	1004	752
72708-8	1900	738	1249	1253	928	976	1733	1175	764	1400	1256
72708-8	1910	798	692	661	525	556	320	856	1006	1052	1109
72708-8	1920	1243	739	692	647	1036	974	1365	1292	1511	1326
72708-8	1930	1526	1842	1660	1166	1333	1759	2077	1906	1676	1244
72708-8	1940	977	612	557	942	808	1754	2536	1460	1606	1007
72708-8	1950	1115	1356	1443	1287	762	966	1347	1905	1135	1728
72708-8	1960	1668	2468	2578	2989	2133	1511	1932	2249	2477	2283
72708-8	1970	1604	1635	1563	1101	1751	1710	1637	2110	2514	2522
72708-8	1980	1922	1636	1736	1487	1503	1784	1510	1583	1799	2982
72708-8	1990	3316	3851	2580	1739	1990	1245	1542	1139	1355	1357
72708-8	2000	1579	1373	1615	1551	1653	912	802	797	559	-9999
72708-7a	1887	1368	1631	1628							
72708-7a	1890	1348	1325	751	692	1368	994	1178	1310	1023	1138
72708-7a	1900	1075	1183	1338	968	437	575	375	411	772	1118
72708-7a	1910	1151	763	1288	1199	1308	1588	2233	2277	2460	2147
72708-7a	1920	2572	1830	2038	1559	1872	1251	1469	1581	2021	1633
72708-7a	1930	1824	2078	1847	941	1132	1181	1181	1045	910	969
72708-7a	1940	1234	1360	1759	2376	1953	2314	2041	1636	2228	1320
72708-7a	1950	1627	1713	1358	1227	878	974	906	1092	649	1378
72708-7a	1960	1345	1093	1490	1763	1302	1607	1456	1860	2252	1901
72708-7a	1970	1704	1467	1801	1535	1020	937	1164	1635	1863	1843
72708-7a	1980	1781	1564	1312	1348	1420	1070	1180	862	871	1208
72708-7a	1990	1332	1550	1128	910	1118	967	1278	1238	1617	1640
72708-7a	2000	1782	1655	1725	1674	1966	1301	1534	1400	1272	-9999

72708-7b	1902	1921	1283	3108	2486	1664	1259	1892	2181		
72708-7b	1910	1391	863	1206	1027	1325	2108	2649	2227	2092	1885
72708-7b	1920	2275	1945	1696	1279	1551	1230	1708	1435	1939	1510
72708-7b	1930	1737	2189	2132	1144	1759	1977	1845	1557	1656	1816
72708-7b	1940	2490	2177	1998	1925	1378	1538	1902	1172	1721	1420
72708-7b	1950	1603	1611	1098	1216	1137	1487	1458	1580	1180	1973

72708-7b	1960	1453	1441	1200	1732	1422	1153	1245	1174	870	838
72708-7b	1970	950	893	1035	979	1289	1760	1531	1582	1549	1653
72708-7b	1980	1507	1131	1093	952	992	901	985	824	788	1013
72708-7b	1990	1303	1386	1189	1038	1237	781	1163	1089	1377	1211
72708-7b	2000	1222	1323	1582	1458	1545	1120	1203	1076	1160	-9999
72708-6	1928	2503	2247								
72708-6	1930	2546	2390	1833	1470	2268	2020	2021	2059	1608	1539
72708-6	1940	2168	1809	1042	1985	1978	1912	2939	2199	2087	1251
72708-6	1950	1233	1699	1526	1721	1541	1733	1980	2035	1678	2481
72708-6	1960	2175	2227	1602	1920	1793	1633	988	794	1048	1019
72708-6	1970	965	936	658	722	1095	1263	1372	1621	1352	1268
72708-6	1980	1163	1080	1245	1265	1363	1129	1068	868	688	941
72708-6	1990	922	1004	618	306	541	451	633	614	807	706
72708-6	2000	777	708	681	575	894	729	1020	769	430	-9999
72708-5	1943	1209	1207	1082	1418	931	1439	1265			
72708-5	1950	2187	2383	2042	2300	1335	1680	1047	1525	894	1363
72708-5	1960	1307	1189	1429	2137	1771	2227	1108	1495	1851	1490
72708-5	1970	1239	741	753	1015	1159	1279	976	1235	1000	1413
72708-5	1980	1568	1878	1903	1339	1429	1290	1511	1286	1237	1207
72708-5	1990	1435	1714	957	842	1112	1057	1411	928	1658	1236
72708-5	2000	1312	1153	1264	1419	1468	1366	1366	1390	1096	-9999
72708-4	1930	389	386	266	148	268	447	399	439	387	427
72708-4	1940	437	527	641	677	791	1007	1103	877	1212	706
72708-4	1950	905	1146	993	395	649	1028	1196	1346	750	1364
72708-4	1960	608	891	1246	1162	1093	1639	1984	1723	1612	1518
72708-4	1970	1651	1224	1384	1088	1466	1652	2082	1747	941	1261
72708-4	1980	1425	1757	2021	1678	1807	1337	1175	1028	658	1052
72708-4	1990	1141	1355	983	555	837	963	1425	1159	1994	1681
72708-4	2000	1779	2209	2171	2136	1959	1753	1669	1418	1164	-9999
72708-3U	1847	812	1434	1545							

72708-3U	1850	836	930	270	537	863	1552	1479	1168	1231	786
72708-3U	1860	966	972	890	650	741	580	479	479	653	584
72708-3U	1870	390	318	371	393	403	503	474	667	490	720
72708-3U	1880	614	565	380	387	194	342	384	350	327	538
72708-3U	1890	406	401	388	544	440	446	587	737	639	674
72708-3U	1900	765	552	457	334	589	555	445	547	708	707
72708-3U	1910	544	259	228	244	281	424	668	968	977	1015
72708-3U	1920	1041	895	1025	1041	1304	858	823	774	925	851
72708-3U	1930	648	958	998	497	790	779	839	669	556	673
72708-3U	1940	740	764	639	649	546	858	941	492	1019	623
72708-3U	1950	390	693	530	906	858	627	599	429	397	492
72708-3U	1960	566	566	682	1094	924	836	649	424	719	553
72708-3U	1970	331	471	574	462	704	937	836	895	676	752
72708-3U	1980	798	856	778	745	694	693	737	357	195	593
72708-3U	1990	642	639	536	409	544	701	733	644	801	751
72708-3U	2000	604	686	760	809	914	850	898	693	599	-9999

72708-3D	1847	795	867	808							
72708-3D	1850	434	647	401	591	533	991	729	631	611	319
72708-3D	1860	422	349	429	297	361	339	263	300	432	214
72708-3D	1870	312	313	304	330	326	431	483	861	519	788
72708-3D	1880	636	554	276	364	124	308	354	378	538	669
72708-3D	1890	521	618	792	869	829	857	1061	1115	1009	1088
72708-3D	1900	1083	1099	921	580	985	842	709	634	842	1002
72708-3D	1910	699	147	387	326	309	336	562	640	704	700
72708-3D	1920	873	677	834	608	821	446	615	444	651	564
72708-3D	1930	541	852	680	317	585	529	577	555	566	790
72708-3D	1940	681	561	408	496	562	813	1443	851	1083	374
72708-3D	1950	345	460	363	637	449	586	527	360	333	450
72708-3D	1960	467	512	564	741	715	827	581	624	848	718
72708-3D	1970	438	462	494	326	413	415	296	448	410	386
72708-3D	1980	480	453	463	387	457	502	398	186	115	291
72708-3D	1990	419	401	291	246	338	416	512	410	429	416
72708-3D	2000	343	383	456	456	606	558	540	447	-9999	

72708-2U	1583	208	248	163	215	276	307	123			
72708-2U	1590	226	249	377	248	254	244	209	209	248	360
72708-2U	1600	445	376	338	323	175	548	608	510	575	643
72708-2U	1610	378	577	894	786	836	536	528	372	329	274
72708-2U	1620	206	202	139	145	114	163	198	140	137	149
72708-2U	1630	165	107	139	65	102	124	206	126	92	129
72708-2U	1640	120	103	68	116	218	166	43	59	0	51
72708-2U	1650	20	33	12	26	64	67	64	69	80	119
72708-2U	1660	89	140	125	247	226	260	99	123	89	99
72708-2U	1670	119	132	188	120	253	180	194	197	143	76
72708-2U	1680	73	159	177	235	95	205	386	492	215	295
72708-2U	1690	392	277	297	248	389	357	230	181	42	60
72708-2U	1700	52	105	93	158	177	177	143	137	174	248
72708-2U	1710	192	196	113	189	194	137	216	240	302	174
72708-2U	1720	319	92	336	354	302	260	307	206	223	517
72708-2U	1730	530	627	480	314	391	297	334	464	391	561
72708-2U	1740	312	337	418	498	604	547	689	709	723	1034
72708-2U	1750	531	803	816	461	280	590	628	775	415	488
72708-2U	1760	485	357	477	398	300	821	962	743	624	963
72708-2U	1770	755	949	995	767	585	804	604	694	536	783
72708-2U	1780	558	835	821	606	597	801	819	755	440	1065
72708-2U	1790	747	666	420	654	564	578	478	414	506	337
72708-2U	1800	297	320	313	503	428	353	461	298	442	345
72708-2U	1810	371	390	213	155	166	282	283	310	299	163
72708-2U	1820	210	331	280	430	404	386	428	535	776	647
72708-2U	1830	621	419	448	345	434	398	481	488	540	610
72708-2U	1840	185	525	150	180	382	321	532	274	264	438
72708-2U	1850	321	534	377	340	277	284	406	388	453	207
72708-2U	1860	361	399	385	260	390	355	324	227	346	413
72708-2U	1870	245	388	360	302	294	283	298	366	207	232
72708-2U	1880	230	368	197	238	105	215	179	259	405	597
72708-2U	1890	395	391	437	461	349	504	564	665	363	428
72708-2U	1900	366	367	327	343	389	375	220	318	391	453

72708-2U	1910	297	174	283	328	257	280	252	343	347	295
72708-2U	1920	377	336	465	399	680	634	726	686	753	486
72708-2U	1930	551	613	501	208	412	304	455	331	414	495
72708-2U	1940	437	328	265	459	679	985	1314	685	678	379
72708-2U	1950	171	435	459	481	534	489	447	173	246	307
72708-2U	1960	283	174	190	446	306	264	200	227	346	267
72708-2U	1970	239	222	264	277	230	315	311	423	324	392
72708-2U	1980	503	500	337	396	447	382	250	151	199	506
72708-2U	1990	432	447	183	212	193	236	263	148	300	261
72708-2U	2000	162	252	304	274	527	517	598	319	-9999	

72708_2D	1583	239	218	151	229	315	351	118			
72708_2D	1590	160	219	490	309	223	231	134	247	216	147
72708_2D	1600	433	473	394	376	258	606	496	422	463	429
72708_2D	1610	226	302	397	445	391	337	301	236	234	314
72708_2D	1620	264	221	167	142	110	135	286	202	294	252
72708_2D	1630	255	284	229	165	418	307	820	692	905	830
72708_2D	1640	537	385	223	363	590	425	178	111	150	86
72708_2D	1650	44	33	40	46	99	94	62	46	99	201
72708_2D	1660	160	248	555	774	787	1074	560	649	664	459
72708_2D	1670	561	590	678	573	911	462	600	650	393	250
72708_2D	1680	151	307	333	409	211	274	592	792	341	292
72708_2D	1690	489	308	301	233	439	469	314	227	74	65
72708_2D	1700	97	103	105	141	408	361	317	286	346	510
72708_2D	1710	427	348	289	344	486	381	515	484	614	451
72708_2D	1720	478	285	472	625	570	567	661	545	771	1147
72708_2D	1730	904	1231	1081	674	553	432	530	473	547	690
72708_2D	1740	484	424	468	389	456	244	280	349	305	336
72708_2D	1750	163	290	252	138	123	279	307	320	259	238
72708_2D	1760	320	293	187	180	77	302	421	377	367	545
72708_2D	1770	563	686	643	453	456	463	440	477	286	482
72708_2D	1780	367	457	540	373	479	443	447	444	329	343
72708_2D	1790	266	399	219	427	502	452	524	444	338	274
72708_2D	1800	213	307	341	402	408	339	595	429	625	564

72708_2D	1810	479	531	232	137	282	381	312	287	266	229
72708_2D	1820	296	343	163	307	275	246	278	406	557	538
72708_2D	1830	770	565	482	541	392	318	263	301	469	582
72708_2D	1840	316	377	147	66	223	195	235	119	200	282
72708_2D	1850	315	483	300	400	286	379	441	378	452	224
72708_2D	1860	382	324	333	172	332	158	146	148	202	243
72708_2D	1870	135	211	216	145	286	286	288	438	217	211
72708_2D	1880	212	204	171	107	27	150	81	163	281	459
72708_2D	1890	308	242	257	269	334	311	387	380	268	309
72708_2D	1900	315	277	260	309	356	300	214	354	452	561
72708_2D	1910	502	256	477	391	355	439	465	492	444	371
72708_2D	1920	435	292	416	251	415	411	466	406	375	389
72708_2D	1930	369	488	359	173	322	258	332	253	331	455
72708_2D	1940	573	255	270	443	679	768	930	677	693	279
72708_2D	1950	142	374	270	449	362	350	383	148	219	288
72708_2D	1960	293	242	239	305	295	215	181	153	284	166
72708_2D	1970	236	266	375	259	275	309	347	438	397	434
72708_2D	1980	530	426	336	372	379	372	220	117	194	456
72708_2D	1990	409	444	222	221	216	263	295	218	290	199
72708_2D	2000	207	205	312	285	513	517	548	284	-9999	
72708-1b	1671	344	407	256	345	305	204	311	202	118	
72708-1b	1680	226	443	400	503	196	290	899	544	230	256
72708-1b	1690	348	309	263	189	395	297	218	213	84	0
72708-1b	1700	66	132	147	392	236	159	207	236	247	334
72708-1b	1710	238	270	224	353	358	133	252	175	227	144
72708-1b	1720	272	37	136	148	125	204	160	134	177	485
72708-1b	1730	381	490	421	277	440	187	189	297	218	447
72708-1b	1740	287	180	269	286	328	244	205	225	248	361
72708-1b	1750	151	181	303	361	109	383	263	432	171	293
72708-1b	1760	342	366	424	441	294	614	506	337	258	347
72708-1b	1770	332	293	283	424	312	254	272	428	297	586
72708-1b	1780	379	923	498	366	294	365	525	386	332	444
72708-1b	1790	404	345	142	206	186	282	296	153	533	399

72708-1b	1800	216	175	159	193	187	168	204	172	177	114
72708-1b	1810	113	380	206	0	76	21	59	57	72	71
72708-1b	1820	116	247	295	525	369	269	236	364	344	175
72708-1b	1830	226	232	315	302	363	185	173	187	286	355
72708-1b	1840	103	421	128	68	252	268	500	310	361	471
72708-1b	1850	314	431	159	161	151	258	218	221	711	573
72708-1b	1860	525	400	304	263	414	177	231	234	478	312
72708-1b	1870	147	160	142	62	260	282	235	493	252	339
72708-1b	1880	366	315	296	298	67	273	398	257	233	571
72708-1b	1890	436	519	503	480	319	280	489	559	274	310
72708-1b	1900	649	401	367	396	490	368	363	691	970	1126
72708-1b	1910	449	226	460	320	310	274	348	300	238	398
72708-1b	1920	703	518	580	419	845	542	704	516	659	488
72708-1b	1930	560	675	674	307	648	628	503	366	486	579
72708-1b	1940	594	469	455	599	473	809	723	330	756	437
72708-1b	1950	517	707	569	606	499	503	469	517	350	596
72708-1b	1960	438	439	640	801	385	435	408	521	371	389
72708-1b	1970	352	335	372	392	473	374	296	715	596	723
72708-1b	1980	439	425	351	477	573	1382	1145	661	535	523
72708-1b	1990	545	383	281	156	339	303	455	301	384	290
72708-1b	2000	275	354	404	413	667	512	525	533	-9999	
72708-1a	1626	381	249	490	451						
72708-1a	1630	363	319	329	154	245	354	341	337	298	228
72708-1a	1640	266	240	191	303	313	139	58	61	61	75
72708-1a	1650	26	41	54	114	191	114	50	66	111	198
72708-1a	1660	239	208	96	126	199	303	189	173	154	220
72708-1a	1670	196	300	474	296	418	306	207	285	184	113
72708-1a	1680	164	301	296	267	108	199	487	352	192	222
72708-1a	1690	262	197	192	146	233	215	150	135	100	0
72708-1a	1700	60	100	0	84	126	61	141	133	203	283
72708-1a	1710	308	348	313	225	289	333	132	197	167	282
72708-1a	1720	226	281	189	167	175	279	183	59	44	193
72708-1a	1730	194	313	314	205	274	167	106	197	129	239

72708-1a	1740	213	141	168	228	208	135	212	266	296	409
72708-1a	1750	143	191	321	346	136	393	243	357	263	273
72708-1a	1760	349	377	396	440	192	508	507	291	282	380
72708-1a	1770	356	322	326	581	448	258	287	436	309	528
72708-1a	1780	483	1116	498	398	333	316	346	218	101	447
72708-1a	1790	233	265	119	181	184	222	282	127	316	217
72708-1a	1800	162	164	118	109	168	172	213	197	192	158
72708-1a	1810	181	259	158	0	56	56	57	90	73	57
72708-1a	1820	159	139	308	324	205	159	218	258	126	185
72708-1a	1830	225	302	309	0	272	184	119	152	144	221
72708-1a	1840	57	189	41	211	107	353	238	271	375	266
72708-1a	1850	312	128	99	67	139	150	107	247	201	200
72708-1a	1860	179	149	113	180	24	76	70	119	194	96
72708-1a	1870	142	128	0	36	150	195	202	298	313	440
72708-1a	1880	381	355	212	287	58	160	203	235	252	464
72708-1a	1890	409	382	223	251	153	136	293	411	249	307
72708-1a	1900	452	98	107	157	213	254	197	349	558	534
72708-1a	1910	222	83	210	184	187	196	269	201	172	200
72708-1a	1920	289	285	380	330	613	355	620	287	251	341
72708-1a	1930	311	440	290	119	344	482	371	287	313	216
72708-1a	1940	303	265	328	408	500	471	580	272	562	286
72708-1a	1950	443	577	422	382	459	406	361	298	204	466
72708-1a	1960	304	200	264	311	214	218	201	195	306	239
72708-1a	1970	229	291	336	332	372	430	362	505	427	569
72708-1a	1980	612	387	355	437	464	856	768	386	390	424
72708-1a	1990	482	336	279	109	322	306	515	357	349	324
72708-1a	2000	267	421	531	630	606	527	586	748	-9999	

