DENDROGEOMORPHIC EVIDENCE OF FREQUENT MASS WASTING FROM REACTION WOOD IN BLACK SPRUCE, NORTHWAY JCT., ALASKAN INTERIOR

by

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This thesis submitted by Catherine E. Heinrich in partial fulfillment of the requirements for the degree of Bachelor of Science with Honors in Geology from St. Lawrence University is hereby approved by the Faculty Advisor under whom the work was done.

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ABSTRACT

Understanding mass-wasting events along the remote transportation corridor of the Alaska Highway (ALCAN) is a crucial infrastructure need. To better understand a problematic section, we focused on the most intensely deformed section (4.8 hectares) along ALCAN mileposts 1265-1267. This section is dominated by complex slumping of blocks of thawing, perennially frozen, sandy silt. We deliberately sampled 30 *Picea mariana* that were tilted and thus visibly affected by mass-wasting events. Each tree was radially cored (n=60) in the direction of the tilt and at 90° to the first core. Reaction wood, and suppression and release events were recorded using microscopic analysis and recorded as modified skeleton plots of event-response phenomena, which resulted in a replication-summary plot. Of the 30 trees sampled, reaction wood was present in 26 trees, suppression was present in 24 trees and release was present in 15. Of the 26 trees with reaction wood, the onset of reaction wood occurred in five, area-wide events recorded in 1966 (5 trees), 1989 (8 trees), 1995 (6 trees), 2006 (7 trees), and 2011 (6 trees), with the 1966 and 1989 events followed by significant growth suppression. Eighty percent of tilting events occurred in areas where the active layer depth was ≤30cm. Generally, from 1900-1988 the area was relatively stable with reaction wood accounting for only 5.2% of recorded radial growth. The onset of instability, however, occurs in 1989 where, from 1989-2013, reaction wood accounts for 32.7% of recorded radial growth. Combined, climate and tree-tilting data, suggest that as these high-latitude sites become more equitable for black spruce growth, the more mass-wasting will occur due to deepening of the active layer, which will likely result in continued and more widespread mass-wasting events. We can expect similar, if not more frequent, mass-wasting events as temperature and precipitation increases in areas with higher amounts of frozen water within the permafrost. Maintaining areas underlain by high ice content should be given priority.

INTRODUCTION

Mass wasting (landslide) damage to infrastructure is a serious scientific and engineering issue across the globe (Dai et al., 2002). In support of the Division of Geological and Geophysical Surveys (DGGS) in Alaska (working with employee, Trent Hubbard ’94) we studied the climate controls on an active mass-wasting event affecting a remote section of the Alaskan-Canadian Highway (ALCAN) near Northway, AK (Figure 1).

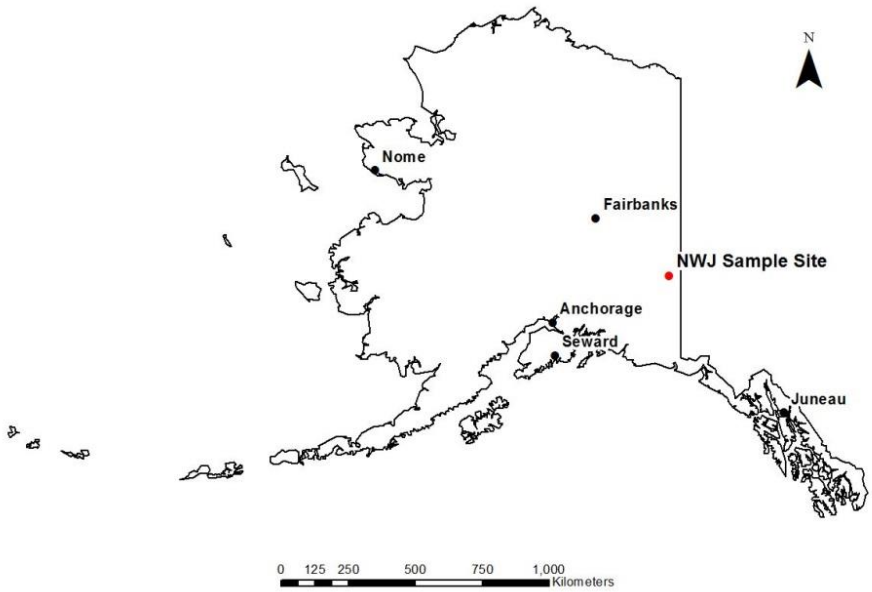


Figure 1: State of Alaska with major cities labeled. Northway Junction sampling location is marked in red and is approximately 40km from the Canadian border.

Damage to infrastructure caused by mass wasting is compounded in areas underlain by permafrost, which are subject to shallow flows of a saturated active layer over the still frozen permafrost zone. Remote areas along the Alaska-Canadian Highway (ALCAN) are subject to damage caused by the annual thawing and freezing of permafrost as well as damage caused by mass wasting, which may or may not be associated with permafrost. The high costs of repairing vital sections of transportation

corridors are only increased by their remote location. According to Foster and Goldsmith (2008) of the Institute of Social and Economic Research (ISER) at University of Alaska Anchorage, the estimated cost of replacing Alaska's public infrastructure would cost nearly $59 billion (64.3 billion in today's dollar). Of that total, replacement cost of transportation is over 33 billion, with public roads accounting for 64% of transportation costs (Figure 2). Climate change could add 15 to 20% to infrastructure costs by 2030 and 10% to 12% by 2080, under different climate projections and taking design adaptations into account (Larsen et al., 2008). Maintaining the ALCAN and other routes in Alaska is vital to Alaskan transportation. Studying these sites is important because it allows us to gain a better understanding of the effects of mass wasting events and permafrost on infrastructure. By better understanding past mass wasting events and the effects of climate on permafrost and infrastructure we can make more cost effective maintenance decisions and prepare for future infrastructure needs.

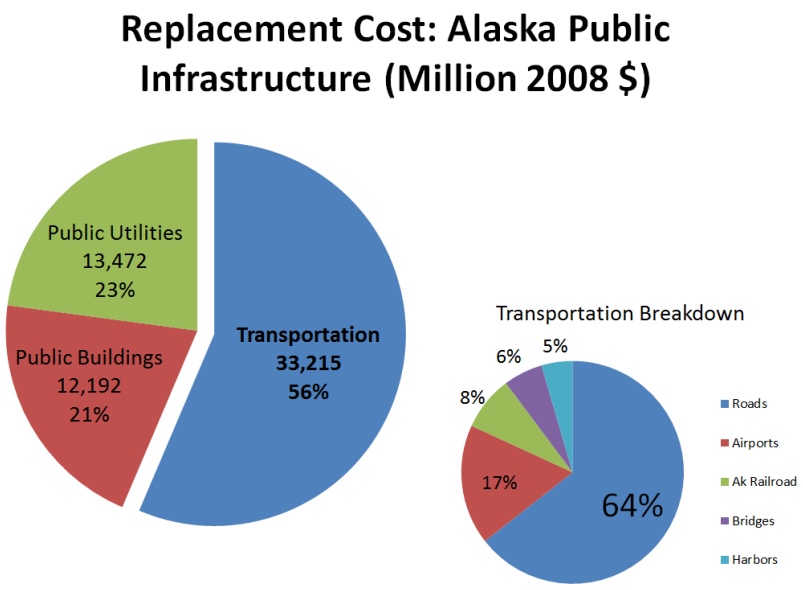


Figure 2: Replacement costs in AK (in $ millions). Data obtained from the Institute of Social and Economic Research University of Alaska Anchorage (Foster and Goldsmith, 2008)

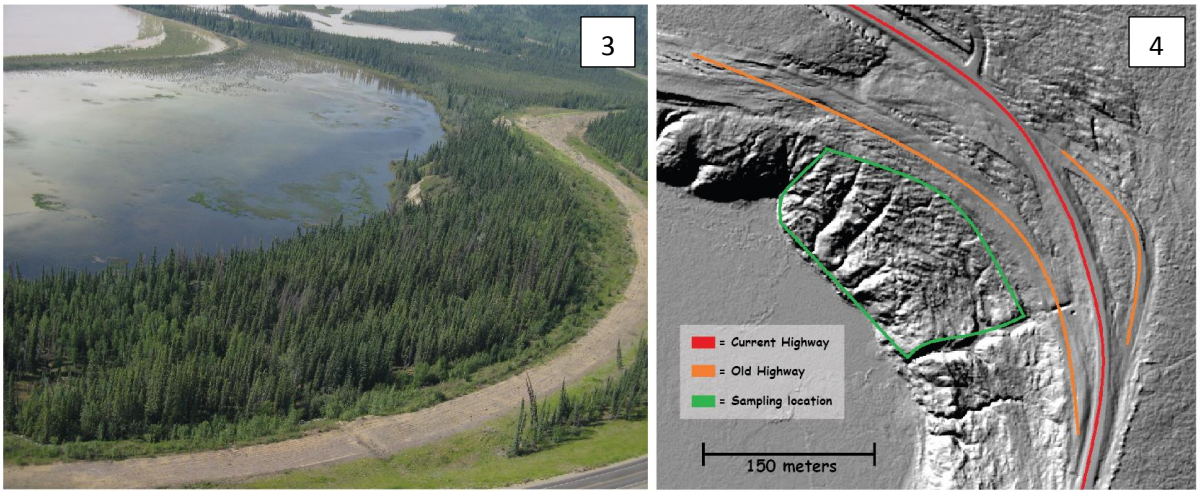
BACKGROUND

Dendrochronology is the science that deals with the dating and study of annual growth layers in trees and shrubs. For this study we used dendrochronological techniques to generate a master chronology and to expand our understanding of the interaction between multiple variables (e.g., mass wasting events) and their affects on tree growth. ALCAN milepost 1265-1267, near Northway, AK, is an ideal location for this study because of recurrent slope failures. A large failure, near ALCAN 1267, has seriously affected the ALCAN multiple times, and in 2004 it required moving the highway alignment northward away from the Chisana River floodplain. Understanding slope movement, especially as it relates to thawing permafrost in this extensive area of frozen silt and sand is important in planning for future maintenance decisions. To best approach this problem, a series of black spruce trees were sampled and prepared for statistical analyses. Tree-ring data was compiled by means of skeleton plotting and digitization using a calibrated stage.

Location

The focus of this study is on an active landslide in interior Alaska near Northway, AK at approximately 62.9692° N, 141.9050° W (Figures 3 and 4) and is within the Tetlin National Wildlife Refuge. It is located in the Northway-Tanacross Lowland, which is part of the Alaska Boreal Interior (Taiga) and, more specifically the Interior Bottomlands (Wilken, et al., 2011). Our sampling site was on a retrogressive landslide on the southwestern side of the ALCAN, 42.27km west of the Canadian border. This region is underlain by horizontal sedimentary rocks (Foster, 1987) and is at an elevation of 429m at the confluence of Moose Creek and Chisana River (Valencia, 2011). The Northway-

Tanacross Lowland consists of three small basins, separated by low rolling hills. The two basins along the north side of the lowland are nearly level plains, broadly oval in plan. Scattered longitudinal dunes mark the floor of the eastern one of these two basins. The third basin, on the southeast, is a gently rolling moraine-covered plain (Wahrhaftig, 1965).



Figures 3 and 4: Photograph (3) taken 07/31/2009 by R.A. Combellick. Milepost 1265-1267 on the ALCAN Highway; about 42km from the Canadian border. LiDAR image (4) shows both the current and old highways as well as the sampling location.

Geology

The low rolling bedrock hills are Precambrian (?) in age and consist of schist and Mesozoic granitic intrusions (Wahrhaftig, 1965). Although our area of study did not overlie any major faults there are active Late Pleistocene and Holocene faults about 65 km to the southwest (Figure 5). Regional surficial materials comprising discontinuous shallow-and-deep deposits of hummocky-to-ridged morainal sediments are interrupted occasionally by Precambrian bedrock outcrops and (CEC, 1997). At Northway, specifically, alpine glaciers never extended into the lowland, so the area is considered periglacial. The Interior Bottomlands are characterized by three basins which, are

mantled with outwash gravel, silt, and moraine deposits. The two northern basins were probably occupied by a lake dammed by a glacier at Cathedral Rapids about 100km to the northwest of Northway Junction (Wahrhaftig, 1965). Lowlands are covered with peatlands and permafrost is widespread, with patterned ground features being common (CEC, 1997, cf. Figure 7). Large lakes in re-entrants (small valleys) in the surrounding hills may be caused by alluviation of the lowland with thousands of lakes and wetlands occupying glacially carved depressions (CEC, 1997). Of these lakes and wetlands, as many as 70% of surface lakes are thaw lakes, which proliferate in areas of fine alluvium. Oxbow lakes and morainal ponds are also present in this region (Wahrhaftig, 1965). Northway Junction, proper, is characterized by discontinuous permafrost with low to moderate ice content in mixed forests on stabilized sand dunes on higher stream terraces with complex slumping of block of thawing perennially frozen sandy silt (Reger et al., 2012). Discontinuous permafrost with low to moderate ice content is also mapped where the aeolian cover sand is thin or lacking on older terraces and abandoned floodplains with extensive scrublands (Reger et al., 2012). Nutrient-poor forest soils are dominant in the southern portion and permafrost soils occur in the northern portion (Figure 7) (CEC, 1997).