Appendix B: COFECHA Output file for Chigertey Gol Valley (CG)

```
------------------------------------------------------------------------------------
[]  Dendrochronology Program Library                                     Run Master24  Program COF
19:48  Sun 26 Apr 2009  Page   1
[]
[]  P R O G R A M      C O F E C H A
Version 6.06P    27146
----------------------------------------------------------------------------------------------------
-------------------------------

 QUALITY CONTROL AND DATING CHECK OF TREE-RING MEASUREMENTS

 File of DATED series:   Master_24.txt

 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  1704 to  2008   305 years
 Continuous time span is               1704 to  2008   305 years
 Portion with two or more series is    1712 to  2008   297 years


                       ****************************************
                       *C* Number of dated series       20 *C*
                       *O* Master series 1704 2008  305 yrs *O*
                       *F* Total rings in all series   3064 *F*
                       *E* Total dated rings checked   3056 *E*
                       *C* Series intercorrelation     .601 *C*
                       *H* Average mean sensitivity    .290 *H*
                       *A* Segments, possible problems    5 *A*
                       *** Mean length of series      153.2 ***
                       ****************************************


PART 2:  TIME PLOT OF TREE-RING SERIES:
19:48  Sun 26 Apr 2009  Page   2
-------------------------------------------------------------------------------------
1500 1550 1600 1650 1700 1750 1800 1850 1900 1950 2000 2050 Ident   Seq Time-span  Yrs
   :    :    :    :    :    :    :    :    :    :    :    : -------- --- ---- ---- ----
   .    .    .    .    .    .    .<===================>    . 7240812a   1 1814 2007  194
   .    .    .    .    .    .    .<===================>    . 7240812b   2 1813 2007  195
   .    .    .    .    .    .    .  <=================>    . 7240811a   3 1832 2007  176
   .    .    .    .    .    .    .<===================>    . 7240811b   4 1814 2007  194
```

```
   .    .    .    .    .    .    .    <==============>    . 7240811c   5 1850 2007  158
   .    .    .    .    .    .    . <=================>    . 72408-6b   6 1828 2008  181
   .    .    .    .    .    .    .    .   <==========>    . 72408-6a   7 1892 2007  116
   .    .    .    .    .    .    .    .    . <=======>    . 72408-1    8 1928 2008   81
   .    .    .    .    .    .    .    .    . <=======>    . 72408-8    9 1924 2007   84
   .    .    .    .    .    .    .    .    <=========>    . 7240813a  10 1900 2007  108
   .    .    .    .    .    .    .    .    <=========>    . 7240813b  11 1902 2007  106
   .    .    .    .    .<============================>    . 7240810b  12 1712 2008  297
   .    .    .    .    .    .    .    .   <==========>    . 72708-9   13 1892 2007  116
   .    .    .    .    .    .    .  <================>    . 7240815A  14 1831 2007  177
   .    .    .    .    .    .<=======================>    . 7240815B  15 1768 2007  240
   .    .    .    .    .    .    .    .   <==========>    . 240814aU  16 1891 2007  117
   .    .    .    .    .    .    .    .   <==========>    . 240814aD  17 1891 2007  117
   .    .    .    .    .    .    .    .  <===========>    . 240814bU  18 1889 2008  120
   .    .    .    .    .    .    .    .<=============>    . 7240810a  19 1860 2007  148
   .    .    .    .    <=============>.    .    .    .    . 7240810c  20 1704 1842  139
   :    :    :    :    :    :    :    :    :    :    :    :
1500 1550 1600 1650 1700 1750 1800 1850 1900 1950 2000 2050
```

```
PART 4:  Master Bar Plot:
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----------------------------------------------------------------------------------------------------
-------------------------------
   Year Rel value  Year Rel value  Year Rel value  Year Rel value  Year Rel value  Year Rel value
Year Rel value  Year Rel value
                   1750h           1800-e          1850--c         1900----a       1950---b
2000-----@
                   1751--b         1801----------F 1851--------C   1901---------D  1951-----@
2001--------C
                   1752----------H 1802--------C   1852h           1902--------C   1952----a
2002------B
```

	1753--------C	1803----------F	1853------A	1903----a	1953-----@
2003---a					
1704----------J	1754h	1804--------C	1854-e	1904---------E	1954--c
2004----a					
1705-----A	1755----------F	1805---------E	1855-----A	1905---------D	1955-------B
2005-d					
1706-e	1756--c	1806-------B	1856-----@	1906----@	1956-----@
2006-------B					
1707-e	1757----a	1807----@	1857-----@	1907-------B	1957---------E
2007--d					
1708-d	1758-d	1808-------C	1858-----A	1908------B	1958-e
2008--d					
1709-------B	1759-e	1809-------B	1859--c	1909----a	1959----------F
1710------B	1760-e	1810-------B	1860--------C	1910f	1960--------C
1711---b	1761------A	1811---------D	1861---------D	1911g	1961i
1712-e	1762------A	1812-----@	1862---------E	1912----a	1962------B
1713---------D	1763---------E	1813-e	1863---b	1913--c	1963---------D
1714f	1764-e	1814g	1864---------E	1914-----@	1964----@
1715----------F	1765----------I	1815----a	1865-----A	1915----------F	1965h
1716---a	1766---------D	1816---b	1866---b	1916----------G	1966-e
1717--------C	1767--------C	1817----a	1867---b	1917-----@	1967--d
1718---------E	1768-d	1818----a	1868-----@	1918-e	1968------A
1719-f	1769-d	1819----a	1869--b	1919--c	1969---a
1720---------E	1770---b	1820-----@	1870-e	1920-----A	1970----@
1721----@	1771---b	1821--------C	1871---a	1921---a	1971-------B
1722--c	1772------A	1822-----@	1872----a	1922-------C	1972---------E
1723-e	1773---------E	1823---b	1873-------C	1923-----@	1973---a
1724---b	1774-------B	1824-----A	1874--------D	1924----------E	1974------B
1725-------B	1775-e	1825-------B	1875----@	1925-------B	1975----------E
1726----------E	1776-e	1826-------C	1876---b	1926---------D	1976----a
1727-e	1777----------F	1827------A	1877----------G	1927------A	1977--------C
1728j	1778------B	1828------B	1878-------B	1928-d	1978---b
1729-------B	1779----------F	1829-----A	1879---------E	1929g	1979------A
1730-e	1780----a	1830----------F	1880-------B	1930-------C	1980--------C

```
   1731--------C   1781----------F 1831--------C   1881--------C   1931--------C   1981---------E
   1732-----A      1782---a        1832--------C   1882---b        1932------B     1982--c
   1733--------D   1783h           1833-------B    1883--c         1933n           1983j
   1734----------L 1784-e          1834------A     1884h           1934---b        1984--c
   1735------A     1785---b        1835-e          1885g           1935--------C   1985-------B
   1736--c         1786----------H 1836g           1886-e          1936-----@      1986-------B
   1737--------C   1787--------C   1837-f          1887g           1937-e          1987-----A
   1738------B     1788--c         1838----a       1888-----@      1938--c         1988-e
   1739--------C   1789---------E  1839--------C   1889--------C   1939------A     1989----@
   1740--c         1790---------E  1840----a       1890----@       1940-------B    1990--------C
   1741---a        1791------A     1841-------C    1891-------B    1941------A     1991--------C
   1742---------E  1792----a       1842i           1892--------C   1942-------B    1992---a
   1743--c         1793-----@      1843----a       1893--------C   1943------B     1993-f
   1744-----A      1794----a       1844-------B    1894------A     1944-------B    1994-----A
   1745g           1795--d         1845-----A      1895--c         1945--------D   1995-----A
   1746--c         1796--c         1846----------G 1896-----@      1946------A     1996---------E
   1747----------F 1797h           1847-f          1897----a       1947--d         1997-----@
   1748------B     1798--c         1848-----@      1898h           1948----------E 1998--------C
   1749------A     1799-d          1849----------F 1899--c         1949--c         1999----a
```

```
PART 5:  CORRELATION OF SERIES BY SEGMENTS:
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----------------------------------------------------------------------------------------------------
-------------------------------
 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   1700 1725 1750 1775 1800 1825 1850 1875 1900 1925 1950 1975
                         1749 1774 1799 1824 1849 1874 1899 1924 1949 1974 1999 2024
 --- -------- ---------  ---- ---- ---- ---- ---- ---- ---- ---- ---- ---- ---- ---- ---- ---- ----
   1 7240812a 1814 2007                      .54  .64  .63  .69  .75  .79  .74  .71
```

2	7240812b	1813	2007					.54	.59	.57	.63	.72	.83	.78	.79
3	7240811a	1832	2007						.76	.69	.67	.71	.78	.76	.79
4	7240811b	1814	2007					.35	.30B	.37	.71	.50	.59	.66	.68
5	7240811c	1850	2007							.75	.71	.75	.72	.67	.58
6	72408-6b	1828	2008						.59	.50	.50	.52	.49	.67	.64
7	72408-6a	1892	2007								.35	.31A	.44	.70	.65
8	72408-1	1928	2008										.35	.76	.68
9	72408-8	1924	2007									.53	.55	.44	.45B
10	7240813a	1900	2007									.84	.70	.56	.66
11	7240813b	1902	2007									.71	.63	.53	.58
12	7240810b	1712	2008	.62	.61	.73	.62	.53	.53	.44	.59	.69	.68	.68	.53
13	72708-9	1892	2007								.23B	.35	.61	.50	.45
14	7240815A	1831	2007						.57	.58	.78	.74	.67	.58	.56
15	7240815B	1768	2007			.30A	.38	.52	.64	.65	.75	.78	.70	.63	.64
16	240814aU	1891	2007								.73	.76	.79	.67	.68
17	240814aD	1891	2007								.79	.76	.70	.34	.35
18	240814bU	1889	2008								.71	.68	.75	.71	.67
19	7240810a	1860	2007							.37	.57	.74	.66	.64	.60
20	7240810c	1704	1842	.62	.63	.72	.63	.61							
Av segment correlation				.62	.62	.58	.54	.51	.58	.55	.63	.66	.65	.63	.62

PART 6: POTENTIAL PROBLEMS:
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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
=====================================================================================================
===============================

 7240812a  1814 to  2007     194 years
Series   1

 [B] Entire series, effect on correlation (  .667) is:
       Lower   1918> -.012   1852> -.011   1823< -.008   1958> -.007   1821< -.006   2005> -.005
Higher   1933  .018   1898  .008

 [E] Outliers     1   3.0 SD above or -4.5 SD below mean for year
       1961 -6.0 SD
=====================================================================================================
===============================

 7240812b  1813 to  2007     195 years
Series   2

 [B] Entire series, effect on correlation (  .675) is:
       Lower   1852> -.015   1918> -.014   1845< -.007   1926< -.006   1850< -.006   1842> -.005
Higher   1933  .024   1961  .016

 [E] Outliers     1   3.0 SD above or -4.5 SD below mean for year
       1918 +3.1 SD
=====================================================================================================
===============================
```

```
 7240811a  1832 to  2007     176 years
Series   3

 [B] Entire series, effect on correlation (  .732) is:
       Lower   1889< -.010   1908< -.008   1957< -.007   1900> -.007   1942< -.006   1997> -.006
Higher   1933  .012   1842  .009

====================================================================================================
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 7240811b  1814 to  2007     194 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
    ---------  ----   ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---
---  ---  ---  ---  ---
    1825 1874    5   -.03 -.21  .08 -.08 -.12  .29 -.25  .02 -.21  .11  .30|-.22  .11  .05 -.08
.32*-.17  .10  .07 -.18  .14

 [B] Entire series, effect on correlation (  .548) is:
       Lower   1854> -.017   1864< -.014   1832< -.013   1933> -.012   1950< -.010   1934< -.010
Higher   1852  .025   1961  .015
     1825 to 1874 segment:
       Lower   1854> -.053   1864< -.040   1832< -.037   1865> -.024   1850> -.023   1863> -.022
Higher   1852  .148   1842  .055

 [D]    1 Absent rings:  Year   Master  N series Absent
                         1852   -2.069       9       1

 [E] Outliers     1   3.0 SD above or -4.5 SD below mean for year
       1854 +3.4 SD
```

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

 7240811c  1850 to  2007     158 years
Series   5

 [B] Entire series, effect on correlation (  .696) is:
       Lower   2007> -.012   1938< -.011   1963< -.011   1958> -.009   1900> -.006   1908< -.006
Higher   1933  .038   1852  .014

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 72408-6b  1828 to  2008     181 years
Series   6

 [B] Entire series, effect on correlation (  .556) is:
       Lower   1933> -.037   1882> -.010   1863> -.009   1828< -.009   1943< -.007   1893< -.007
Higher   1852  .017   1847  .014

 [E] Outliers     4   3.0 SD above or -4.5 SD below mean for year
       1842 -6.4 SD;    1882 +3.1 SD;    1888 +3.1 SD;    1933 +4.7 SD
====================================================================================================
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 72408-6a  1892 to  2007     116 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
    ---------  ----   ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---
---  ---  ---  ---  ---
    1900 1949    0    .07  .16  .23 -.09 -.02  .03  .07  .22 -.15  .09  .31*-.06  .00 -.30 -.06 -.02
-.07  .00 -.20 -.12  .15
```

```
 [B] Entire series, effect on correlation (  .499) is:
       Lower   1933> -.053   1936< -.043   1910> -.023   1904< -.016   1972< -.016   2003< -.013
Higher   1961  .027   1898  .023
     1900 to 1949 segment:
       Lower   1933> -.088   1936< -.075   1910> -.046   1904< -.029   1939< -.022   1907< -.010
Higher   1918  .033   1937  .032

 [E] Outliers     2   3.0 SD above or -4.5 SD below mean for year
       1910 +3.6 SD;    1933 +4.3 SD
=====================================================================================================
===============================

 72408-1   1928 to  2008      81 years
Series   8

 [B] Entire series, effect on correlation (  .407) is:
       Lower   1933> -.098   1928> -.025   1947> -.022   2003< -.016   1981< -.014   1930< -.013
Higher   1961  .060   1965  .033

 [C] Year-to-year changes diverging by over 4.0 std deviations:
       1932 1933   4.0 SD

 [E] Outliers     2   3.0 SD above or -4.5 SD below mean for year
       1933 +4.8 SD;    1947 +3.2 SD
=====================================================================================================
===============================

 72408-8   1924 to  2007      84 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
```

```
    ---------  ----   ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---
---  ---  ---  ---  ---
    1958 2007   -4   -.14 -.03  .04 -.19 -.20 -.10  .51* .16 -.23 -.25  .45| .31    -    -    -    -
-    -    -    -    -

 [B] Entire series, effect on correlation (  .479) is:
       Lower   1986< -.040   1943< -.030   1935< -.014   1977< -.013   1944< -.012   1927> -.010
Higher   1933  .135   1965  .025
     1958 to 2007 segment:
       Lower   1986< -.078   1977< -.022   1993> -.019   1972< -.014   1973> -.012   1999> -.011
Higher   1965  .050   1975  .025

====================================================================================================
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 7240813a  1900 to  2007     108 years
Series  10

 [B] Entire series, effect on correlation (  .697) is:
       Lower   1956< -.032   1955< -.010   1982> -.010   1989< -.009   1900< -.008   1984< -.008
Higher   1933  .065   1965  .010

====================================================================================================
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 7240813b  1902 to  2007     106 years
Series  11

 [B] Entire series, effect on correlation (  .639) is:
       Lower   1999< -.020   1946< -.018   1962< -.014   1938> -.010   1992> -.010   1948< -.009
Higher   1933  .078   1983  .010

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```
 7240810b  1712 to  2008     297 years
Series  12

 [B] Entire series, effect on correlation (  .558) is:
       Lower   1813< -.020   1727> -.012   2001< -.010   1733< -.008   1870> -.007   1835> -.006
Higher   1933  .014   1734  .008

 [C] Year-to-year changes diverging by over 4.0 std deviations:
       1812 1813  -5.1 SD    1813 1814   4.1 SD

 [D]    1 Absent rings:  Year   Master  N series Absent
                         1813   -1.299       4      1
                                                        Present in series    2  7240812b time span
1813 to  2007
                                                        Present in series   15  7240815B time span
1768 to  2007
                                                        Present in series   20  7240810c time span
1704 to  1842

 [E] Outliers     2   3.0 SD above or -4.5 SD below mean for year
       1813 -8.5 SD;    1870 +3.1 SD
====================================================================================================
===============================

 72708-9   1892 to  2007     116 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
    ---------  ----   ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---
---  ---  ---  ---  ---
    1892 1941   -4   -.05 -.17 -.28 -.33 -.25  .09  .24* .22  .22  .23  .23| .14 -.27 -.28 -.21  .05
.06  .05  .16  .08 -.01
```

```
 [B] Entire series, effect on correlation (  .387) is:
       Lower   1918> -.023   1996< -.017   1898> -.015   1902< -.015   2000< -.012   2003> -.012
Higher   1933  .031   1958  .020
     1892 to 1941 segment:
       Lower   1918> -.058   1902< -.039   1898> -.030   1895> -.021   1932< -.021   1917> -.017
Higher   1933  .164   1924  .032

 [E] Outliers     2   3.0 SD above or -4.5 SD below mean for year
       1918 +3.9 SD;    2003 +3.0 SD
====================================================================================================
===============================

 7240815A  1831 to  2007     177 years
Series  14

 [B] Entire series, effect on correlation (  .640) is:
       Lower   1937< -.012   1870> -.011   1866< -.011   1968< -.009   1965> -.007   1863> -.006
Higher   1933  .023   1842  .015

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 7240815B  1768 to  2007     240 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
    ---------  ----   ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---
---  ---  ---  ---  ---
    1768 1817    0   -.20 -.08  .00  .05 -.19 -.13 -.31 -.35 -.08  .04  .30* .16  .19  .19  .19  .13
.01  .07  .29  .00 -.31

 [B] Entire series, effect on correlation (  .592) is:
```

```
      Lower   1768> -.020   1811< -.019   1812< -.007   1929> -.007   1854> -.006   1952< -.005
Higher   1933  .032   1852  .010
     1768 to 1817 segment:
      Lower   1811< -.077   1768> -.075   1812< -.030   1793< -.019   1776< -.015   1770< -.014
Higher   1786  .044   1783  .036

 [E] Outliers     1   3.0 SD above or -4.5 SD below mean for year
      1768 +3.6 SD
====================================================================================================
===============================

 240814aU  1891 to  2007     117 years
Series  16

 [B] Entire series, effect on correlation (  .686) is:
      Lower   1983< -.060   1900< -.017   1898> -.009   1927< -.008   1945< -.008   1929> -.007
Higher   1933  .050   1961  .008

 [C] Year-to-year changes diverging by over 4.0 std deviations:
      1982 1983  -4.1 SD

 [E] Outliers     1   3.0 SD above or -4.5 SD below mean for year
      1983 -8.0 SD
====================================================================================================
===============================

 240814aD  1891 to  2007     117 years
Series  17

 [B] Entire series, effect on correlation (  .574) is:
      Lower   1995< -.046   1994> -.019   1900< -.015   1927< -.013   1961> -.009   1955< -.008
Higher   1933  .091   1898  .016

 [C] Year-to-year changes diverging by over 4.0 std deviations:
```

```
       1932 1933  -4.6 SD

 [E] Outliers     1   3.0 SD above or -4.5 SD below mean for year
       1994 +5.0 SD
====================================================================================================
===============================

 240814bU  1889 to  2008     120 years
Series  18

 [B] Entire series, effect on correlation (  .648) is:
       Lower   1945< -.035   1900< -.018   1927< -.017   1990< -.012   1986< -.011   1898> -.009
Higher   1933  .076   1961  .025

 [E] Outliers     1   3.0 SD above or -4.5 SD below mean for year
       1945 -4.5 SD
====================================================================================================
===============================

 7240810a  1860 to  2007     148 years
Series  19

 [B] Entire series, effect on correlation (  .566) is:
       Lower   1891< -.021   1870< -.017   1961> -.015   1992< -.012   1888< -.012   1933> -.010
Higher   1898  .013   1965  .010

====================================================================================================
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 7240810c  1704 to  1842     139 years
Series  20

 [*] Early part of series cannot be checked from 1704 to 1711 -- not matched by another series
```

```
 [B] Entire series, effect on correlation (  .626) is:
       Lower   1733> -.016   1842> -.014   1727< -.013   1730> -.013   1776> -.011   1716> -.010
Higher   1754  .012   1734  .012

 [E] Outliers     1   3.0 SD above or -4.5 SD below mean for year
       1733 +3.4 SD
====================================================================================================
===============================


PART 7:  DESCRIPTIVE STATISTICS:
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----------------------------------------------------------------------------------------------------
-------------------------------

                                                              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 7240812a 1814 2007    194      8      0    .667    .51   1.22   .237   .753   .261   2.44   .315
-.014   1
   2 7240812b 1813 2007    195      8      0    .675    .50   1.40   .242   .773   .274   2.48   .397
-.048   1
   3 7240811a 1832 2007    176      7      0    .732    .51   1.76   .265   .748   .303   2.64   .346
-.015   1
   4 7240811b 1814 2007    194      8      1    .548    .54   1.14   .217   .667   .300   2.47   .335
.002   1
   5 7240811c 1850 2007    158      6      0    .696    .65   1.77   .287   .671   .277   2.81   .454
-.014   1
```