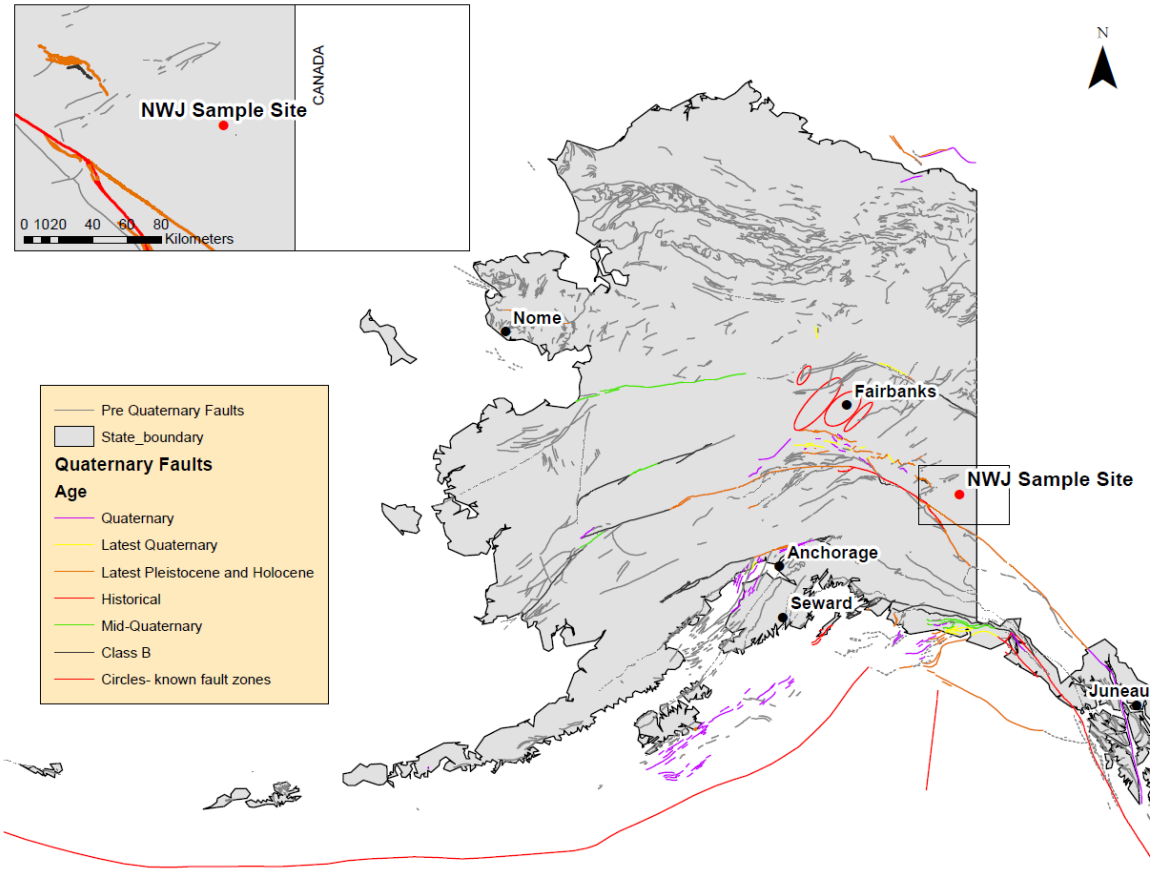


Figure 5: GIS map of Alaskan faults. Note inset map on top left. Map created by author, data obtained from Koehler (2013).

Mass-wasting

Mass-wasting is the movement of unconsolidated debris down slope due to gravity (Alimohammadlou et al., 2013) and has both environmental and socio-economic effects. Gravity is the main driver of this force, but water can also be a major factor. Different types of mass wasting include creep, slides, flows, topples, and falls. When the gravitational force acting on a slope exceeds its resisting force, the slope will fail causing a mass-wasting event. The movement can be so subtle and slow that it is hard to detect or it can be swift and devastating. "Creep is the slow downslope transport of soil or regolith by bulk motion under the influence of gravity. This motion occurs in a variety of settings.

The motion is usually so slow that it is difficult to measure except on long timescales (months to years)" (Anderson and Anderson, 2011, p. 320). Frost creep and gelifluction are both examples of slow downslope movements of unconsolidated materials in periglacial environments like Northway Junction. Slow downslope movement of sediments is a significant process in periglacial areas. It is responsible for tongue-shaped features called solifluction lobes. This slow downslope movement occurs in the short summers of Arctic and alpine areas, and results from frozen soils attaining excess water as they freeze through the growth of ice lenses. In the spring and summer the ice melts which super-saturates the near-surface soil from the surface downward. Because the saturated soil is weakened it is subjected to shear stress associated with slopes, which allows it to flow (Anderson and Anderson, 2011).

Permafrost

Permafrost is ground that remains below 0°C more than two consecutive years. About 20 percent of the land area of the earth is located in climatic zones where the mean annual temperature falls below 0°C (Woods and Leonards, 1964). Unlike more temperate climates, the average temperature at the poles and at high latitudes is so cold the ground does not completely thaw during the summer months. This perennially frozen ground is known as permafrost. Most of the permafrost existing today formed during cold glacial periods, and has persisted through warmer interglacial periods, including the Holocene (IPA, 2014). The active-layer in permafrost is the layer of ground that is subject to annual thawing and freezing in areas underlain by permafrost. The thickness of this layer in most circumstances depends mainly on the moisture content which varies from 10-20 cm in

thickness in wet organic soils and from 2-3 m in well drained gravel (Péwé, 1979; Figure 6). Below the active layer is the permafrost table. The permafrost table is less affected by annual changes in temperature. Isothermal permafrost is below the permafrost table and is unaffected by annual temperature change. As depth increases the soil becomes frost-free due to the geothermal gradient. The geothermal gradient is the rate of increasing temperature with respect to increasing depth in Earth's interior (Figure 6).

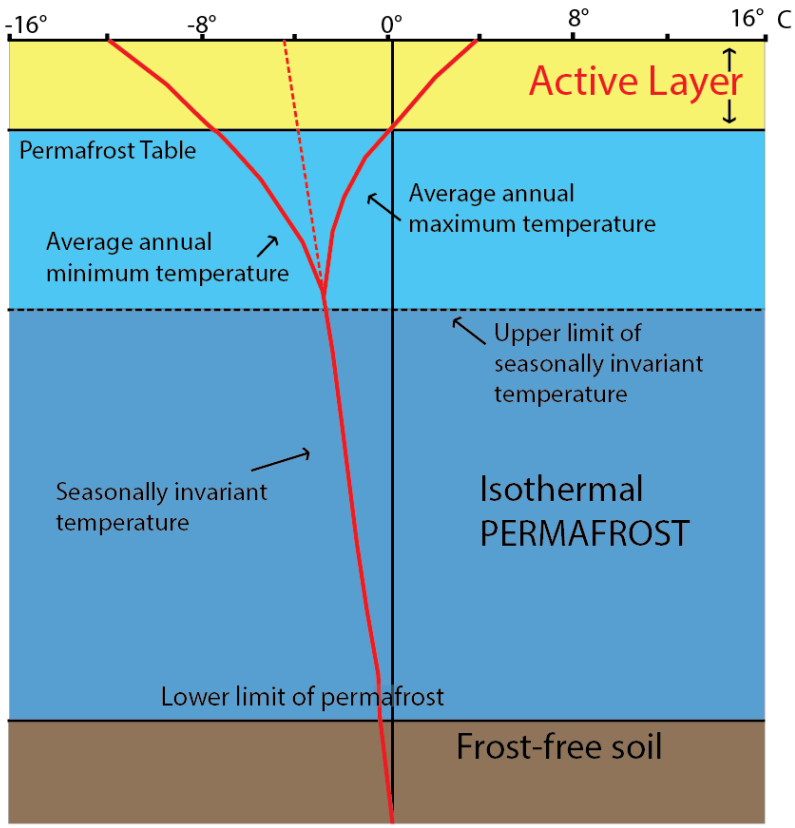


Figure 6. Schematic cross-section of permafrost zones. The active layer is subject to annual freezing and thawing as temperature increases from left to right. The trumpet-shaped lines at the top show seasonal-maximum and minimum temperatures in the active zone. Below the active layer is the permafrost table. As depth increases, there is frost-free soil due to the geothermal gradient. Modified from Péwé (1954).

The lowest elevation of alpine permafrost has risen in most mountainous areas in the twentieth century due to climate warming (Clague, 2013). Permafrost thaw has lowered the strength of rock with fractures or other structural discontinuities because ice in the fractures melts (Clague, 2013). When permafrost thaws it can have a broad range of implications on surrounding infrastructure such as mass wasting events due to unstable sediment (Figure 7). The most dramatic, widespread, and economically important examples of the influence of permafrost on life in the north deal with construction and maintenance of roads, railroads, airfields, bridges, buildings, dams, sewers, oil and gas pipelines, and communications lines (Péwé, 1979). There are generally two methods of construction in permafrost areas. The method of construction preserving the permafrost has been termed the passive method, and alternately, the destroying of permafrost, the active method (Péwé, 1979).