6	72408-6b	1828	2008	181	7	0	.556	.76	1.85	.295	.625	.272	2.50	.328	-.053	2
7	72408-6a	1892	2007	116	5	1	.499	.81	1.78	.333	.598	.276	2.54	.470	.023	1
8	72408-1	1928	2008	81	3	0	.407	1.89	3.62	.889	.698	.341	2.40	.408	.046	1
9	72408-8	1924	2007	84	4	1	.479	1.13	2.94	.579	.796	.267	2.57	.428	.047	1
10	7240813a	1900	2007	108	4	0	.697	1.00	2.19	.337	.575	.252	2.47	.411	-.002	1
11	7240813b	1902	2007	106	4	0	.639	.97	2.04	.283	.607	.194	2.52	.407	-.021	1
12	7240810b	1712	2008	297	12	0	.558	.51	1.55	.263	.817	.269	2.53	.283	.012	1
13	72708-9	1892	2007	116	5	1	.387	.77	2.13	.442	.751	.369	2.69	.429	-.064	2
14	7240815A	1831	2007	177	7	0	.640	.70	1.47	.259	.578	.281	2.56	.436	.021	1
15	7240815B	1768	2007	240	10	1	.592	.52	1.32	.249	.635	.337	2.80	.424	-.022	1
16	240814aU	1891	2007	117	5	0	.686	.77	1.81	.341	.581	.331	2.38	.300	.046	1
17	240814aD	1891	2007	117	5	0	.574	1.54	65.11	5.942	.001	.331	3.07	.367	-.019	1
18	240814bU	1889	2008	120	5	0	.648	.82	1.97	.338	.556	.310	2.47	.321	-.054	1
19	7240810a	1860	2007	148	6	0	.566	.34	.87	.143	.633	.307	2.52	.449	-.001	1
20	7240810c	1704	1842	139	5	0	.626	.43	.97	.172	.647	.257	2.81	.573	.083	1
---	--------	---------		-----	-----	-----	------	-----	-----	-----	-----	-----	-----	-----	-----	--
Total or mean:				3064	124	5	.601	.70	65.11	.510	.652	.290	3.07	.386	-.005	

Appendix C: COFECHA Output file for Leya Gol Valley (LG)

```
--------------------------------------------------------------------------------
[]  Dendrochronology Program Library                              Run Master_27
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[]  P R O G R A M      C O F E C H A
Version 6.06P    27146
--------------------------------------------------------------------------------

 QUALITY CONTROL AND DATING CHECK OF TREE-RING MEASUREMENTS

 File of DATED series:   Master_27.txt

 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  1583 to  2008   426 years
 Continuous time span is               1583 to  2008   426 years
 Portion with two or more series is    1583 to  2008   426 years

 >> 0727081a    1833 absent in   1 of    4 series, but is not usually narrow: master index is   .281
 >> 0727081a    1872 absent in   1 of    6 series, but is not usually narrow: master index is  -.357

                   ****************************************
                   *C* Number of dated series        12 *C*
                   *O* Master series 1583 2008  426 yrs *O*
                   *F* Total rings in all series   2470 *F*
                   *E* Total dated rings checked   2470 *E*
                   *C* Series intercorrelation     .618 *C*
                   *H* Average mean sensitivity    .300 *H*
                   *A* Segments, possible problems    6 *A*
                   *** Mean length of series      205.8 ***
                   ****************************************

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

 72708-2U    1 absent rings:   1648
 0727081b    2 absent rings:   1699  1813
 0727081a    5 absent rings:   1699  1702  1813  1833  1872

             8 absent rings    .324%


PART 2:  TIME PLOT OF TREE-RING SERIES:
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------------------------------------------------------------------------------------
1500 1550 1600 1650 1700 1750 1800 1850 1900 1950 2000 2050 Ident   Seq Time-span Yrs
 :    :    :    :    :    :    :    :    :    :    :    : -------- --- ---- ---- ----
```

```
  .    .    .    .    .    .    .    .  <===========>    . 072708-8   1 1886 2008  123
  .    .    .    .    .    .    .    .  <===========>    . 72708-7a   2 1887 2008  122
  .    .    .    .    .    .    .    .    <=========>    . 72708-7b   3 1902 2008  107
  .    .    .    .    .    .    .    .    . <=======>    . 072708-6   4 1928 2008   81
  .    .    .    .    .    .    .    .    .   <=====>    . 072708-5   5 1943 2008   66
  .    .    .    .    .    .    .    .    .  <======>    . 72708-4W   6 1930 2008   79
  .    .    .    .    .    .    .   <===============>    . 72708-3U   7 1847 2008  162
  .    .    .    .    .    .    .   <===============>    . 72708-3D   8 1847 2007  161
  .    .  <==========================================>    . 72708-2U   9 1583 2007  425
  .    .  <==========================================>    . 72708-2D  10 1583 2007  425
  .    .    .    . <=================================>    . 0727081b  11 1671 2007  337
  .    .    . <======================================>    . 0727081a  12 1626 2007  382
  :    :    :    :    :    :    :    :    :    :    :    :    :    :    :    :    :
1500 1550 1600 1650 1700 1750 1800 1850 1900 1950 2000 2050
```

PART 3: Master Dating Series:
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Year	Value	No Ab	Year	Value	No Ab	Year	Value	No Ab	Year	Value	No Ab	Year	Value	No Ab	Year	Value	No Ab
1850	-.124	6	1900	.573	8	1950	-.575	12	2000	-.464	12						
1851	.713	6	1901	.106	8	1951	.654	12	2001	-.047	12						
1852	-1.036	6	1902	-.142	9	1952	-.204	12	2002	.650	12						
1853	-.504	6	1903	-.682	9	1953	.025	12	2003	.559	12						
1854	-.507	6	1904	.290	9	1954	-.540	12	2004	1.622	12						
1855	.675	6	1905	.292	9	1955	.020	12	2005	.376	12						
1856	.686	6	1906	-1.142	9	1956	-.022	12	2006	.660	12						
1857	.730	6	1907	-.313	9	1957	-.440	12	2007	-.225	12						
1858	1.443	6	1908	1.080	9	1958	-1.695	12	2008	-1.785	7						
1859	-.551	6	1909	1.548	9	1959	.641	12									

1860	.738	6		1910	.100	9	1960	-.171	12
1861	.490	6		1911	-2.429	9	1961	-.391	12
1862	.470	6		1912	-.548	9	1962	.175	12
1863	-.617	6		1913	-.976	9	1963	1.552	12
1864	.033	6		1914	-1.094	9	1964	.376	12
1865	-.611	6		1915	-.786	9	1965	.343	12
1866	-.946	6		1916	.333	9	1966	-.418	12
1867	-.946	6		1917	.547	9	1967	-.358	12
1868	.889	6		1918	.358	9	1968	.693	12
1869	.097	6		1919	.200	9	1969	-.214	12
1870	-.947	6		1920	1.128	9	1970	-.737	12
1871	-.351	6		1921	-.174	9	1971	-.940	12
1872	-.357	6	1<<	1922	.482	9	1972	-.436	12
1873	-1.394	6		1923	-.850	9	1973	-1.145	12
1874	.102	6		1924	1.149	9	1974	-.339	12
1875	.508	6		1925	-.328	9	1975	.165	12
1876	.460	6		1926	.814	9	1976	-.167	12
1877	1.933	6		1927	-.125	9	1977	1.076	12
1878	.234	6		1928	.779	10	1978	.324	12
1879	1.088	6		1929	.009	10	1979	.897	12
1880	.833	6		1930	.351	11	1980	.949	12
1881	.857	6		1931	1.395	11	1981	.620	12
1882	-.495	6		1932	.538	11	1982	.398	12
1883	-.372	6		1933	-3.215	11	1983	.222	12
1884	-4.007	6		1934	-.013	11	1984	.562	12
1885	-.873	6		1935	.138	11	1985	.600	12
1886	-1.053	7		1936	.209	11	1986	.310	12
1887	-.604	8		1937	-.593	11	1987	-1.379	12
1888	.162	8		1938	-.637	11	1988	-2.057	12
1889	1.628	8		1939	-.317	11	1989	.349	12

```
  1890   .172   8       1940   .242  11       1990   .892  12
  1891   .311   8       1941  -.471  11       1991  1.118  12
  1892  -.040   8       1942  -.850  11       1992  -.676  12
  1893   .211   8       1943   .208  12       1993 -2.355  12
  1894   .263   8       1944   .018  12       1994  -.596  12
  1895   .000   8       1945   .962  12       1995  -.991  12
  1896   .977   8       1946  1.834  12       1996   .457  12
  1897  1.411   8       1947  -.359  12       1997  -.804  12
  1898  -.076   8       1948  1.290  12       1998   .719  12
  1899   .197   8       1949  -.850  12       1999  -.086  12
----------------------------------------------------------------------------------------------------
-------------------------------

PART 4:  Master Bar Plot:
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----------------------------------------------------------------------------------------------------
-------------------------------
   Year Rel value  Year Rel value  Year Rel value  Year Rel value  Year Rel value  Year Rel value
Year Rel value  Year Rel value
                   1600---------D  1650f           1700h           1750g           1800-d
1850----@       1900-------B
                   1601--------C   1651-e          1701-d          1751----@       1801--b
1851--------C   1901-----@
                   1602-----@      1652-f          1702-e          1752--------C   1802--c
1852-d          1902----a
                   1603---a        1653-c          1703-----@      1753---a        1803------A
1853--b         1903--c
                   1604j           1654------A     1704--------C   1754l           1804-------B
1854--b         1904------A
                   1605----------F 1655----a       1705----@       1755---------D  1805-----@
1855--------C   1905------A
                   1606---------E  1656-d          1706-----A      1756------A     1806---------E
1856--------C   1906-e
```

```
                1607-------B    1657-d          1707-----@      1757---------E  1807------B
1857--------C   1907---a
                1608---------D  1658--b         1708-------B    1758-c          1808---------E
1858----------F 1908---------D
                1609---------D  1659-------B    1709----------G 1759---a        1809-------B
1859--b         1909----------F
                1610-e          1660-----@      1710---------D  1760------A     1810--------C
1860--------C   1910-----@
                1611-----@      1661-------B    1711--------C   1761-----@      1811----------G
1861-------B    1911j
                1612----------F 1662-----@      1712---b        1762----@       1812---a
1862-------B    1912--b
                1613----------F 1663---------D  1713-------B    1763---a        1813l
1863--b         1913-d
                1614----------F 1664---------E  1714---------D  1764l           1814-e
1864-----@      1914-d
                1615--------C   1665----------H 1715--b         1765---------E  1815--b
1865--b         1915-c
                1616-------B    1666----@       1716------A     1766----------E 1816--b
1866-d          1916------A
                1617---b        1667-----@      1717-----A      1767-----@      1817---b
1867-d          1917-------B
                1618---b        1668--b         1718--------C   1768--b         1818--b
1868---------D  1918------A
                1619-----A      1669--b         1719---a        1769--------C   1819h
1869-----@      1919------A
                1620--b         1670---a        1720-------B    1770------B     1820--c
1870-d          1920---------E
                1621--c         1671-------B    1721k           1771-------B    1821------A
1871---a        1921----a
                1622h           1672----------E 1722----a       1772-------B    1822---a
1872---a        1922-------B
                1623h           1673----@       1723-----@      1773--------C   1823---------E
1873-f          1923-c
```

1624l 1674----------F 1724---a 1774----a 1824------B
1874-----@ 1924---------E
1625f 1675------A 1725-----@ 1775--b 1825----a
1875-------B 1925---a
1626------A 1676----a 1726----@ 1776--c 1826-----@
1876-------B 1926--------C
1627-f 1677-------B 1727g 1777------A 1827---------D
1877----------H 1927----@
1628-------B 1678-c 1728-f 1778g 1828---------D
1878------A 1928--------C
1629-------B 1679i 1729----------F 1779---------D 1829-------B
1879---------D 1929-----@
1630------A 1680h 1730---------D 1780--b 1830---------D
1880--------C 1930------A
1631---a 1681-----@ 1731----------H 1781----------H 1831-------B
1881--------C 1931----------F
1632-----@ 1682-----A 1732----------F 1782---------D 1832--------C
1882--b 1932-------B
1583--------C 1633j 1683-------B 1733-----@ 1783---a 1833------A
1883---a 1933m
1584--------C 1634----a 1684g 1734-------B 1784----a 1834--------C
1884p 1934----@
1585-d 1635-------B 1685---a 1735-d 1785------A 1835---a
1885-c 1935-----A
1586------A 1636----------G 1686----------H 1736-d 1786--------C 1836--b
1886-d 1936------A
1587----------E 1637---------D 1687----------H 1737-----@ 1787------A 1837----a
1887--b 1937--b
1588----------F 1638---------D 1688---a 1738--b 1788g 1838-------B
1888-----A 1938--c
1589k 1639---------D 1689-----@ 1739----------E 1789---------E 1839----------E
1889----------G 1939---a
1590--b 1640--------C 1690---------D 1740---a 1790----a 1840g
1890-----A 1940------A

```
   1591-----@      1641-------B    1691------A     1741-e          1791-------B    1841---------D
1891------A     1941--b
   1592----------H 1642---a        1692------A     1742----a       1792j           1842i
1892----@       1942-c
   1593------A     1643---------D  1693---a        1743------A     1793----@       1843h
1893------A     1943------A
   1594---a        1644----------H 1694----------F 1744--------C   1794----@       1844---a
1894------A     1944-----@
   1595--b         1645---------D  1695---------E  1745-d          1795-------B    1845-----@
1895-----@      1945---------D
   1596g           1646-c          1696------A     1746----a       1796--------C   1846---------D
1896---------D  1946----------G
   1597-d          1647--c         1697-----@      1747-------B    1797--c         1847---a
1897----------F 1947---a
   1598-d          1648--c         1698h           1748-------B    1798---------E  1848-------B
1898----@       1948---------E
   1599-c          1649--b         1699i           1749----------G 1799-----@      1849---------D
1899-----A      1949-c


PART 4:  Master Bar Plot:
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----------------------------------------------------------------------------------------------------
------------------------------
   Year Rel value  Year Rel value  Year Rel value  Year Rel value  Year Rel value  Year Rel value
Year Rel value  Year Rel value
   1950--b         2000--b
   1951--------C   2001----@
   1952----a       2002--------C
   1953-----@      2003-------B
   1954--b         2004----------F
   1955-----@      2005------B
   1956----@       2006--------C
   1957---b        2007----a
```

```
1958g           2008g
1959--------C
1960----a
1961---b
1962-----A
1963----------F
1964------B
1965------A
1966---b
1967---a
1968--------C
1969----a
1970--c
1971-d
1972---b
1973-e
1974---a
1975-----A
1976----a
1977---------D
1978------A
1979---------D
1980---------D
1981--------B
1982------B
1983------A
1984-------B
1985-------B
1986------A
1987-f
1988h
1989------A
1990---------D
1991---------D
```

```
1992--c
1993i
1994--b
1995-d
1996-------B
1997-c
1998--------C
1999----@
```

PART 5: CORRELATION OF SERIES BY SEGMENTS:
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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	1575 1624	1600 1649	1625 1674	1650 1699	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	072708-8	1886 2008													.37	.50	.55	.44	.47
2	72708-7a	1887 2008													.53	.64	.66	.60	.54
3	72708-7b	1902 2008														.71	.69	.45	.47
4	072708-6	1928 2008															.54	.62	.68
5	072708-5	1943 2008															.46	.56	.60

```
   6 72708-4W 1930 2008                                                                         .31A
.31A .42
   7 72708-3U 1847 2008                                                     .80  .78  .77  .78  .76
.61  .67
   8 N727083D 1847 2007                                                     .61  .61  .79  .86  .81
.62  .63
   9 72708-2U 1583 2007   .77  .72  .72  .85  .80  .71  .71  .70  .67  .72  .57  .56  .74  .71  .59
.55  .61
  10 72708_2D 1583 2007   .78  .69  .63  .77  .81  .65  .57  .54  .49  .56  .62  .73  .71  .70  .50
.40  .48
  11 0727081b 1671 2007                  .76  .80  .76  .69  .64  .58  .66  .63  .62  .69  .79  .81
.52  .54
  12 0727081a 1626 2007             .58  .70  .29A .21B .73  .75  .62  .45  .17B .31A .66  .71  .71
.60  .59
 Av segment correlation   .77  .70  .64  .77  .67  .58  .68  .66  .59  .60  .57  .60  .66  .71  .62
.52  .56

PART 6:  POTENTIAL PROBLEMS:
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-------------------------------

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

 072708-8  1886 to  2008     123 years
Series   1

 [B] Entire series, effect on correlation (  .447) is:
      Lower   1890< -.032   1911> -.020   1933> -.019   1915< -.011   1899< -.009   1961> -.009
Higher   1958  .020   2008  .012

 [E] Outliers     1   3.0 SD above or -4.5 SD below mean for year
      1933 +3.5 SD
====================================================================================================
===============================

 72708-7a  1887 to  2008     122 years
Series   2

 [B] Entire series, effect on correlation (  .547) is:
      Lower   1904< -.040   1892< -.039   2005< -.019   1974< -.015   1985< -.011   1942> -.009
Higher   1933  .062   1958  .014

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

 72708-7b  1902 to  2008     107 years
Series   3

 [B] Entire series, effect on correlation (  .604) is:
      Lower   1995< -.027   1968< -.020   2008> -.011   1952< -.010   1992> -.009   1924< -.009
Higher   1933  .094   1963  .009
```

```
 [E] Outliers     1   3.0 SD above or -4.5 SD below mean for year
       1940 +3.2 SD
=====================================================================================================
===============================

 072708-6  1928 to  2008      81 years
Series   4

 [B] Entire series, effect on correlation (  .616) is:
       Lower   1942< -.040   1932< -.012   1972< -.010   1958> -.010   1947> -.009   1957> -.008
Higher   1933  .017   1949  .016

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

 072708-5  1943 to  2008      66 years
Series   5

 [B] Entire series, effect on correlation (  .547) is:
       Lower   1945< -.026   1950> -.016   1987> -.014   1956< -.010   2007> -.010   1988> -.010
Higher   2008  .028   1993  .026

 [E] Outliers     1   3.0 SD above or -4.5 SD below mean for year
       1950 +3.2 SD
=====================================================================================================
===============================

 72708-4W  1930 to  2008      79 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
```

```
   ---------  ----   ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---
---  ---  ---  ---  ---
   1930 1979    0   -.16 -.07 -.07 -.13  .18 -.07  .09  .04  .07 -.20  .31* .01 -.12 -.15  .05  .12
-.13 -.13 -.02  .28 -.15
   1950 1999    0   -.27 -.05 -.19 -.14  .24 -.03  .14 -.02  .10 -.07  .31*-.06 -.05 -.18  .10  .12
-.08  .00  .01  .11    -

 [B] Entire series, effect on correlation (  .417) is:
      Lower   1953< -.096   1960< -.033   1978< -.027   1966> -.015   1963< -.012   1957> -.009
Higher   1993  .031   1933  .025
     1930 to 1979 segment:
      Lower   1953< -.112   1960< -.031   1978< -.029   1966> -.020   1963< -.014   1957> -.012
Higher   1933  .055   1958  .040
     1950 to 1999 segment:
      Lower   1953< -.123   1978< -.031   1960< -.029   1966> -.026   1963< -.020   1957> -.016
Higher   1993  .064   1958  .050

 [E] Outliers     2   3.0 SD above or -4.5 SD below mean for year
      1953 -5.3 SD;    1966 +3.3 SD
====================================================================================================
===============================

 72708-3U  1847 to  2008     162 years
Series   7

 [B] Entire series, effect on correlation (  .725) is:
      Lower   1988< -.014   1930< -.011   1923> -.011   1995> -.010   1953> -.005   1912< -.005
Higher   1933  .043   1884  .008

 [E] Outliers     1   3.0 SD above or -4.5 SD below mean for year
      1988 -7.9 SD
====================================================================================================
===============================
```

```
 N727083D  1847 to  2007     161 years
Series   8

 [B] Entire series, effect on correlation (  .714) is:
       Lower   1869< -.017   1850< -.012   1995> -.008   1870> -.008   1976< -.007   1969> -.005
Higher   1933  .042   1911  .015

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

 72708-2U  1583 to  2007     425 years
Series   9

 [B] Entire series, effect on correlation (  .690) is:
       Lower   1859< -.006   1599> -.004   1869> -.004   1745> -.004   1712< -.003   1916< -.003
Higher   1589  .013   1911  .006

 [D]    1 Absent rings:  Year   Master  N series Absent
                         1648    -.708       3      1
                                                        Present in series   10  72708_2D time span
1583 to  2007
                                                        Present in series   12  0727081a time span
1626 to  2007

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

 72708_2D  1583 to  2007     425 years
Series  10

 [B] Entire series, effect on correlation (  .624) is:
       Lower   1957< -.011   1822< -.008   1923< -.006   1969< -.006   1753< -.005   1798< -.005
Higher   1933  .012   1589  .010

 [E] Outliers     3   3.0 SD above or -4.5 SD below mean for year
       1604 +4.1 SD;    1728 +3.4 SD;    1764 -5.5 SD
```

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

 0727081b  1671 to  2007     337 years
Series  11

 [B] Entire series, effect on correlation (  .687) is:
       Lower   1859> -.010   1753> -.005   1764> -.005   1799> -.005   1886> -.004   1812> -.004
Higher   1933  .015   1884  .011

 [D]    2 Absent rings:  Year   Master  N series Absent
                         1699   -2.309       4       2
                                                        Present in series    9  72708-2U time span
1583 to  2007
                                                        Present in series   10  72708_2D time span
1583 to  2007
                                                        Absent  in series   12  0727081a time span
1626 to  2007
                         1813   -3.069       4       2
                                                        Present in series    9  72708-2U time span
1583 to  2007
                                                        Present in series   10  72708_2D time span
1583 to  2007
                                                        Absent  in series   12  0727081a time span
1626 to  2007

 [E] Outliers     6   3.0 SD above or -4.5 SD below mean for year
       1703 +3.4 SD;    1764 +4.0 SD;    1799 +3.1 SD;    1859 +3.2 SD;    1985 +3.2 SD;    1988 +3.1
SD
====================================================================================================

 0727081a  1626 to  2007     382 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
    ---------  ----   ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---
---  ---  ---  ---  ---
    1675 1724    0   -.16  .04 -.04 -.12 -.03  .24  .17  .10 -.17  .25  .29* .18 -.24  .01  .01  .27
-.23 -.23  .00 -.01 -.08
    1700 1749   -1   -.24 -.05 -.01  .12  .18  .14 -.16  .20  .07  .32* .21|-.14 -.23 -.08 -.26  .21
-.17 -.04  .11  .04 -.05
    - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
- - - - - - - - - - - -
    1825 1874    1    .05  .02 -.13 -.07  .01 -.17  .07 -.08  .15  .04  .17| .29*-.08  .16 -.22  .04
.00  .11 -.04 -.11  .04
    1850 1899    0    .17 -.09  .03 -.34 -.04 -.23 -.02  .03  .17  .21  .31* .17 -.05  .00 -.25 -.21
.05 -.13  .04 -.01 -.08

 [B] Entire series, effect on correlation (  .518) is:
      Lower   1721> -.029   1833< -.020   1864< -.016   1822> -.006   1872< -.006   1843> -.006
Higher   1933  .016   1884  .010
     1675 to 1724 segment:
      Lower   1721> -.170   1716< -.040   1715> -.034   1719> -.028   1712> -.019   1718< -.012
Higher   1686  .057   1684  .038
     1700 to 1749 segment:
      Lower   1721> -.168   1716< -.035   1715> -.035   1719> -.029   1712> -.019   1718< -.011
Higher   1727  .037   1731  .036
     1825 to 1874 segment:
      Lower   1864< -.062   1833< -.044   1843> -.032   1859> -.030   1863> -.025   1828< -.021
Higher   1842  .079   1840  .064
     1850 to 1899 segment:
      Lower   1864< -.111   1859> -.039   1863> -.033   1872< -.028   1851< -.025   1890> -.022
Higher   1884  .156   1889  .033

 [C] Year-to-year changes diverging by over 4.0 std deviations:
      1720 1721   4.2 SD    1863 1864  -4.0 SD
```

```
 [D]    5 Absent rings:  Year   Master  N series Absent
                         1699   -2.309       4       2
                                                       Present in series    9  72708-2U time span
1583 to  2007
                                                       Present in series   10  72708_2D time span
1583 to  2007
                                                       Absent  in series   11  0727081b time span
1671 to  2007
                         1702   -1.235       4       1
                                                       Present in series    9  72708-2U time span
1583 to  2007
                                                       Present in series   10  72708_2D time span
1583 to  2007
                                                       Present in series   11  0727081b time span
1671 to  2007
                         1813   -3.069       4       2
                                                       Present in series    9  72708-2U time span
1583 to  2007
                                                       Present in series   10  72708_2D time span
1583 to  2007
                                                       Absent  in series   11  0727081b time span
1671 to  2007
                         1833     .281       4       1  >> WARNING:  Ring is not usually narrow
                                                       Present in series    9  72708-2U time span
1583 to  2007
                                                       Present in series   10  72708_2D time span
1583 to  2007
                                                       Present in series   11  0727081b time span
1671 to  2007
                         1872    -.357       6       1  >> WARNING:  Ring is not usually narrow