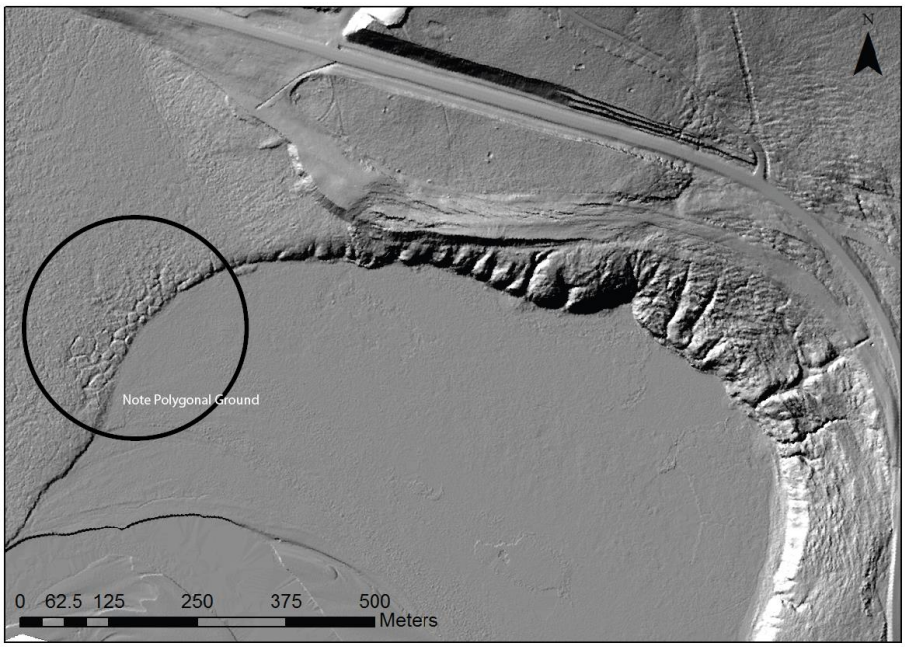


Figure 7: LiDAR image of mass-wasting location for sampling. Note the multi-repaired roadway in the landslide zone and patterned ground (circled). This image was taken on the ALCAN highway in south central Alaska at our study location.

Ecoregion (Gallant et al., 1995)

The area of our study is located in the Interior Bottomlands ecoregion. This region is characterized by a continental climate with temperatures usually remain above freezing throughout the summer (June through August), though may dip below freezing during this time. This region is composed of flat to nearly flat bottomlands along larger rivers of interior Alaska. The bottomlands are dotted with thaw and oxbow lakes. Soils are poorly drained and shallow, often over permafrost. Predominant vegetation communities include forests dominated by spruce and hardwood species, tall shrub thickets, and wetlands. Needleleaf, broadleaf and mixed forest stands occur on a variety of sites in the Interior Bottomlands Ecoregion. Tall scrub communities form thickets on floodplains. Scrublands, which have open to closed canopies of low shrubs dominated by dwarf birch and ericaceous shrubs, include black spruce and larch and are one of the most widespread ecosystems in Alaska (Jorgenson et al., 2001). The wettest sites support a variety of wetland communities, such as low scrub bogs, wet graminoid herbaceous meadows, and wet forb herbaceous marshes and meadows. Needleleaf forests are dominated by white spruce (*Picea glauca*), black spruce (*Picea mariana*), or a combination of the two. Closed stands of white spruce occupy young river terraces where soil drainage is good. Closed stands of black spruce occur on well drained to poorly drained floodplain soils (Gallant, et al, 1995).

Dendrogeomorphology

Dendrochronology is the science that deals with the dating and study of annual growth layers, or tree rings in woody trees and shrubs. The importance of

dendrochronology is not that you can tell how old a tree is, but that you can date a variety of events with a one-year precision. Because of this one-year resolution, the science of dendrochronology has blossomed beyond typical forestry needs (e.g., stand age). Dendrogeomorphology is the analysis of geomorphologic processes through dendrochronological techniques and was first introduced by Alestalo (1971). The application of dendrochronology to geomorphic processes can provide a temporal and spatial aspect to the practical problems surrounding mass movement. These annually resolved tree-ring records also preserve valuable archives of past geomorphic processes on time scales from decades to centuries (Stoffel and Corona, 2014). Many of these processes are significant natural hazards, understanding their distribution, timing and controls provides crucial information that can assist in the prediction, mitigation and defense against these hazards and their effects on society.

Picea mariana (black spruce)

Picea mariana (black spruce, bog spruce, swamp spruce) is an abundant conifer of the northern parts of North America. Its wood is yellow-white in color, relatively light in weight, and strong (Viereck et al., 1990). Black spruce occurs on a wide range of sites. It grows on wet lowlands and drier uplands, in a variety of soils. It is most common on poorly drained sites underlain with permafrost. Black spruce dominates most spruce-fir ecosystems of boreal North America (Figure 8). Black spruce communities are generally classified into forest and woodland types. Ericaceous shrubs often grow in black spruce understories, with mosses and lichens in ground layers. Additionally, black spruce is important in other boreal mixed-conifer and conifer-hardwood communities. It is

primarily a boreal species, although its distribution extends south into the Great Lakes and Northeast regions of the United States. Black spruce's expansion north is hindered by permanently frozen soils. In interior Alaska, young glacial deposits halt its distribution in the southern Brooks Range (Lloyd, et al., 2007). Climate warming is apparently favoring expansion of black spruce's distribution in the north (Chapin et al, 2010) and shrinkage in the south (Hogg, 1994). Because black spruce is an abundant and hearty species in the poorly drained acidic soils of the Interior Bottomlands it is a good candidate for our sampling.

Figure 8: Black spruce distribution (USDA, 1971). Note the highlighted regions represent areas where native black spruce are located. http://www.fs.fed.us/database/feis/plants/tree/picmar/all.html

Growth Anomalies in Trees

Mass movement can cause responses in tree growth such as trunk curvature, reaction wood, growth anomaly (suppression, release, eccentric growth), scar development, etc. (Shroder, 1978). Subsequent growth in the trunk of a tilted tree will attempt to restore its vertical position and the reaction will be most clearly visible in that segment of the tree to which the center of gravity has been moved through the inclination of the stem axis (Mattheck 1993, from Stoffel and Corona, 2014). In conifers, compression wood (also referred to as reaction wood) will be produced on the underside of the trunk. Individual rings will be considerably larger and slightly darker in appearance as compared to the upslope side (Stoffel and Corona, 2014). Growth-ring disturbances are usually in the form of reaction wood and scars (Owczarek, 2005). Reaction wood forms to compensate for physical stressors (e.g., tilting due to mass wasting) and forms on the opposite side of the applied force (Figure 9). Mass-wasting may cause mechanical disturbances as well as shortages of water and nutrient supply, resulting in suppressed tree growth and the formation of narrow rings. The counterpart to growth suppression is growth release. Large and devastating geomorphic events can eliminate neighboring trees resulting in a new environment with less competition, more light, nutrients and/or water, creating improved conditions and a response of growth increase and wider rings (Stoffel and Corona, 2014).

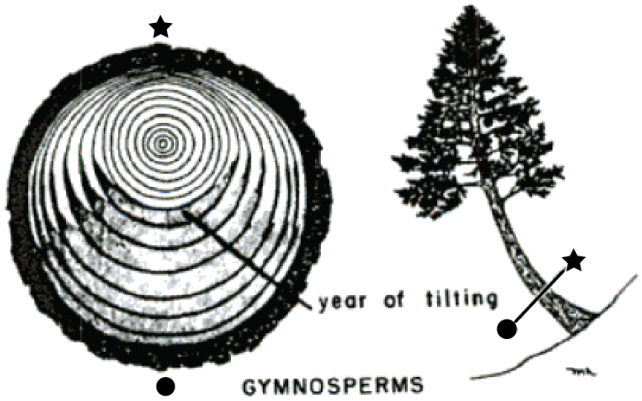


Figure 9. Tilted trees produce reaction wood in an effort to realign with the vertical; gymnosperms (such as black spruce) produce compression wood (also called reaction wood) on the tilted side of the tree (from Fritts 1976).

METHODS

We used remote-sensing technology such as Google Street View, aerial photographs and images from Alaska's DGGS courtesy of Trent Hubbard to examine the location prior to beginning data collection in the field. We also used LiDAR (Light Detection and Ranging Data) (Figures 3 and 5) images to examine the slope failure and related features. LiDAR imaging shows slumping, polygonal cracks, and the location of the highway both before and after it was effected affected by mass wasting in 2004.