 [E] Outliers     8   3.0 SD above or -4.5 SD below mean for year
      1715 +3.1 SD;    1721 +6.5 SD;    1728 -4.9 SD;    1822 +3.3 SD;    1833 -6.1 SD;    1843 +4.2
SD;    1864 -5.0 SD;
```

1872 -5.9 SD

==

PART 7: DESCRIPTIVE STATISTICS:

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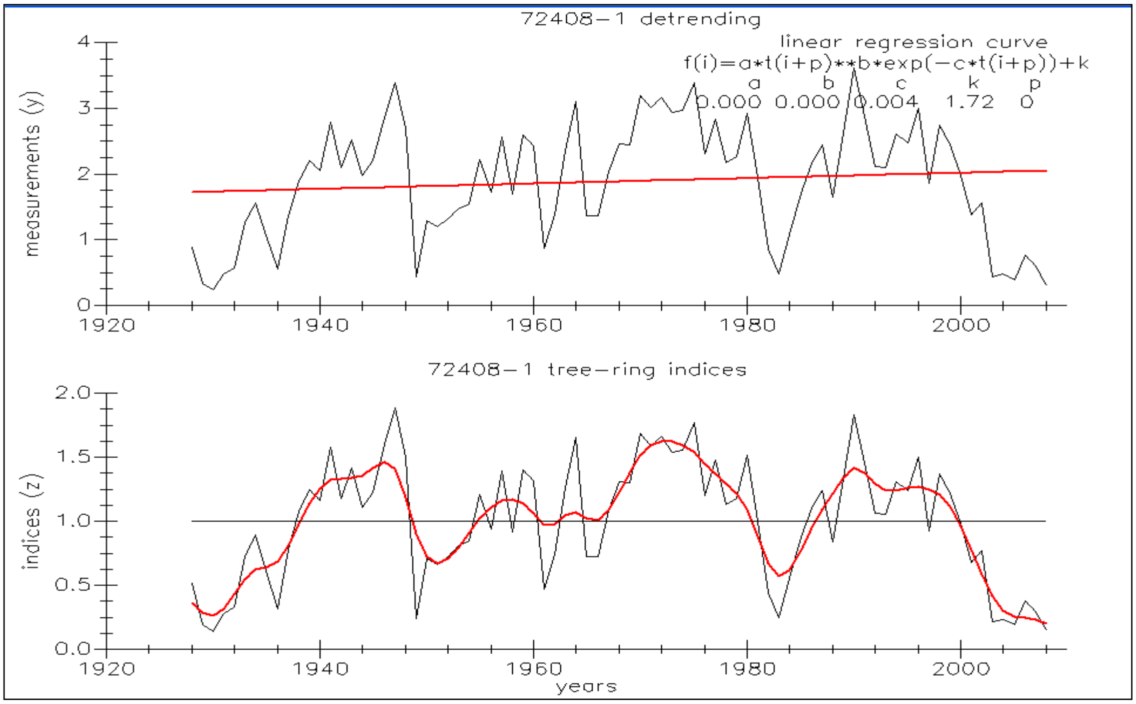
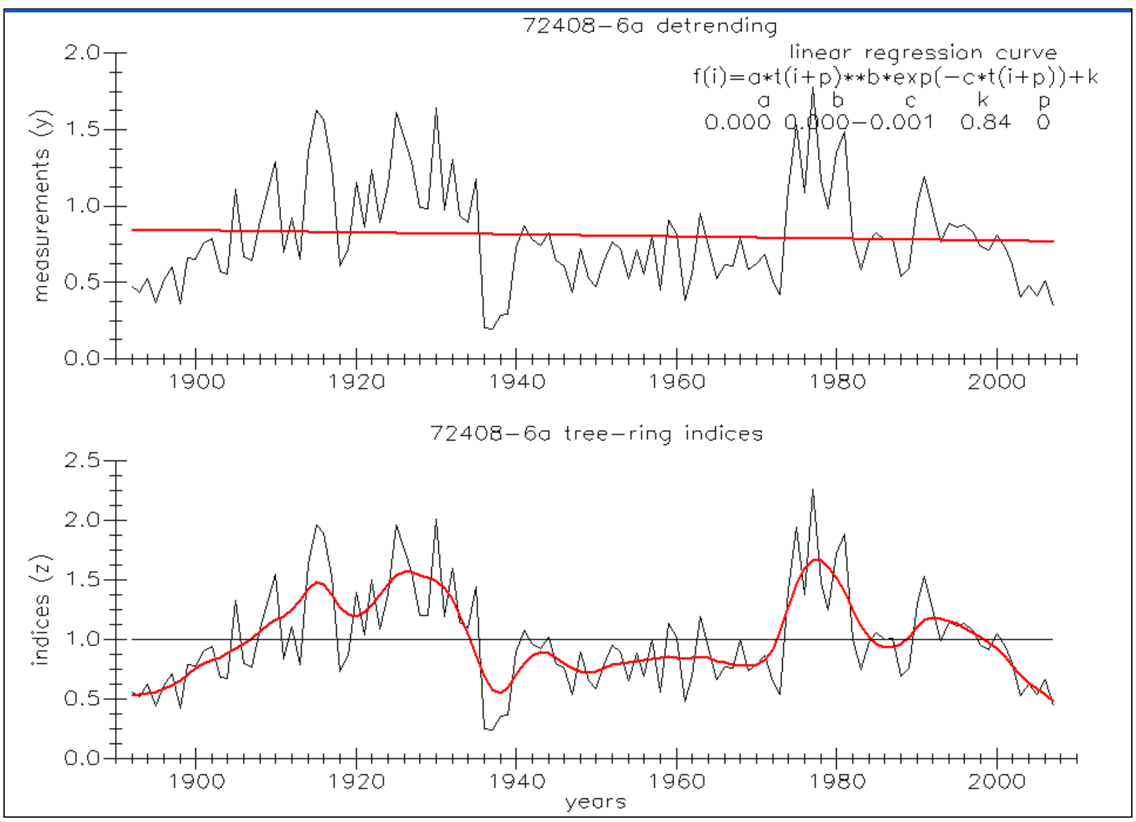
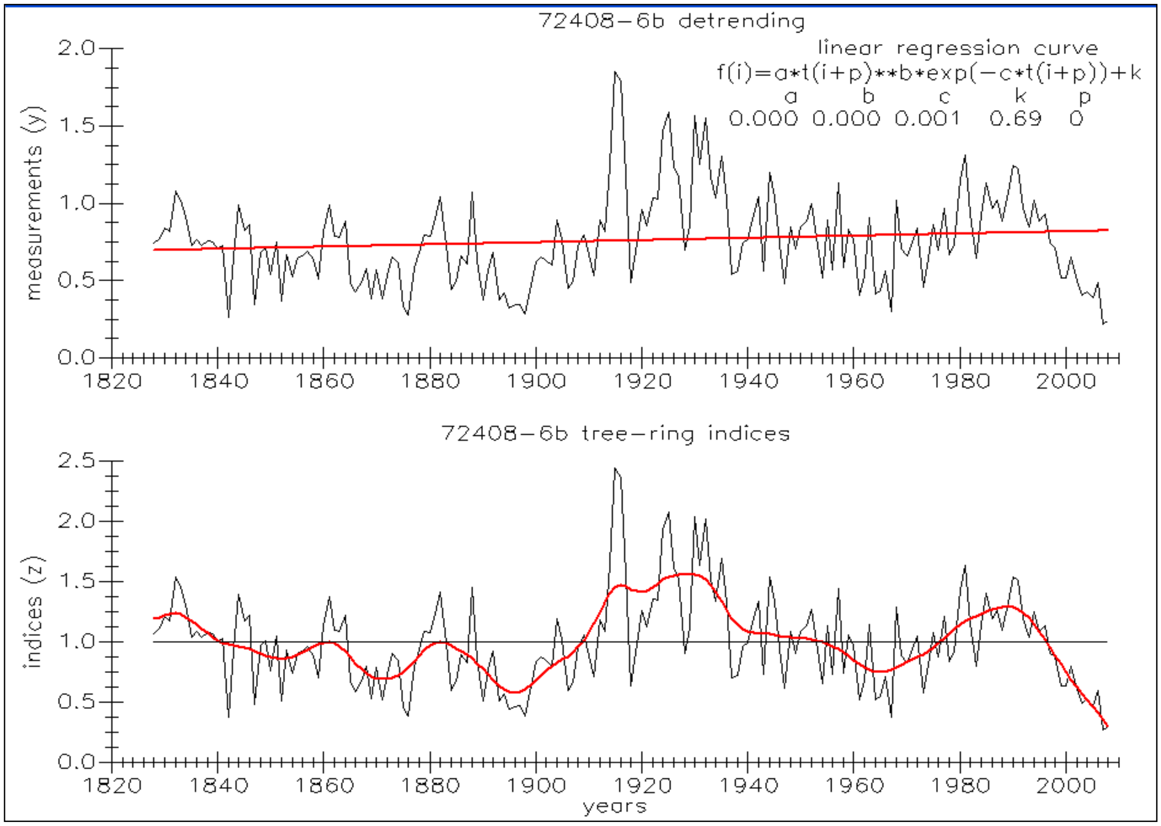
						Corr	//-------- Unfiltered --------\\				//---- Filtered -----\\				
			No.	No.	No.	with	Mean	Max	Std	Auto	Mean	Max	Std	Auto	AR
Seq	Series	Interval	Years	Segmt	Flags	Master	msmt	msmt	dev	corr	sens	value	dev	corr	()
1	072708-8	1886 2008	123	5	0	.447	1.46	3.85	.601	.756	.227	2.64	.436	-.083	2
2	72708-7a	1887 2008	122	5	0	.547	1.41	2.57	.447	.727	.201	2.56	.530	-.041	1
3	72708-7b	1902 2008	107	4	0	.604	1.48	3.11	.444	.597	.197	2.60	.394	-.087	1
4	072708-6	1928 2008	81	3	0	.616	1.38	2.94	.610	.833	.199	2.64	.445	.087	1
5	072708-5	1943 2008	66	3	0	.547	1.38	2.38	.368	.428	.223	2.65	.561	-.072	1
6	72708-4W	1930 2008	79	3	2	.417	1.16	2.21	.531	.822	.248	2.44	.444	-.019	1
7	72708-3U	1847 2008	162	7	0	.725	.67	1.55	.255	.680	.234	2.47	.326	.032	1
8	N727083D	1847 2007	161	7	0	.714	.55	1.44	.231	.678	.259	2.68	.412	-.022	1

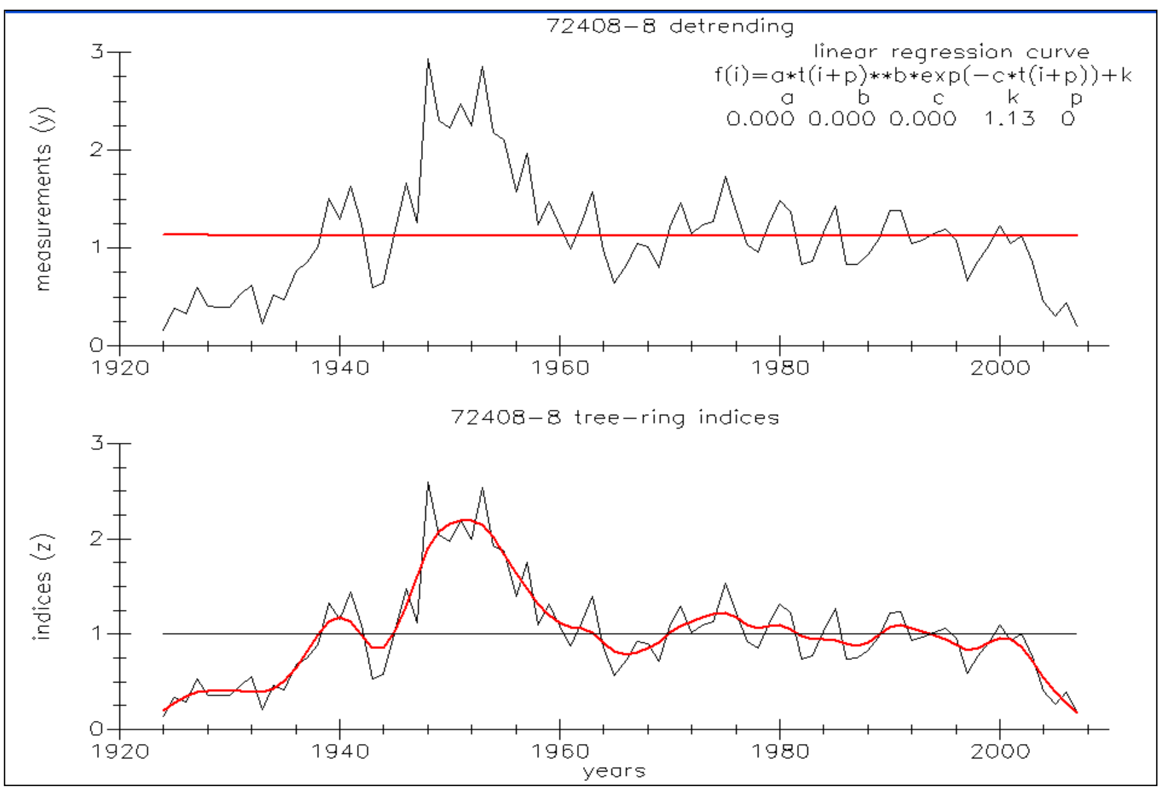
9	72708-2U	1583	2007	425	17	0	.690	.36	1.31	.208	.777	.305	2.71	.388	-.055	1
10	72708_2D	1583	2007	425	17	0	.624	.36	1.23	.181	.732	.301	2.65	.453	-.050	1
11	0727081b	1671	2007	337	14	0	.687	.36	1.38	.189	.595	.375	2.77	.372	-.018	1
12	0727081a	1626	2007	382	15	4	.518	.26	1.12	.147	.642	.399	2.85	.377	-.014	1

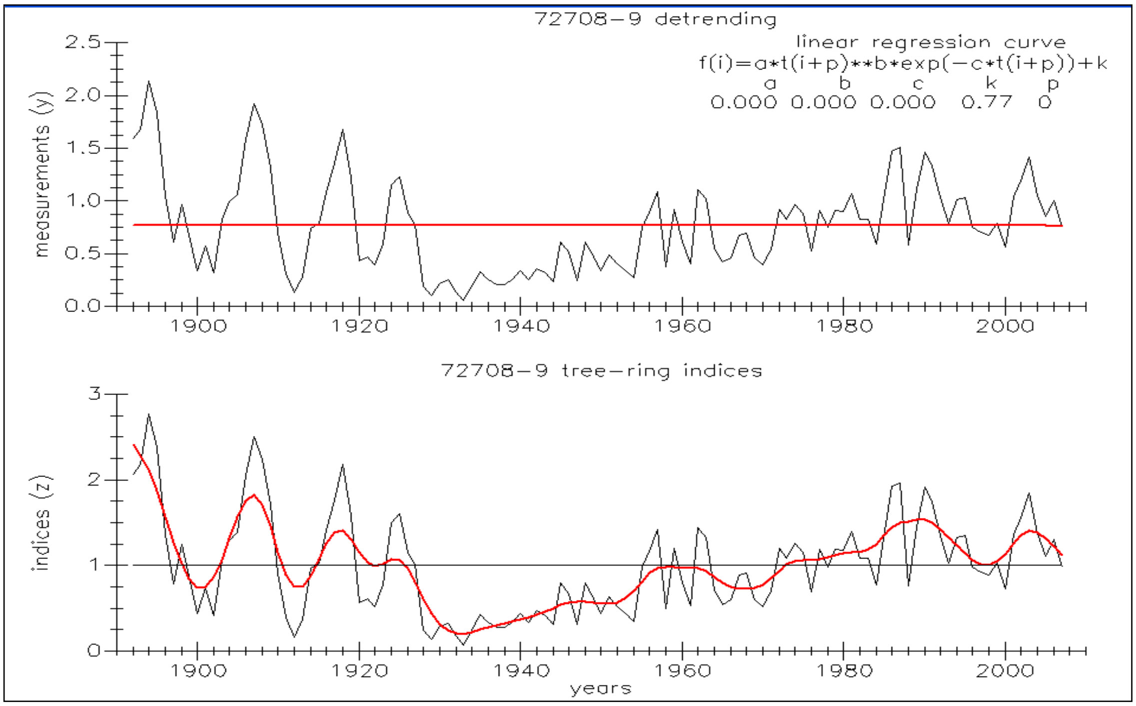
Appendix D: ARSTAN graphs of individual cores for Chigertey Gol Valley

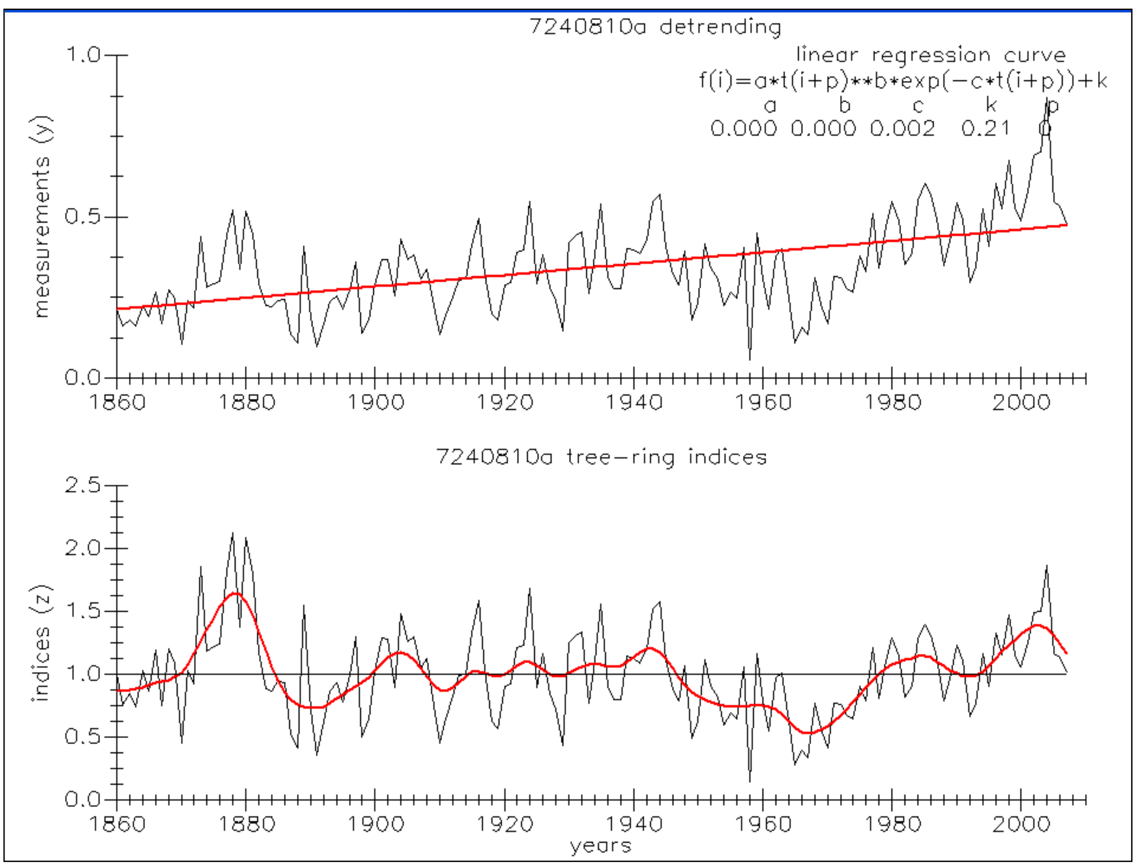


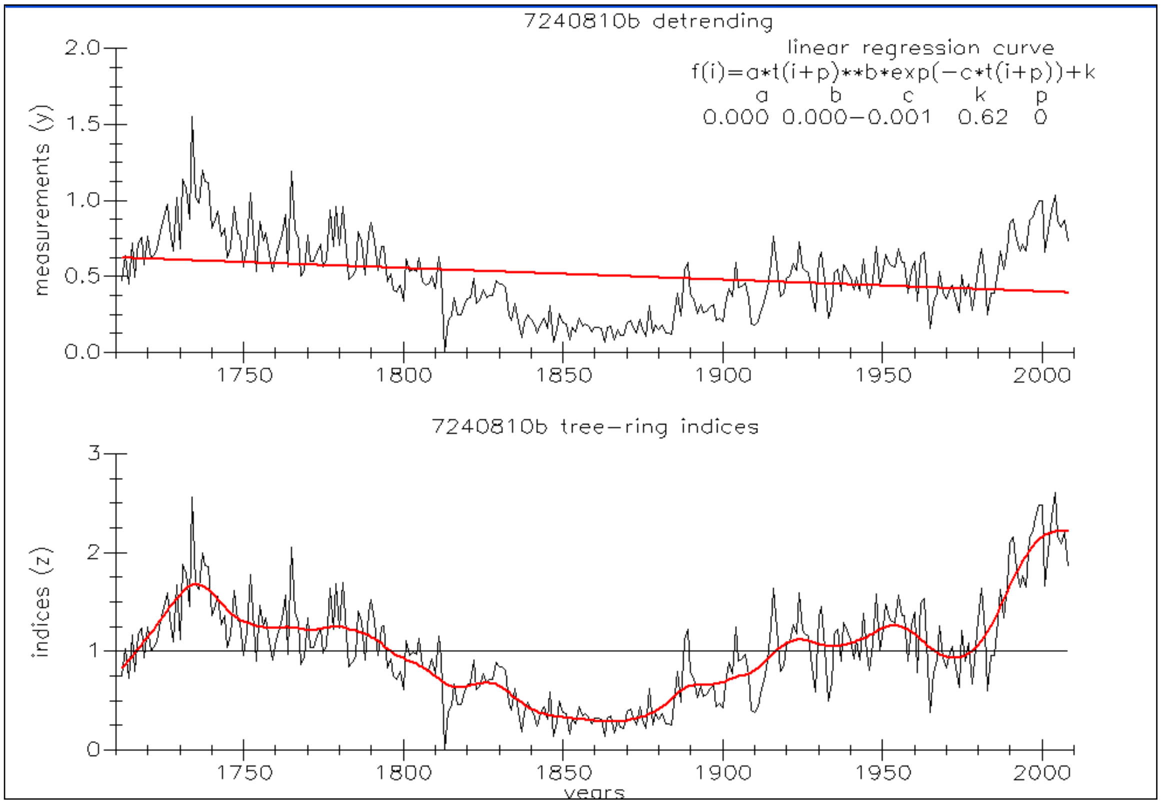


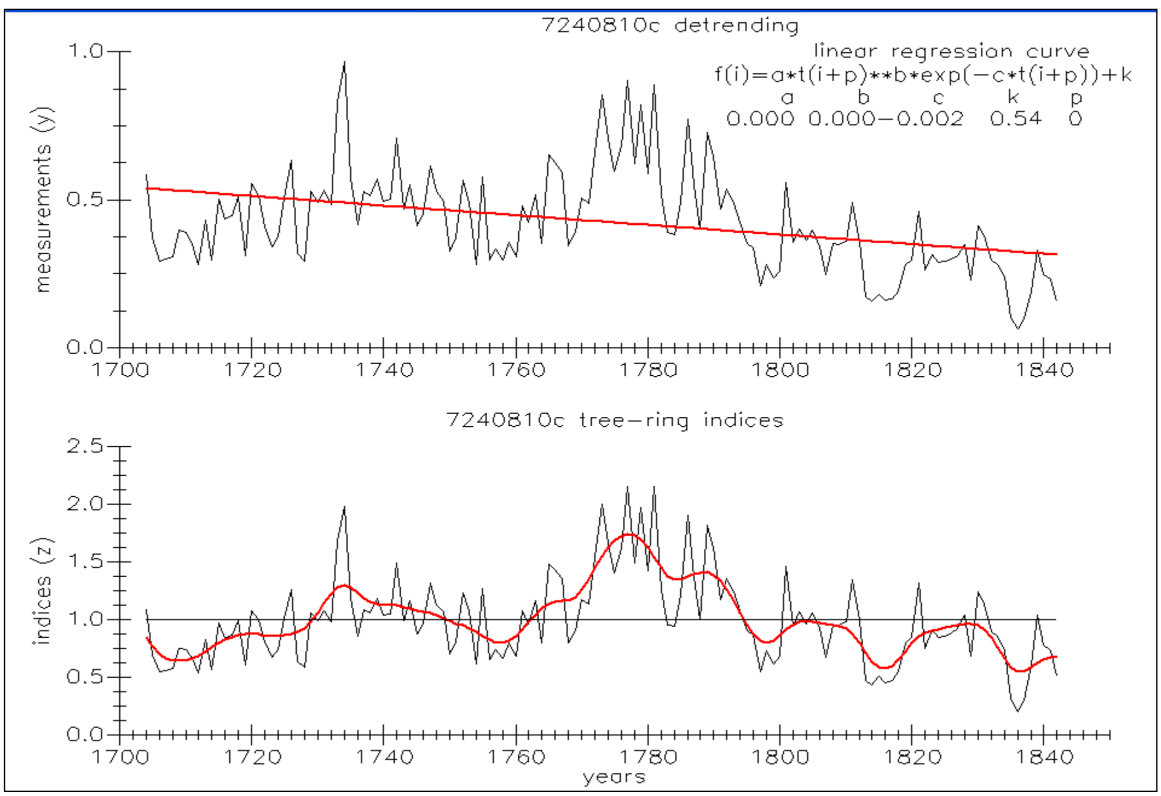

72408−6b detrending
linear regression curve
f(i)=a*t(i+p)**b*exp(−c*t(i+p))+k
a b c k p
0.000 0.000 0.001 0.69 0
measurements (y)
72408−6b tree−ring indices
indices (z)
years

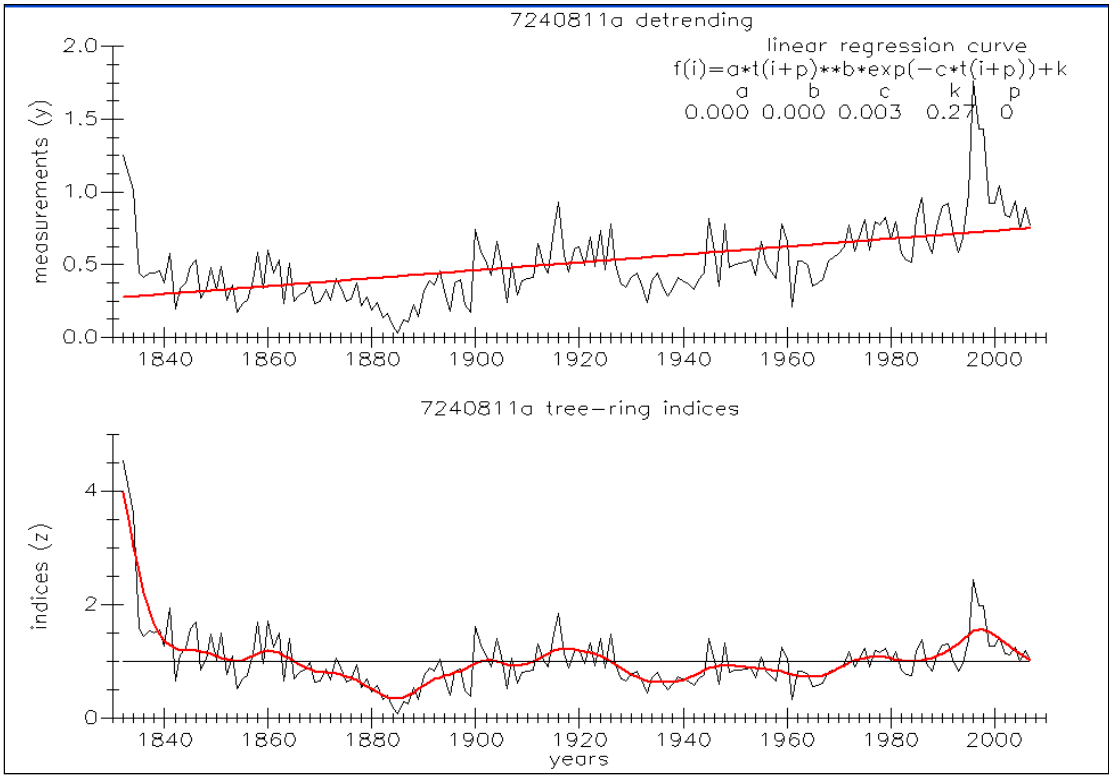

72408−8 detrending
linear regression curve
f(i)=a*t(i+p)**b*exp(−c*t(i+p))+k
a b c k p
0.000 0.000 0.000 1.13 0
measurements (y)
72408−8 tree−ring indices
indices (z)
years

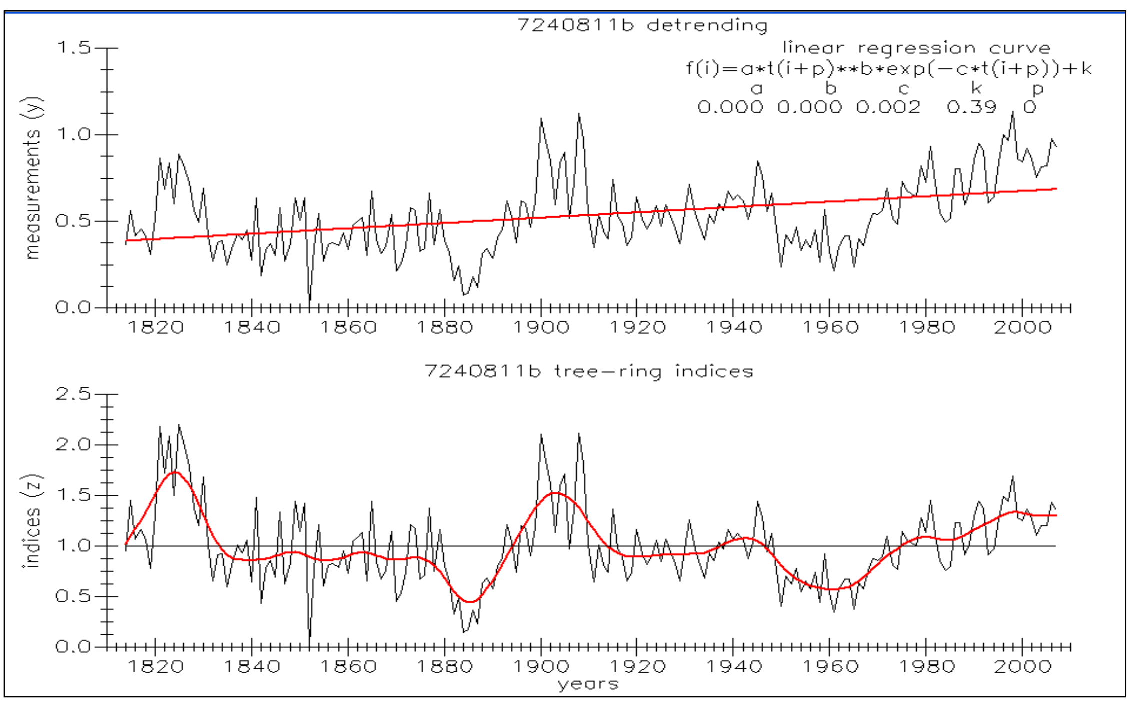

72708-9 detrending
linear regression curve
f(i)=a*t(i+p)**b*exp(-c*t(i+p))+k
a b c k p
0.000 0.000 0.000 0.77 0
measurements (y)
72708-9 tree-ring indices
indices (z)
years

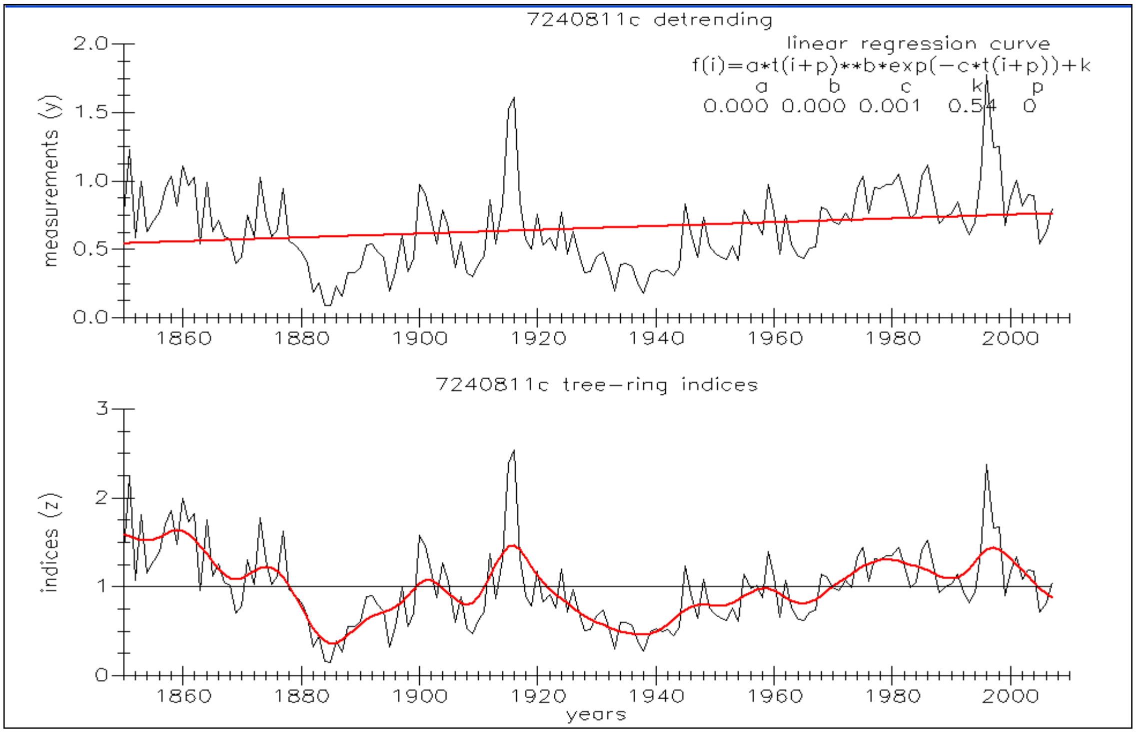

7240810a detrending
linear regression curve
f(i)=a*t(i+p)**b*exp(-c*t(i+p))+k
a b c k p
0.000 0.000 0.002 0.21 0
measurements (y)
7240810a tree-ring indices
indices (z)
years


7240810b detrending
linear regression curve
f(i)=a*t(i+p)**b*exp(−c*t(i+p))+k
a b c k p
0.000 0.000−0.001 0.62 0
measurements (y)
7240810b tree−ring indices
indices (z)
years

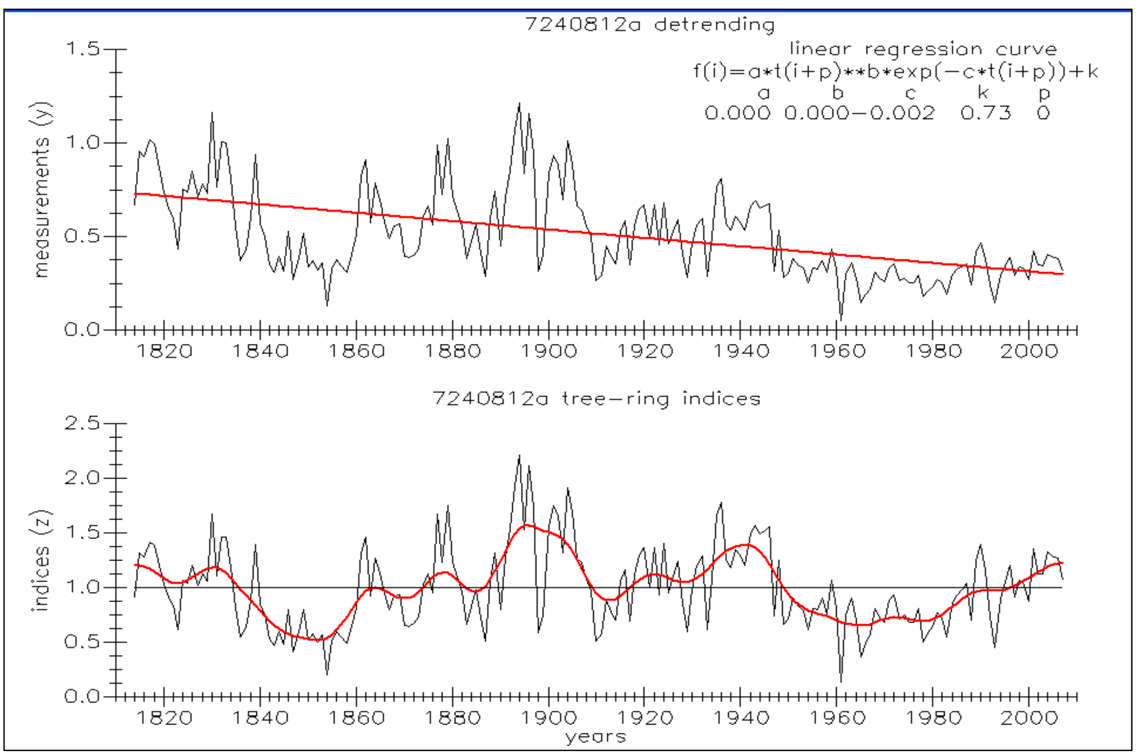

7240810c detrending
linear regression curve
f(i)=a*t(i+p)**b*exp(−c*t(i+p))+k
a b c k p
0.000 0.000−0.002 0.54 0
measurements (y)
7240810c tree−ring indices
indices (z)
years


7240811a detrending
linear regression curve
f(i)=a*t(i+p)**b*exp(-c*t(i+p))+k
a b c k p
0.000 0.000 0.003 0.27 0
measurements (y)
7240811a tree-ring indices
indices (z)
years

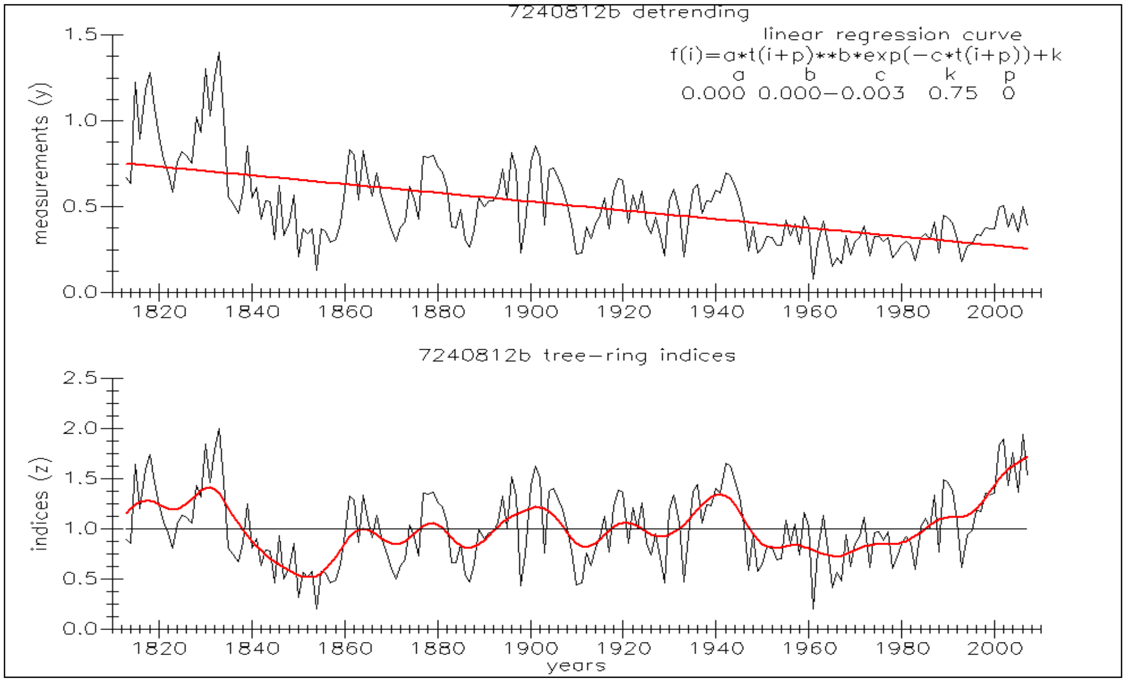

7240811b detrending
linear regression curve
f(i)=a*t(i+p)**b*exp(-c*t(i+p))+k
a b c k p
0.000 0.000 0.002 0.39 0
measurements (y)
7240811b tree-ring indices
indices (z)
years

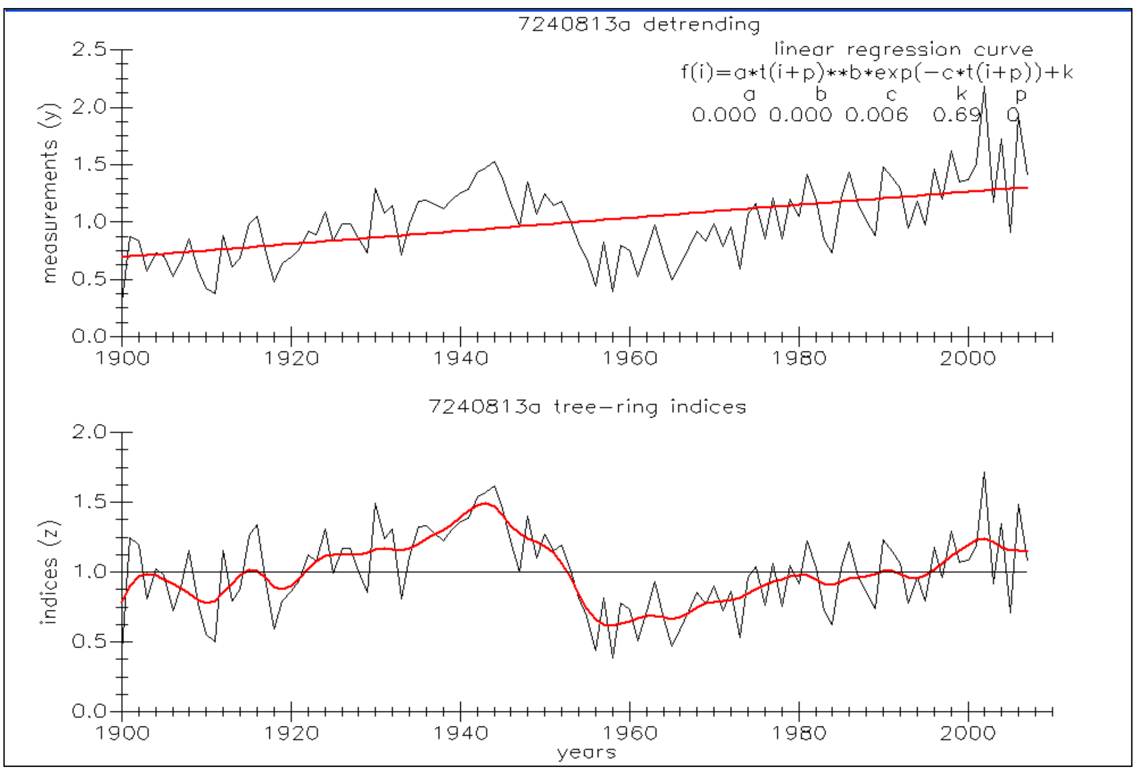


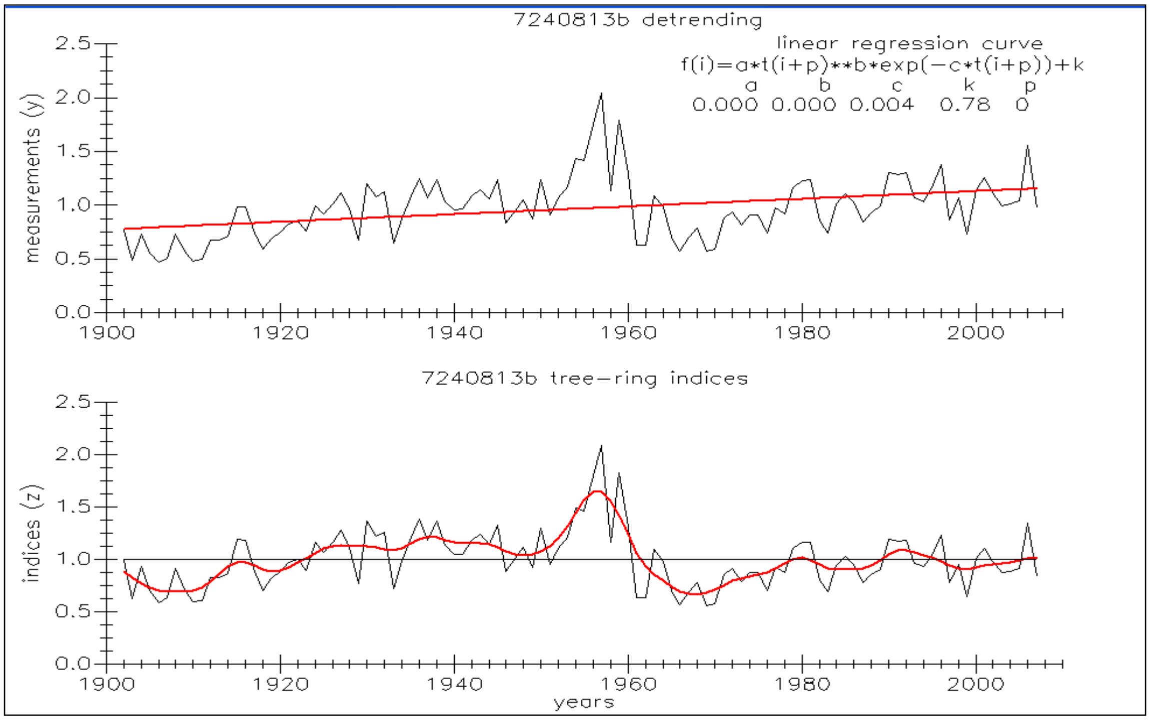
7240811c detrending
linear regression curve
f(i)=a*t(i+p)**b*exp(-c*t(i+p))+k
a b c k p
0.000 0.000 0.001 0.54 0
measurements (y)
7240811c tree-ring indices
indices (z)
years

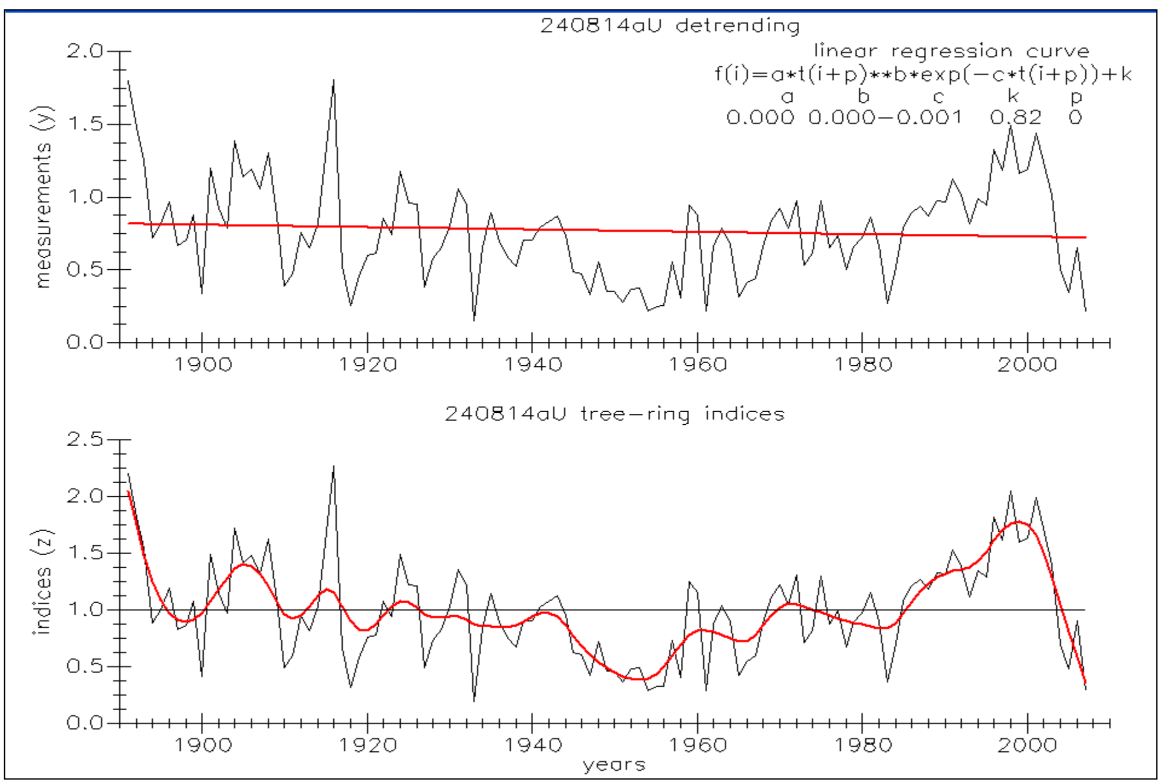


7240812a detrending
linear regression curve
f(i)=a*t(i+p)**b*exp(-c*t(i+p))+k