Tree Sampling

Once onsite we selected trees to sample, all of which were visibly tilted. A Swedish increment borer was used to collect two samples each from 30 black spruce trees. We took two cores at each sample location. One core was taken through the reaction wood (core a), or the direction in which the tree was tilting towards and another was taken at a 90° angle to the first (core b) as suggested by Fantucci and McCord (1995)

and Stoffel (personal communication). At each location we recorded the GPS coordinates, height of the tree, diameter at breast height (DBH), height at which the sample was taken, elevation, direction and angle of the tilt, direction and angle of slope (if any), the crown density and the average active layer depth of the permafrost as of June 1, 2014, as well as any additional notes. We defined the active layer depth as the mean of three depth measurements equally spaced around the tree and 1.2 meters away from the trunk (Figure 4). We took three different depths around the tree and averaged them together for an average active layer depth (ALD). After each tree was sampled it was marked with flagging tape. After the borings were removed from the increment borer they were stored in paper straws and labeled.

Sample Preparation

Prior to mounting, all cores were removed from their paper straws and dried overnight. When dried, cores were mounted with Elmer's glue to wooden mounts; mounts were be labeled with permanent marker. The cores were taped over with masking tape to retain the core during the glue-drying phase (24 hours). Cores were sanded with progressively finer sand paper from coarse, 120-grit paper to very fine, 1000-grit paper. Sanding allowed direct observation of individual cells and ring boundaries and reaction wood (See Figure 10).

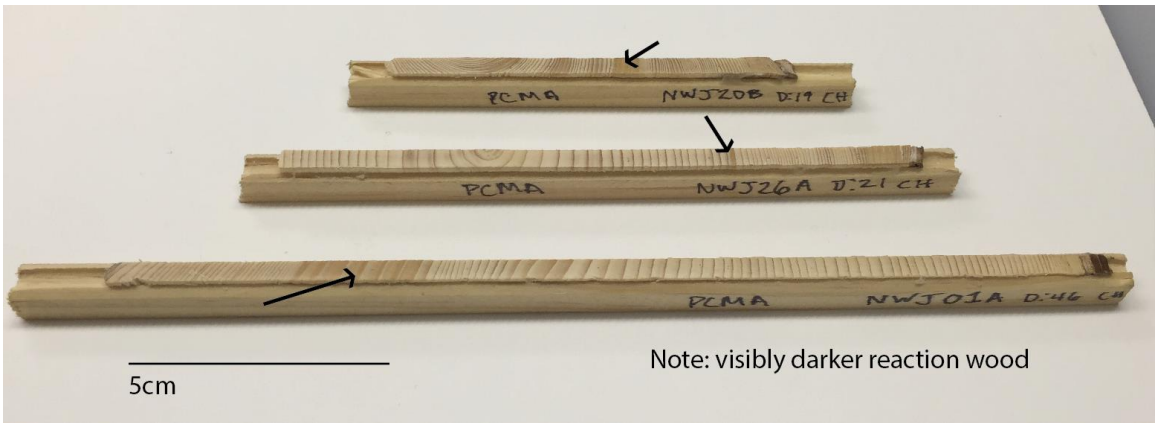


Figure 10: Three fully prepared cores glued to grooved wooden mounts and sanded with progressively finer grits. These cores are labeled with PCMA which is the code for black spruce and are labeled with their sample number and their DBH. The left sides of the cores are the oldest rings and the rings on the right side are the youngest and the furthest material on the right is bark. Arrows denote examples of reaction wood.

Data Gathering

Skeleton Plotting

Once all cores mounted and sanded, they were dot-counted to determine age (See Figure 11 for concept). Next, each core was skeleton plotted and thus, re-counted to minimize error. Skeleton plotting is a basic technique developed by Douglass in the early 1900's (see Stokes and Smiley, 1996) to help a) annotate the decadal rings (or ring years that end in zero) by "dot marking" them, and b) highlight those rings that are narrower than their neighbors and c) recognize environmental changes to ring widths (e.g. suppression or release).

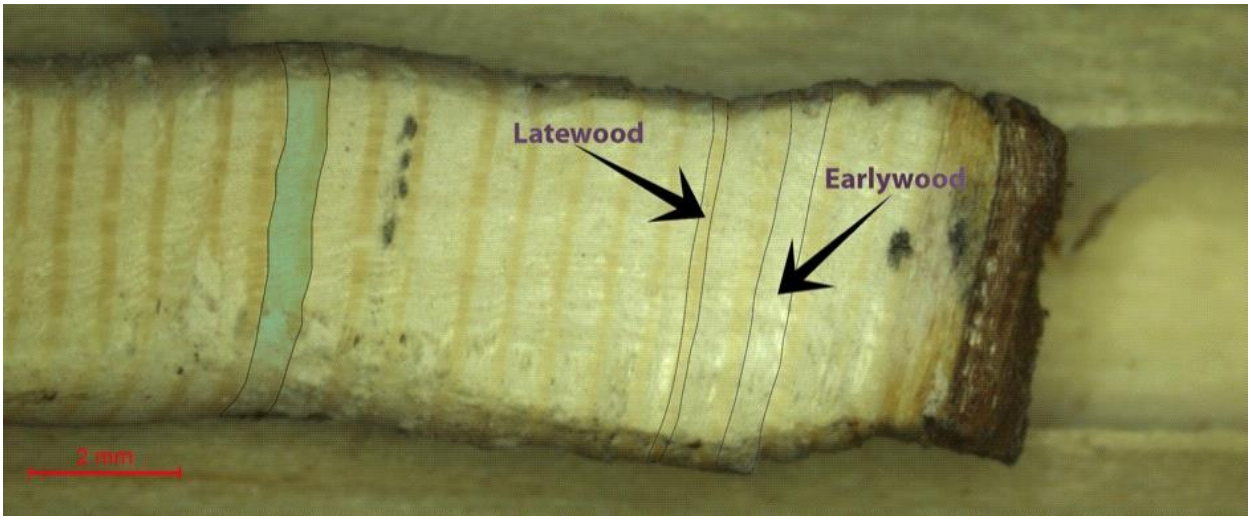


Figure 11: Mounted tree core showing early and latewoods (arrows) and a full annual ring (highlighted by blue box). Also, note the series of four dots near the center of the core, the represents a "millennial" dot count (i.e., year 2000). Tree is growing from left to right.

We used a modified skeleton plot from Shroder (1978), which focuses on growth anomalies. Each individual core was analyzed for reaction wood, growth suppression and growth release (Figure 12). The final digitized copy was created after each individual core was plotted by hand and then transferred to a master copy. Growth suppression was recorded if the ring had a decrease in size of 50% or more from the previous ring (Fantucci and McCord, 1995). A ring was said to have growth release if the ring had an increase of 50% or more from the previous ring (Fantucci and McCord, 1995). A reaction wood response was only recorded if 50% or more of the ring was distinctly darker in color. Becoming “intimate” with the wood in this manner helped during the following, mechanical measurement via an incremental stage.

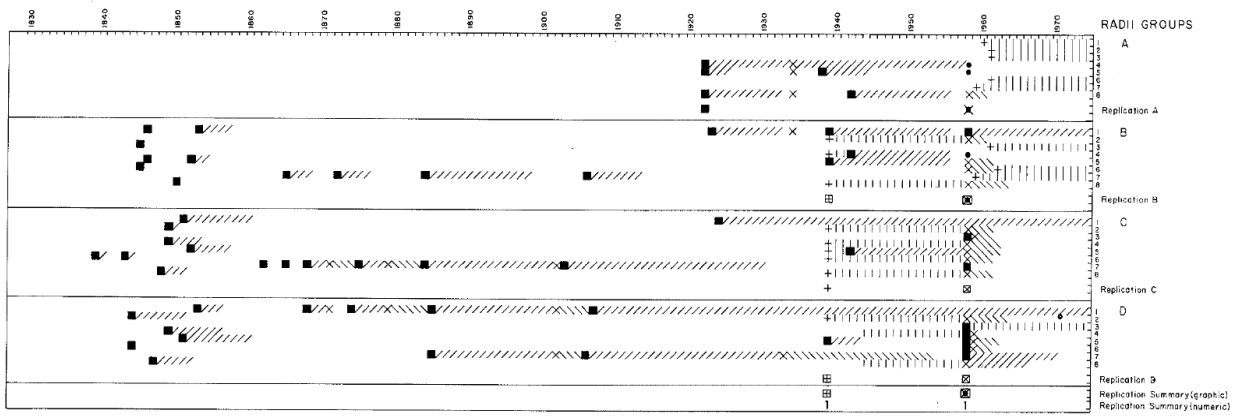


Figure 12: Example of compiled dendrogeomophological skeleton plots. Squares represent reaction wood, "x" represents suppression, a "+" represents release and circles represent corrasion. Large symbols represent abrupt first appearances while small symbols represent a gradual first appearance. Response continuation is marked by a backslash or a foreslash. (from Shroder, 1978).

Incremental Stage

Subsequent to skeleton plotting (e.g., focusing on the cores and their subtleties) the same cores were processed on a Velmex digitized stage. This digitized stage captured ring-width data to 0.001mm of precision. Each ring was measured from latewood to latewood with measurements recorded by the program MeasureJ2X. These data were x,y data, or year,width. These files were saved and used during the data analysis portion with COFECHA.

COFECHA

The core measurements and dating were verified with the program COFECHA (Holmes, 1983). COFECHA makes it possible to find double or false rings and/or reading mistakes and is essentially a quality-control program used to check the crossdating and overall quality of tree-ring chronologies. Years that do not match at the 99% confidence level are flagged for the user to examine (Grissino-Mayer, 2001). COFECHA provides

series intercorrelations and average mean sensitivities. Series intercorrelation measures the strength of the common signal in the chronology and is a measure of chronology reliability. The highest values are around 0.900, for very drought-sensitive conifers, and the lowest values for trees that can still be reliably cross-dated are around 0.400. The highest values of series intercorrelation are generally more desirable; however trees of some species and in some regions will have higher values than others (NOAA, 2015). Average mean sensitivity is the relative change in ring-width from one year to the next and varies by species and region. In order to increase the chronologic length and increase the series intercorrelation and average mean sensitivity we added Schweingruber's tree ring data, (Schweingruber, 1983) to our COFECHA input.

ARSTAN

ARSTAN is a program that detrends individual tree-ring measurement series removing unwanted trends, especially age-related trends and those from local/regional disturbances unrelated to climate. The program was developed by Dr. Edward R. Cook of the Tree-Ring Laboratory at Lamont-Doherty Earth Observatory, Columbia University, with important modifications by Paul Krusic of Columbia University. By using the program ARSTAN, the ring-width measurements are detrended using a 50-year cubic smoothing spline (Cook and Peters, 1981). The purpose of standardization is to amplify the climatic signal (high frequency or interannual variation) while removing the effect of non-climatic factors (e.g. age-related trend) (low-frequency or long-term variation) (Fritts, 1976).

DENDROCLIM 2002

"Tree-ring chronologies are often calibrated against instrumental climate records using correlation and response functions. DENDROCLIM 2002 uses bootstrapped confidence intervals to estimate the significance of both correlation and response function coefficients" (Biondi and Waikul, 2004). DENDROCLIM 2002 was developed by Dr. Franco Biondi and his colleagues to allow correlation and response function analyses of the climate/tree growth relationship using both evolutionary and moving intervals. Input data required are monthly temperature and precipitation data as well as the tree-ring index chronology. The standard chronology we created was then used to correlate to temperature, precipitation and snowfall data obtained for Northway Airport, Northway, AK 99764. The data set provides temperature, precipitation and snowfall data from 1949 until June of 2014. Data from Northway Airport was used because the location is proximal (our sampling site is located within 12 kilometers from Northway Airport). Again, we combined our data from Northway Junction (Heinrich et al., 2014) with Schweingruber's tree ring data, ak_012 (1983). Weather and chronology data were managed using Excel and Kaleidagraph for statistical analyses and graphing.

Spectral Analyses

We used MTMCohere to run our spectral analyses. A spectral analysis is an analysis in terms of a spectrum of frequencies or related quantities. The goal of spectral analysis is to estimate the spectral density of a random signal from a sequence of time samples of the signal. The results allow detection of periodicities in the data by observing peaks at the frequencies corresponding to these periodicities. The MTM code of J. Park

was adapted to perform significance of spectral peaks relative to “robust red noise” background as described by Mann and Lees (1996) and to calculate MTM spectral coherence of two series with automatic determination of confidence levels. They developed a new technique for signal detection in climate time series that accounts for the physics governing the climatic system.

Spatial Analyses

Using ArcGIS and ArcMap10.2.2 as well as Surfer11 we were able to generate maps of our samples showing various characteristics (tilt angle, tilt direction, slope, etc.) across space and time Geographic Information System and Geographic Information Science (GIS). GIScience is the academic theory behind the development, use and application of geographic information systems. GISystem is a computer system for capturing, storing, checking, integration, manipulation, analyzing and displaying data related to positions of the Earth’s surface. GIS data is stored in layers, which, are then linked together by geography or location. GIS is important because it can relate unrelated information by using location as the key index variable. GIS is such a powerful and important tool because it can spatially represent information. GIS allows us to visualize our data and figure out what is happening in order to make better informed decisions. Using GIS we were able to add the x,y location of each tree sampled and attach attributes that we gathered in the field, such as ALD, DBH, and direction of tilt, to each respective tree. LiDAR imagery, courtesy of Trent Hubbard, 2012, gave our analysis more depth due to high-resolution elevation data due to the nature of LiDAR. We also used Surfer in

order to preform terrain modeling, landscape visualization, surface analysis, and contour mapping, to visually show trends in our data set.

DATA / RESULTS

General Stand and Chronology Characteristics

From Northway Junction, AK, 60 cores were obtained from 30 trees. After dot counting each sample, the oldest dated ring in the collection was from 1819, therefore the chronology from Northway Junction (not including Schweingruber) dates from 1819 to 2013 (Heinrich et al., 2014). General field data and ages we recorded in Excel (Appendix A). Sample NWJ03 had the largest tilt angle of 30° while, sample NWJ30 had the smallest tilt with an angle of 3°. The average tilt angle of the 30 samples was 12.8 degrees. The averages of active layer depth of permafrost ranged from 6.6cm-73.3cm with an average depth of 24cm.

Table 1: Field data condensed.

Measurement	**Average**	**Standard deviation (σ)**
DBH	32.5cm	8.68cm
Height	20.8m	5.34m
ALD	24cm	13.84cm
Elevation	556m	5.19m
Tilt Angle	13°	7.19°
Slope Angle	12°	6.65°
Crown Density: Low (1) to High (5)	2.8	1.28

Reaction wood, suppression and release growth

Of the 30 trees sampled, reaction wood was present in 26 trees, suppression was present in 24 trees and release was present in 15. Of the 26 trees with reaction wood (Figure 7), onsets of reaction wood occurred in 1966 (5 trees), 1989 (8 trees), 1995 (6 trees), 2006 (7 trees), and 2011 (6 trees), with the 1966 and 1989 events followed by significant growth suppression (Figure 14). Eighty percent of tilting events occurred in areas where the active layer depth was ≤30cm. We counted the number of sticks that had an onset of reaction wood in each year and divided that number by the amount of sticks that were alive during that year for the percent of reaction wood that had an onset in that year (Figure 13).