a b c k p
0.000 0.000−0.002 0.73 0
measurements (y)
7240812a tree-ring indices
indices (z)
years


7240812b detrending
linear regression curve
f(i)=a*t(i+p)**b*exp(−c*t(i+p))+k
a b c k p
0.000 0.000−0.003 0.75 0
measurements (y)
7240812b tree−ring indices
indices (z)
years


7240813a detrending
linear regression curve
f(i)=a*t(i+p)**b*exp(−c*t(i+p))+k
a b c k p
0.000 0.000 0.006 0.69 0
measurements (y)
7240813a tree−ring indices
indices (z)
years


7240813b detrending
linear regression curve
f(i)=a*t(i+p)**b*exp(−c*t(i+p))+k
a b c k p
0.000 0.000 0.004 0.78 0
measurements (y)
7240813b tree−ring indices
indices (z)
years


240814aU detrending
linear regression curve
f(i)=a*t(i+p)**b*exp(−c*t(i+p))+k
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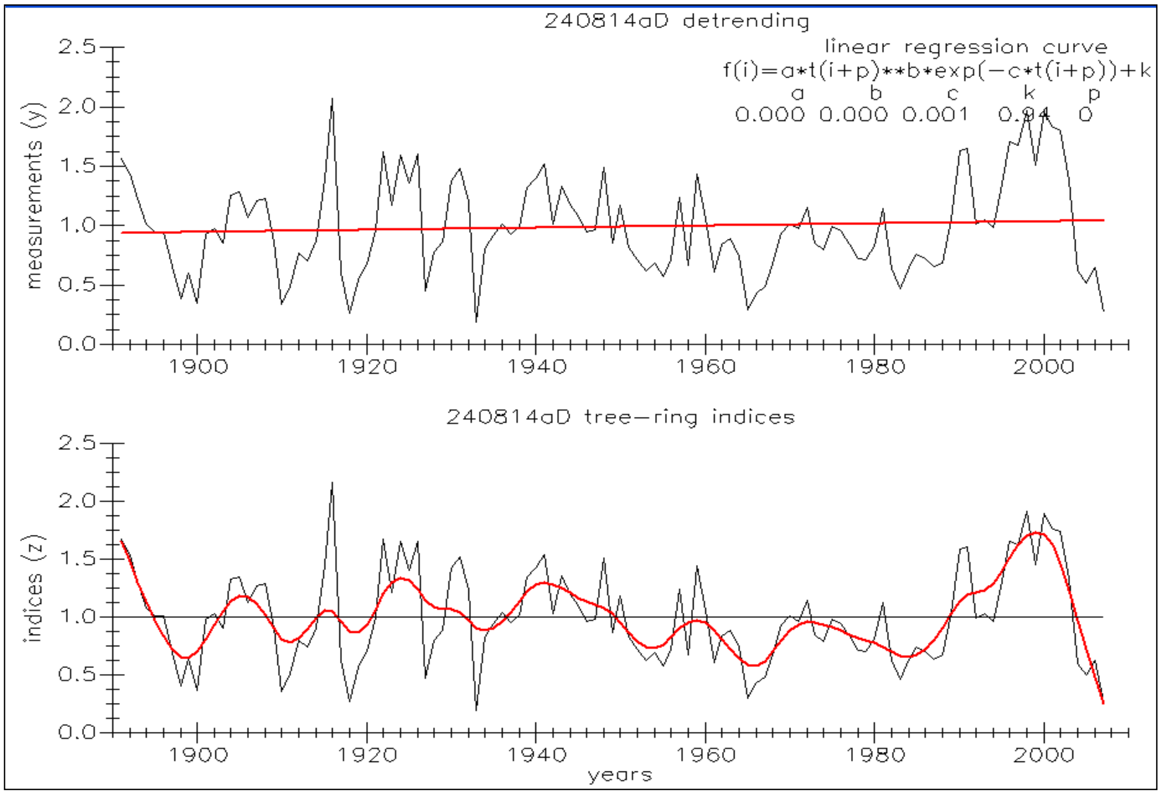
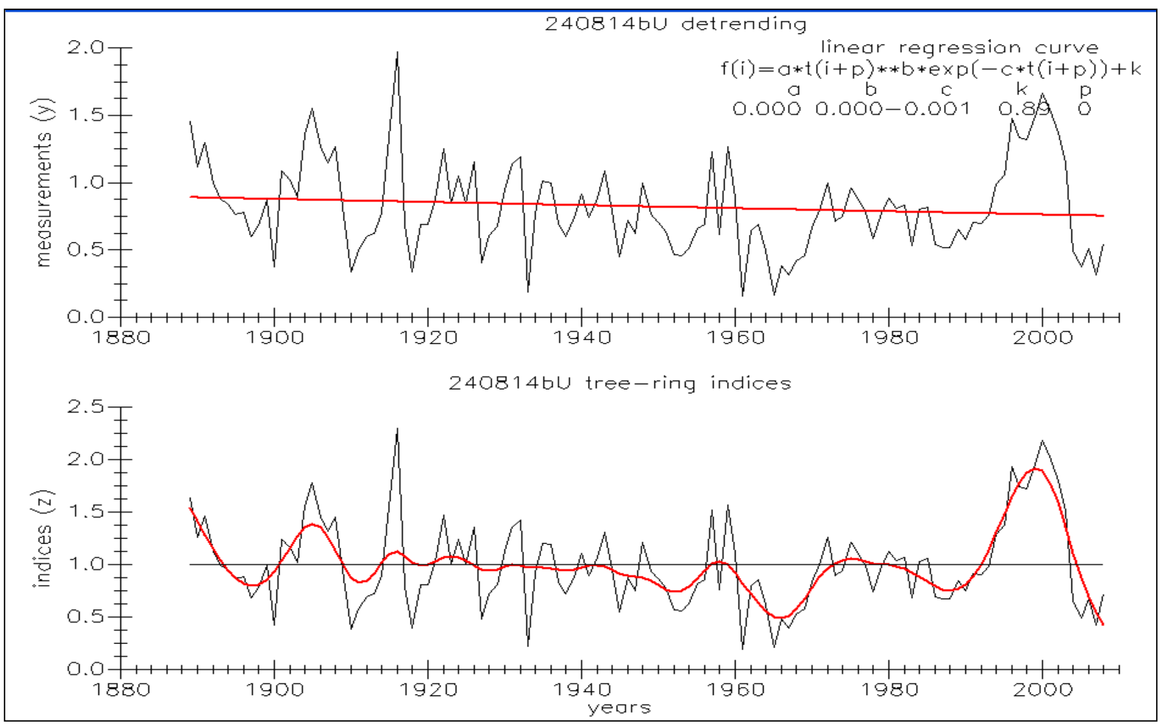
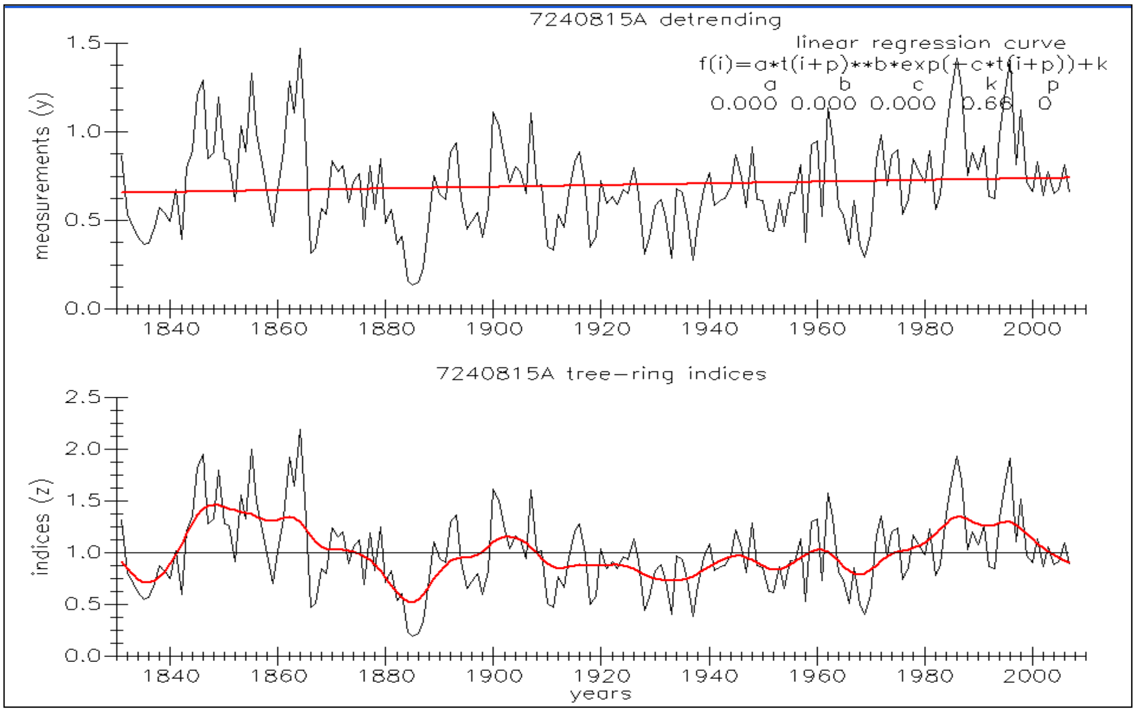
measurements (y)
240814aU tree−ring indices
indices (z)
years


240814aD detrending
linear regression curve
f(i)=a*t(i+p)**b*exp(-c*t(i+p))+k
a b c k p
0.000 0.000 0.001 0.94 0
measurements (y)
240814aD tree-ring indices
indices (z)
years


240814bU detrending
linear regression curve
f(i)=a*t(i+p)**b*exp(-c*t(i+p))+k
a b c k p
0.000 0.000-0.001 0.89 0
measurements (y)
240814bU tree-ring indices
indices (z)
years


7240815A detrending
linear regression curve
f(i)=a*t(i+p)**b*exp(-c*t(i+p))+k
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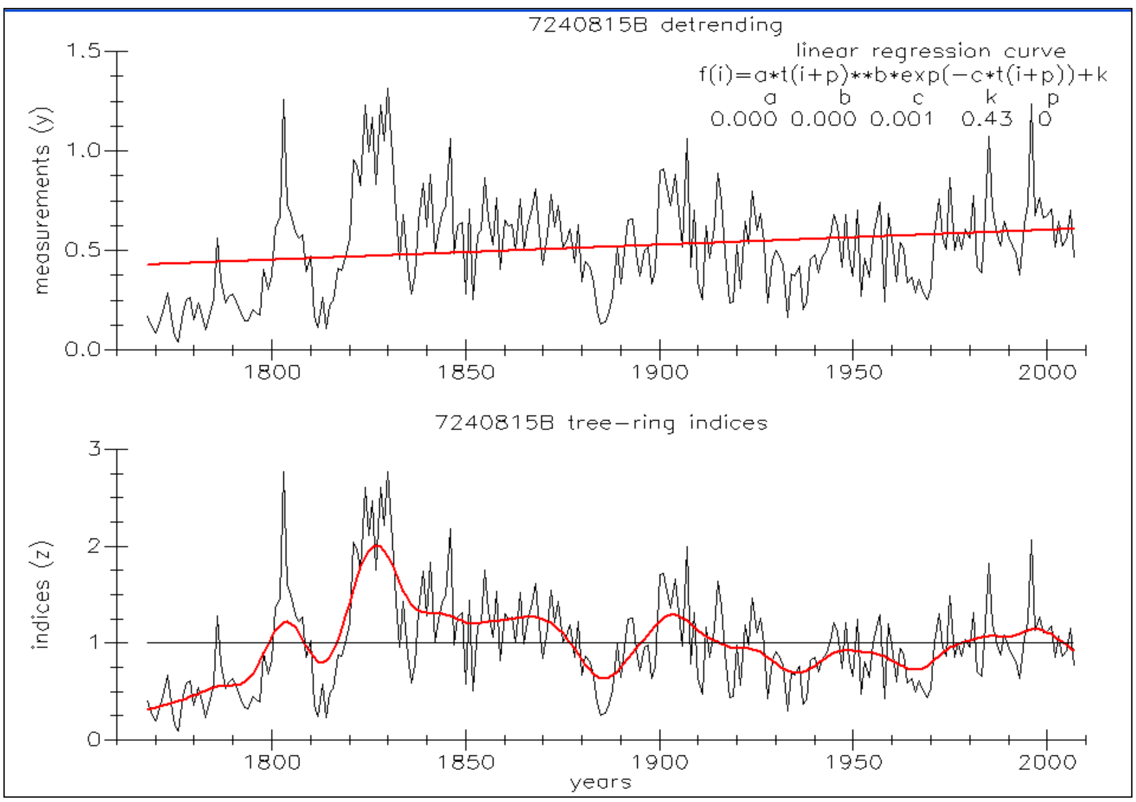
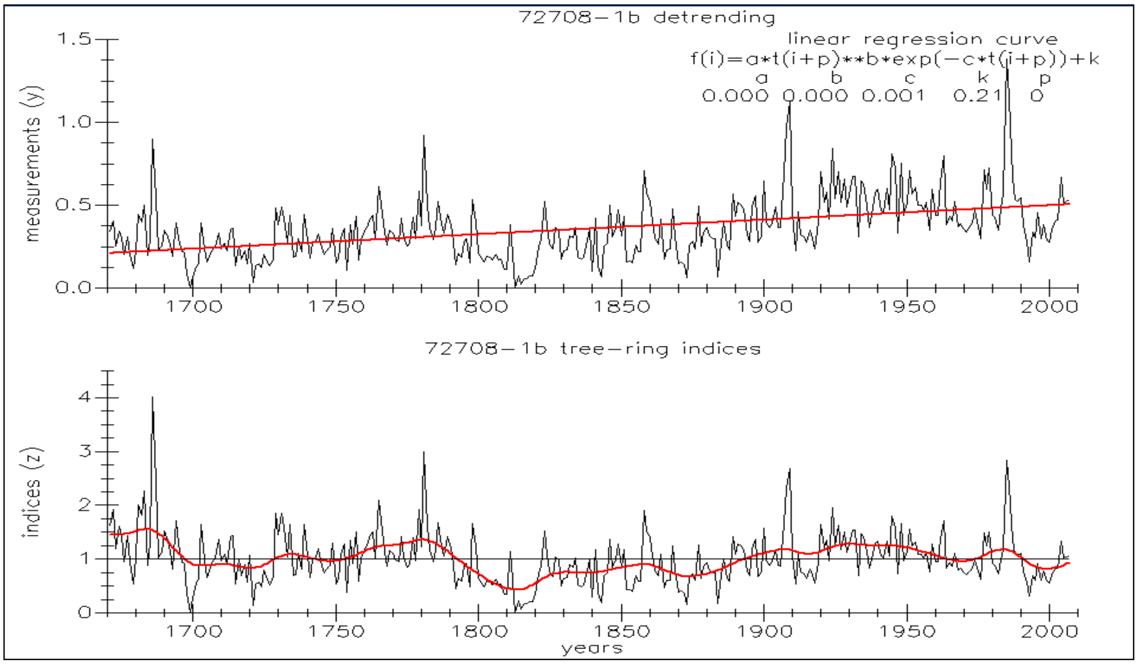
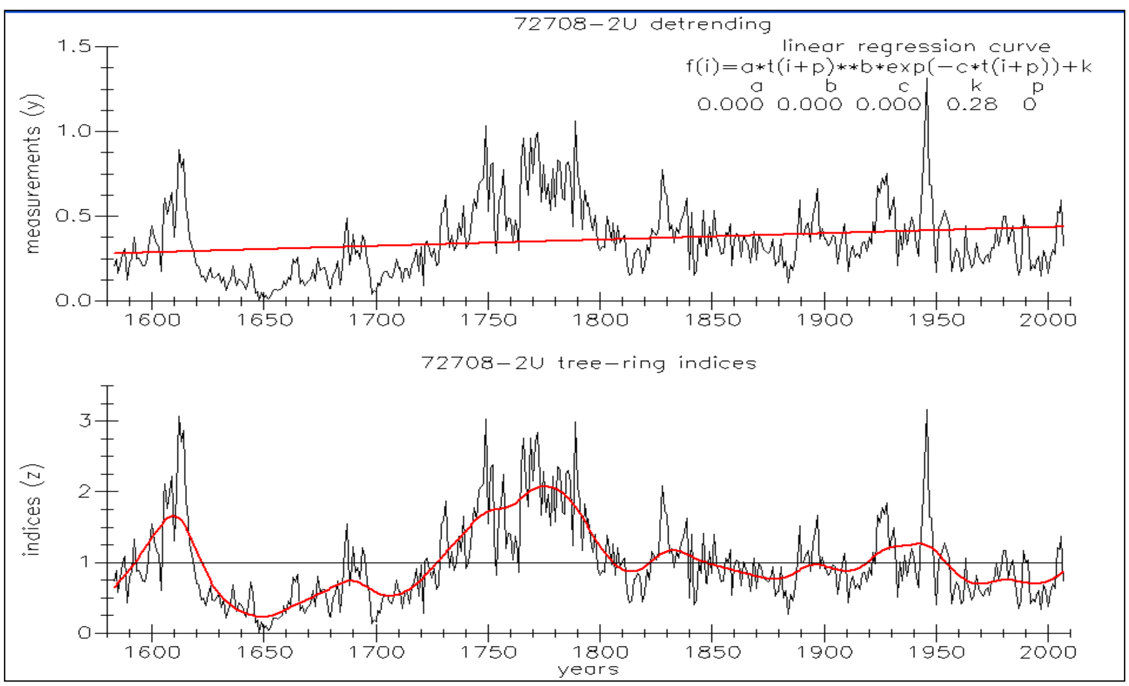
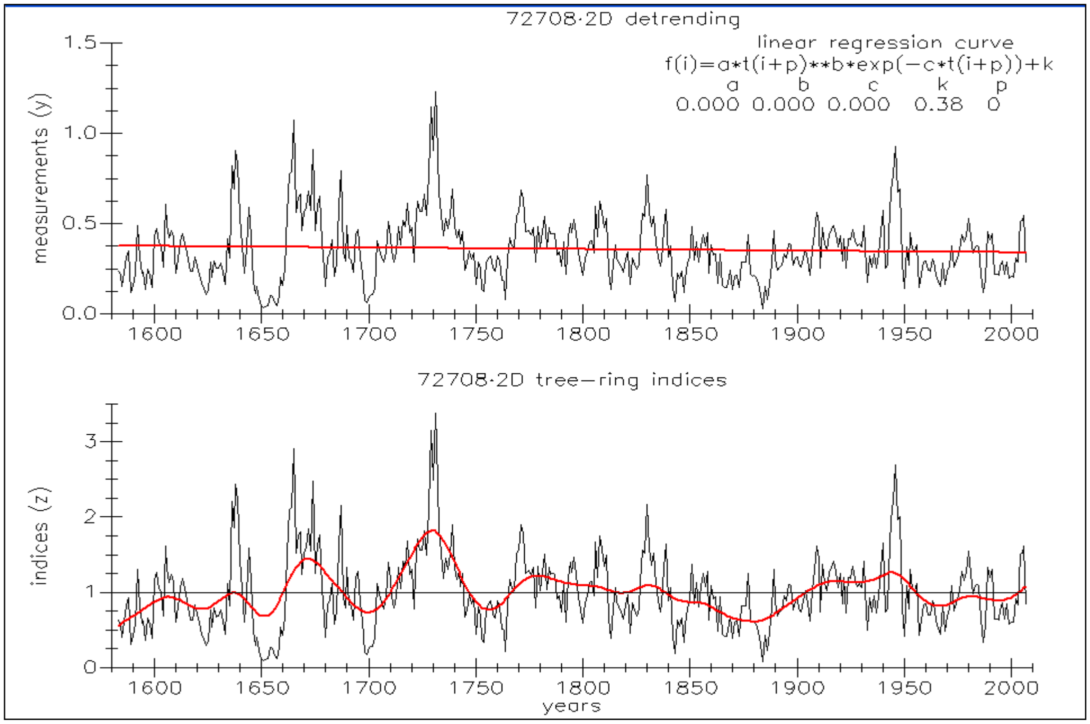
0.000 0.000 0.000 0.66 0
measurements (y)
7240815A tree-ring indices
indices (z)
years

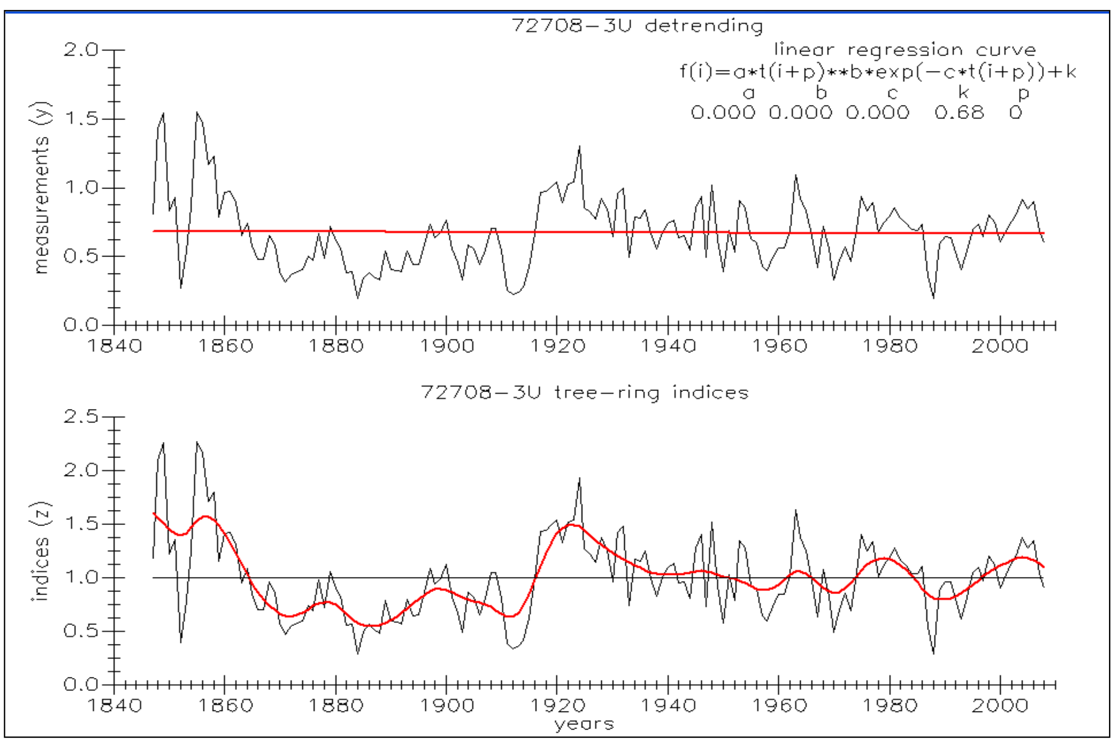

7240815B detrending
linear regression curve
f(i)=a*t(i+p)**b*exp(-c*t(i+p))+k
a b c k p
0.000 0.000 0.001 0.43 0
measurements (y)
7240815B tree-ring indices
indices (z)
years

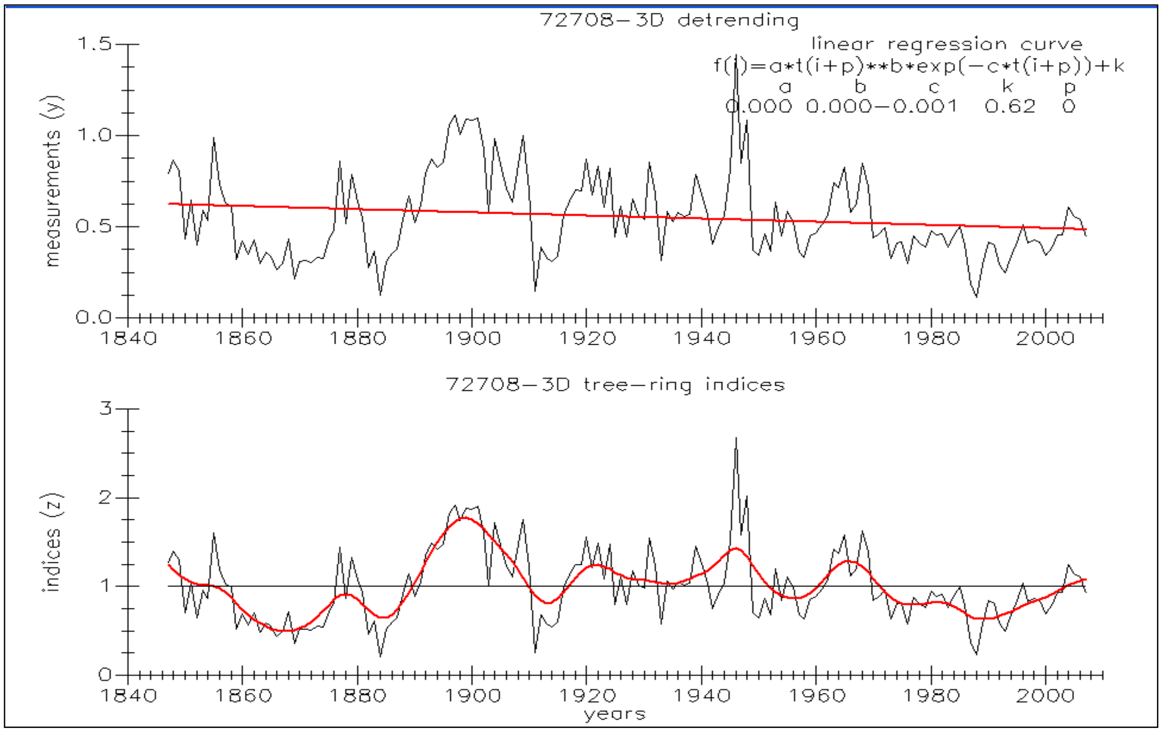