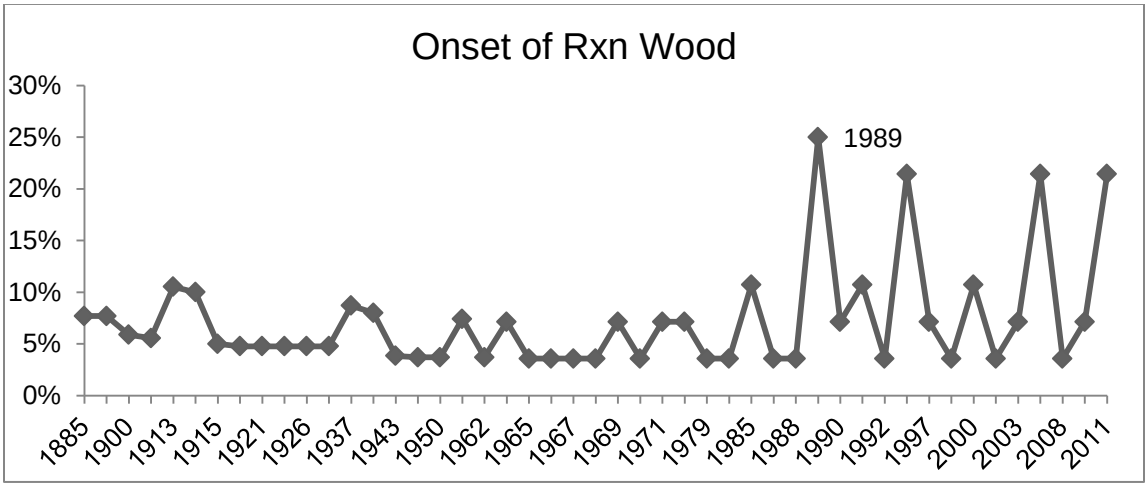


Figure 13: The largest percentage of onset of reaction wood occurred in 1989. The earliest year that we see an onset of reaction wood is in 1885.

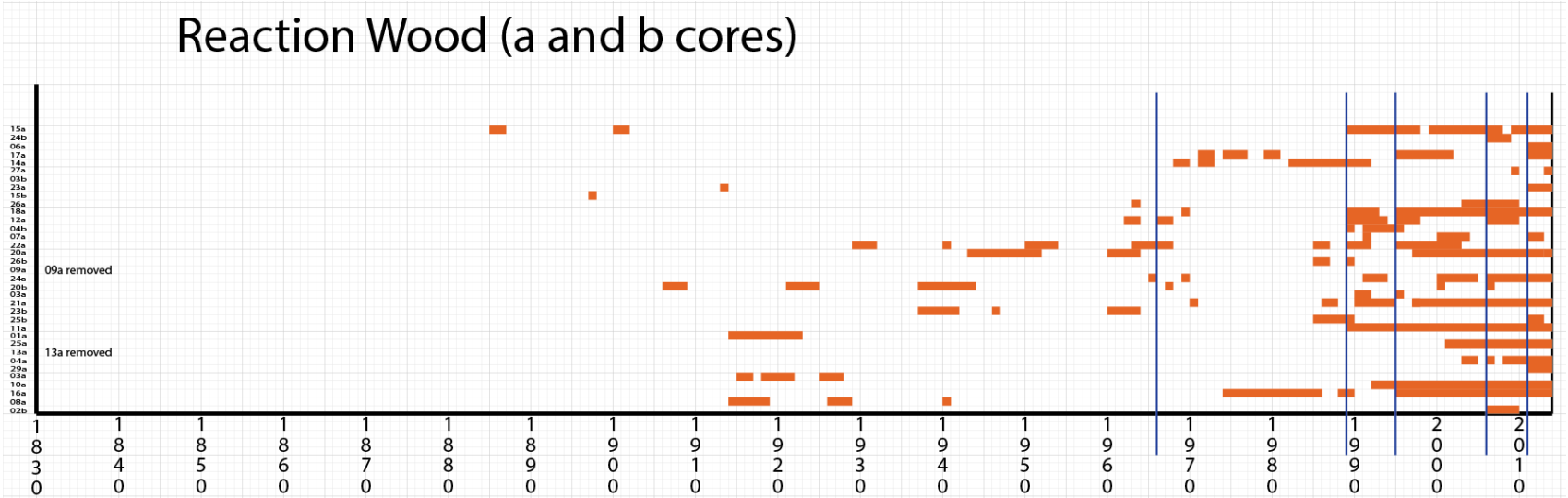


Figure 14: Digitized version of modified skeleton plot for reaction wood in both a and b cores. Each orange square represents one year of reaction wood growth. The blue vertical lines highlight years during widespread onset of reaction wood.

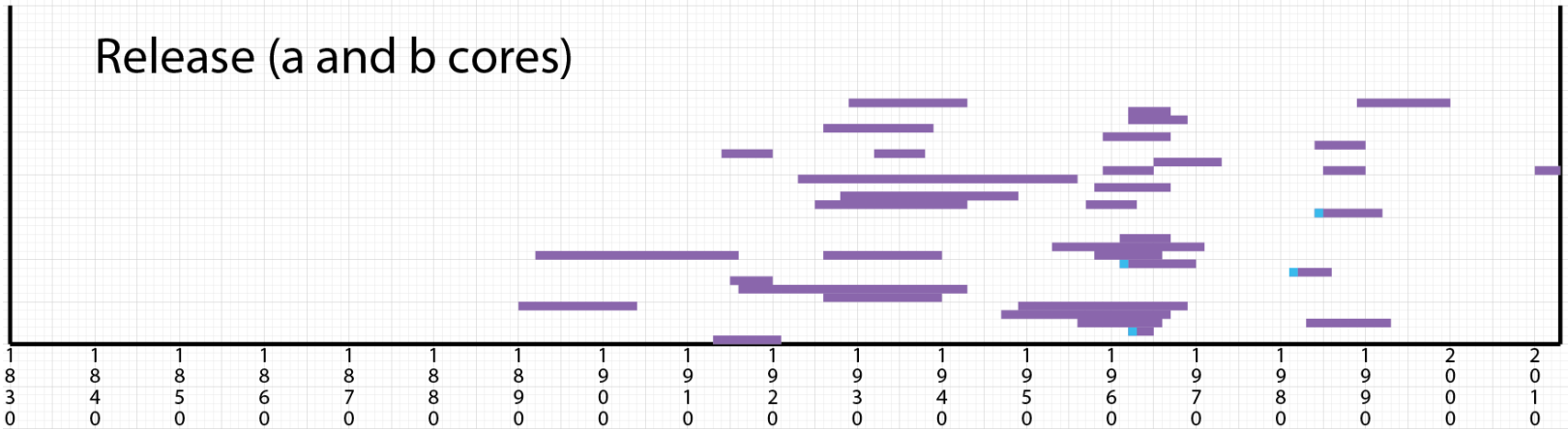


Figure 15: Digitized version of modified skeleton plot showing growth release in both a and b cores. Each purple square represents one year of release and the blue squares represent a sudden onset of release.