Appendix E: ARSTAN Graphs for individual cores for Leya Gol Valley (LG)

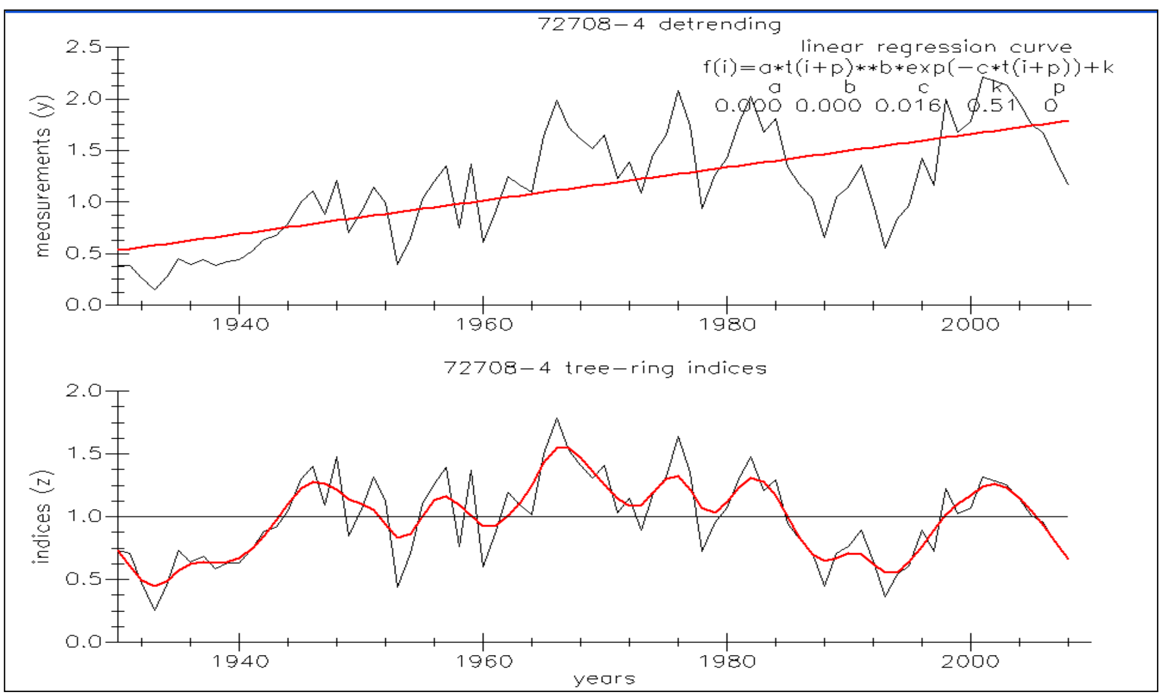


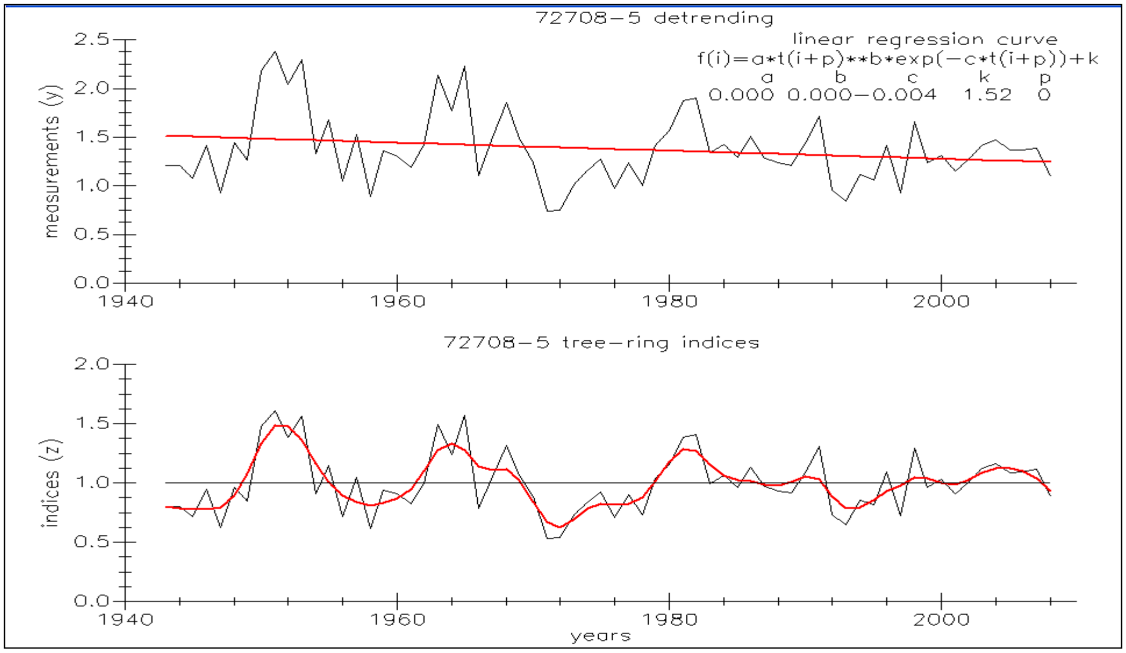


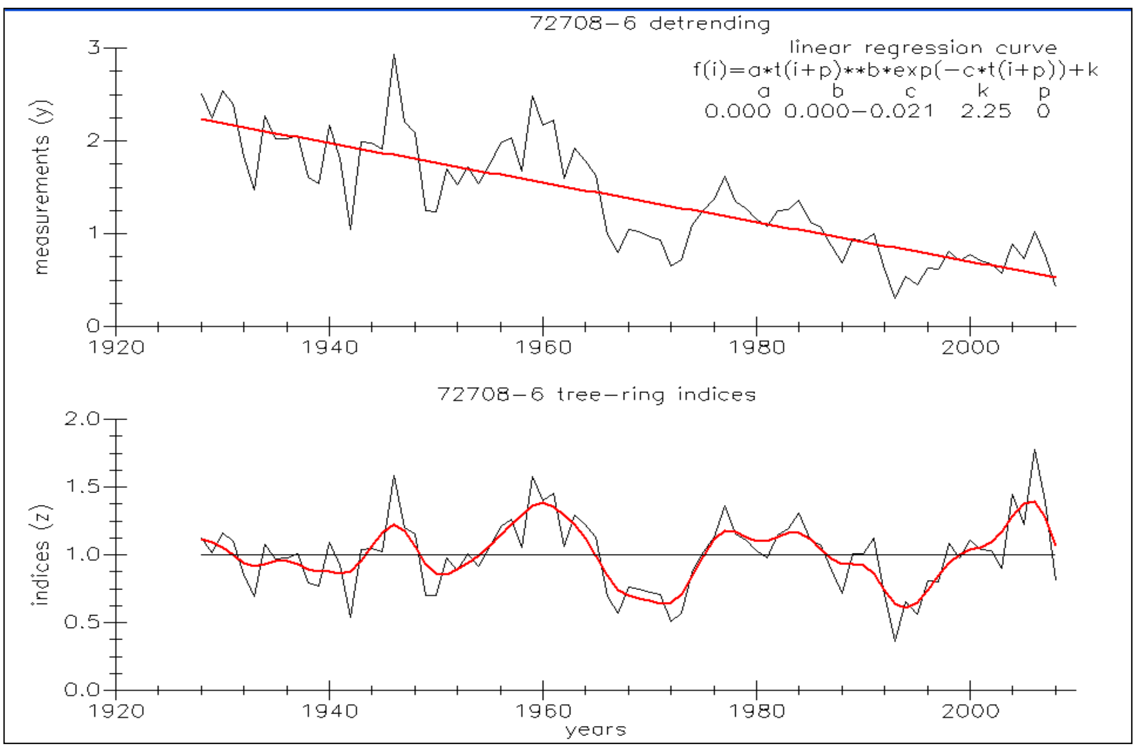

72708·2D detrending
linear regression curve
f(i)=a*t(i+p)**b*exp(-c*t(i+p))+k
a b c k p
0.000 0.000 0.000 0.38 0
measurements (y)
72708·2D tree-ring indices
indices (z)
years

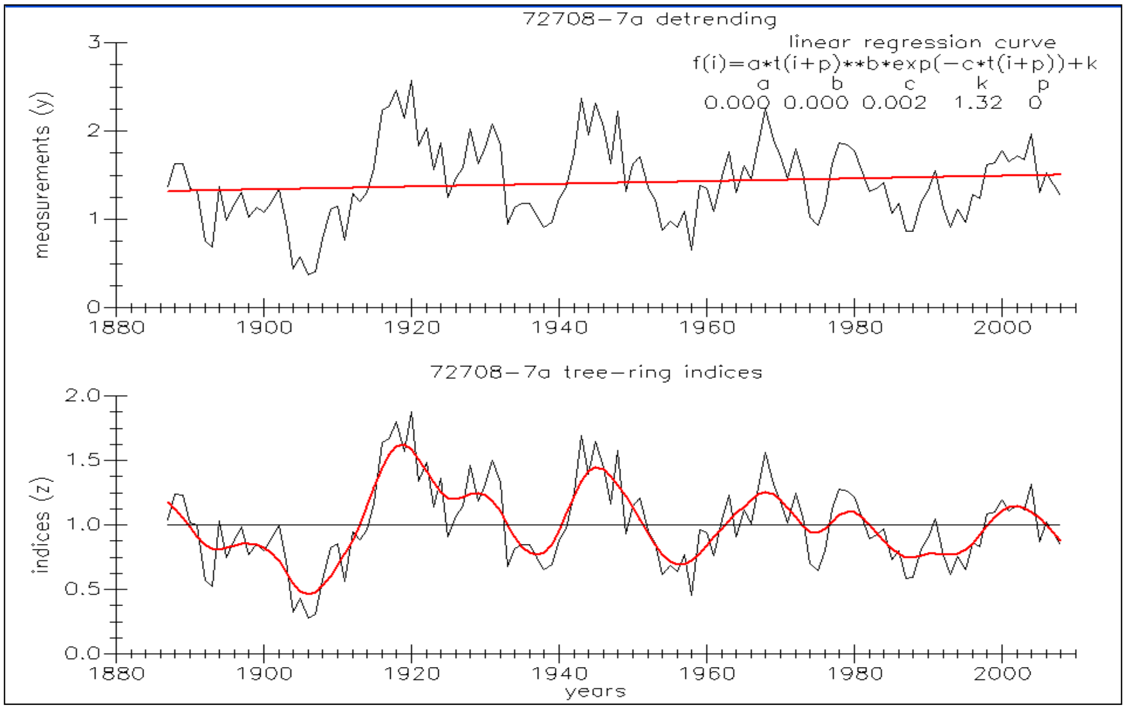

72708-3U detrending
linear regression curve
f(i)=a*t(i+p)**b*exp(-c*t(i+p))+k
a b c k p
0.000 0.000 0.000 0.68 0
measurements (y)
72708-3U tree-ring indices
indices (z)
years

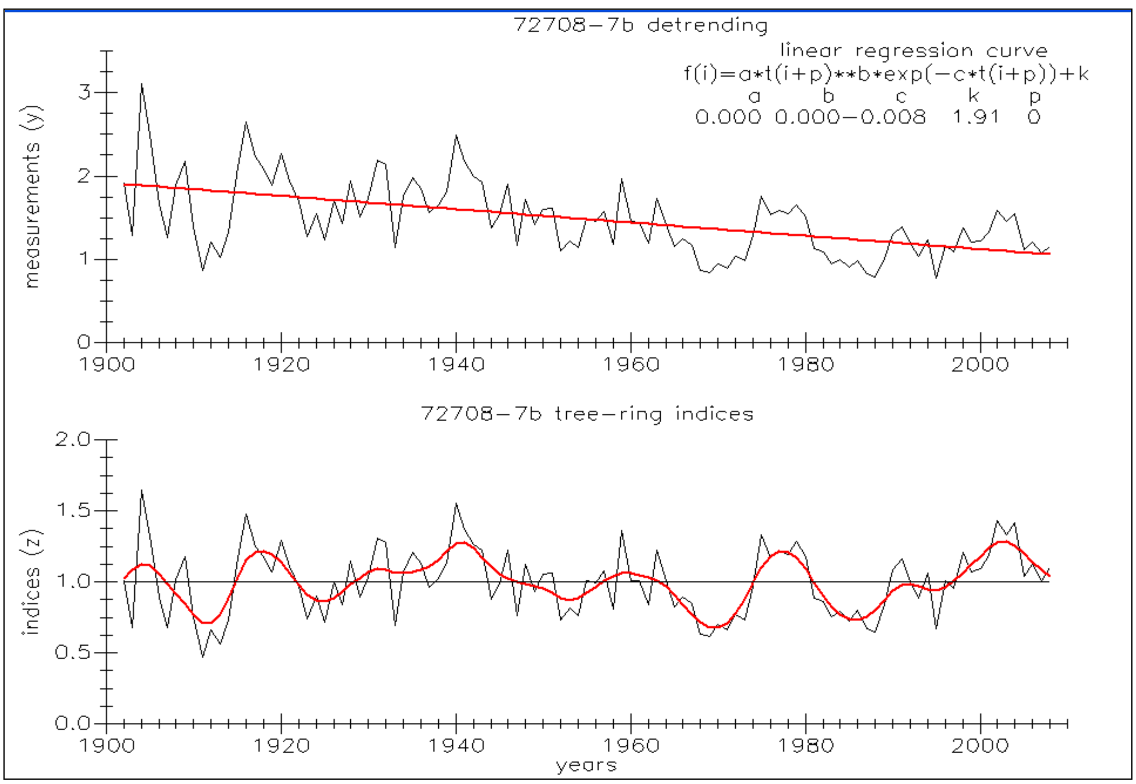

72708−3D detrending
linear regression curve
f(i)=a*t(i+p)**b*exp(−c*t(i+p))+k
a b c k p
0.000 0.000−0.001 0.62 0
measurements (y)
72708−3D tree−ring indices
indices (z)
years

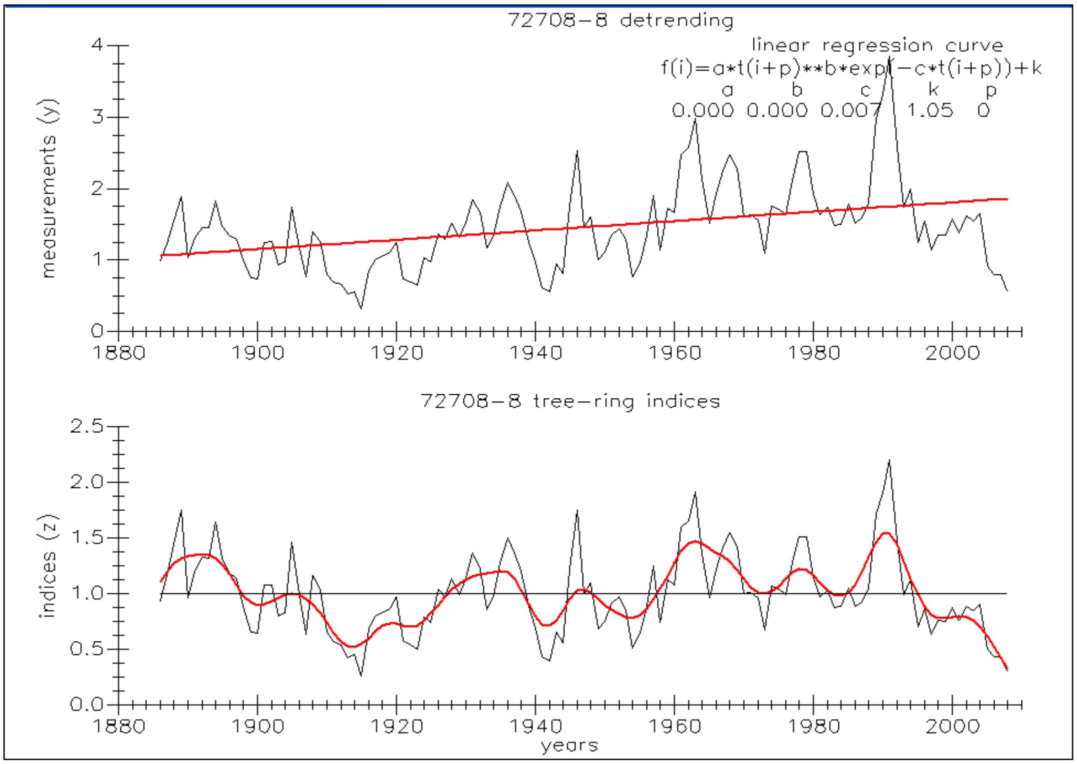

72708−4 detrending
linear regression curve
f(i)=a*t(i+p)**b*exp(−c*t(i+p))+k
a b c k p
0.000 0.000 0.016 0.51 0
measurements (y)
72708−4 tree−ring indices
indices (z)
years


72708−5 detrending
linear regression curve
f(i)=a∗t(i+p)∗∗b∗exp(−c∗t(i+p))+k
a b c k p
0.000 0.000−0.004 1.52 0
measurements (y)
72708−5 tree−ring indices
indices (z)
years


72708−6 detrending
linear regression curve
f(i)=a∗t(i+p)∗∗b∗exp(−c∗t(i+p))+k
a b c k p
0.000 0.000−0.021 2.25 0
measurements (y)
72708−6 tree−ring indices
indices (z)
years


72708−7a detrending
linear regression curve
f(i)=a*t(i+p)**b*exp(−c*t(i+p))+k
a b c k p
0.000 0.000 0.002 1.32 0
measurements (y)
72708−7a tree−ring indices
indices (z)
years


72708−7b detrending
linear regression curve
f(i)=a*t(i+p)**b*exp(−c*t(i+p))+k
a b c k p
0.000 0.000−0.008 1.91 0
measurements (y)
72708−7b tree−ring indices
indices (z)
years


72708-8 detrending
linear regression curve
f(i)=a*t(i+p)**b*exp(-c*t(i+p))+k
a b c k p
0.000 0.000 0.007 1.05 0
measurements (y)
72708-8 tree-ring indices
indices (z)
years