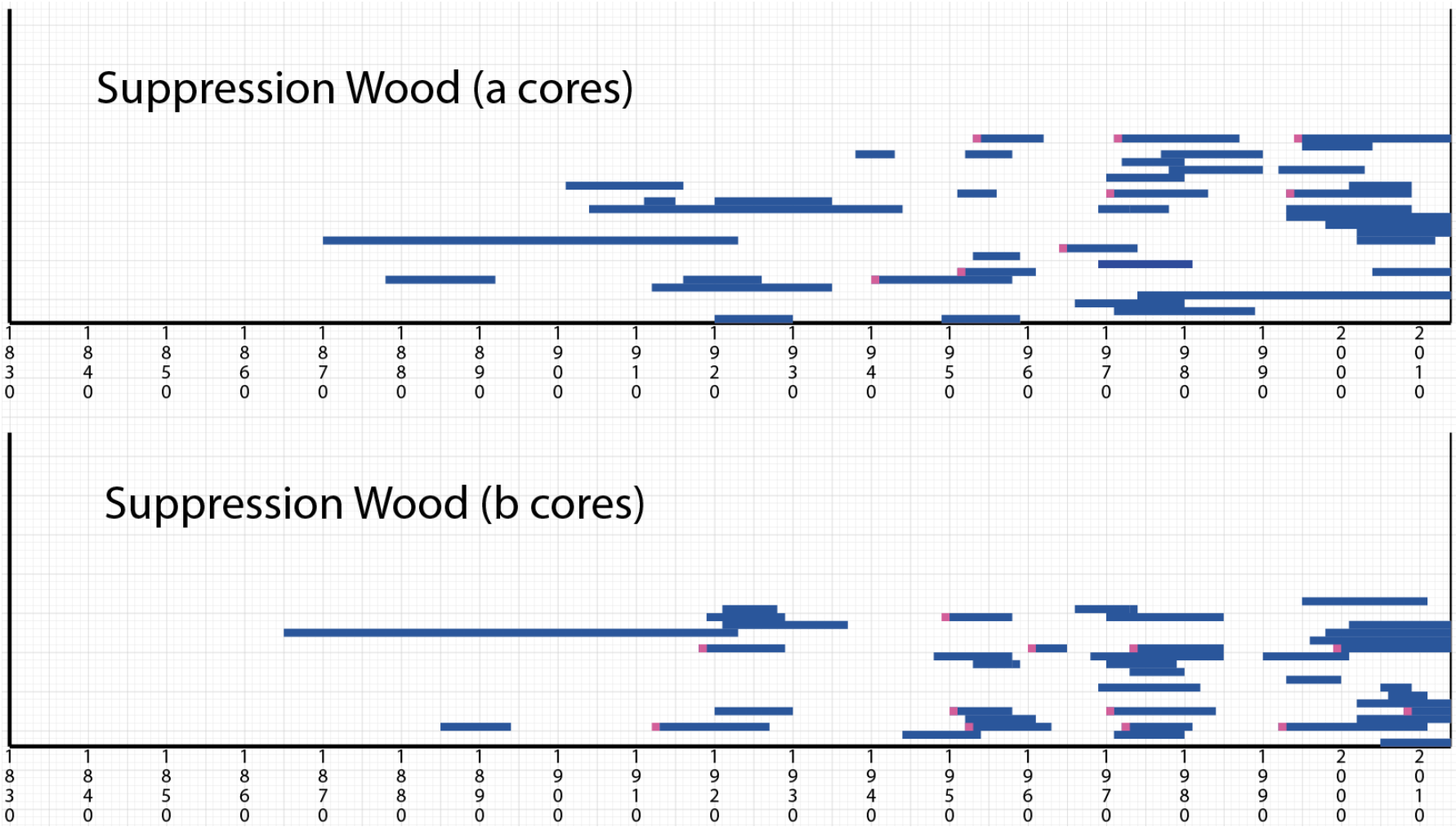


Figure 16: Digitized version of modified skeleton plot for suppression wood in both a and b cores. The blue squares each represent one year of suppressed growth each pink square represents an abrupt onset of suppression.

Growth-Environment Relationships

In order to examine controls on tilting we applied an Excel correlation function to our field data, such as elevation, ALD, and tilt angle (Table 2). There is a positive correlation (0.2967) between the angle of the tilt and the average active layer depth of the permafrost (Figure 11). There is not a correlation (0.0067) between the direction of the tilt of the tree and the direction of the slope. There is a positive correlation (0.5433) between the diameter at breast height and the height of the tree. Correlation values for all field data were calculated (Appendix B).

Table 2: Correlation values for Growth-environment relationships

Confidence Interval	T-Distribution	Correlation Coefficient
99%	2.757	0.251783
95%	2.045	0.196146
90%	1.699	0.166237

COFECHA Results

After crossdating our samples with COFECHA, two flagged samples (09A and 13A) were removed due to the sample not being able to statistically correlate with the other samples. This is possibly due to partial loss of sample (bark) or non-climatic growth factors. After the two flagged samples were removed, the remaining samples, along with Schweingruber's (1983) chronology from Northway, Alaska, were crossdated in COFECHA (input: Appendix C) and a series of graphs were generated showing measurements (Figure 17), tree ring indices (Figure 18), spaghetti plots (Figure 19) and individual detrends (Figure 20) (output: Appendix D).

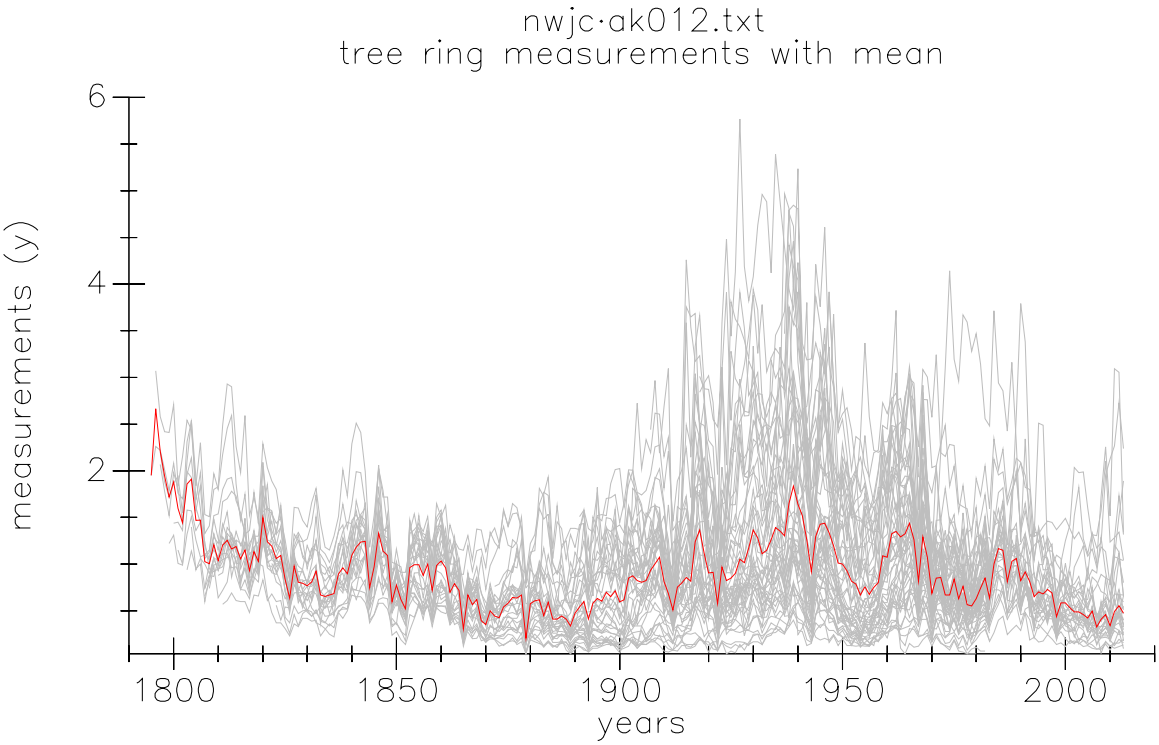


Figure 17: COFECHA output of all tree ring measurements with mean.

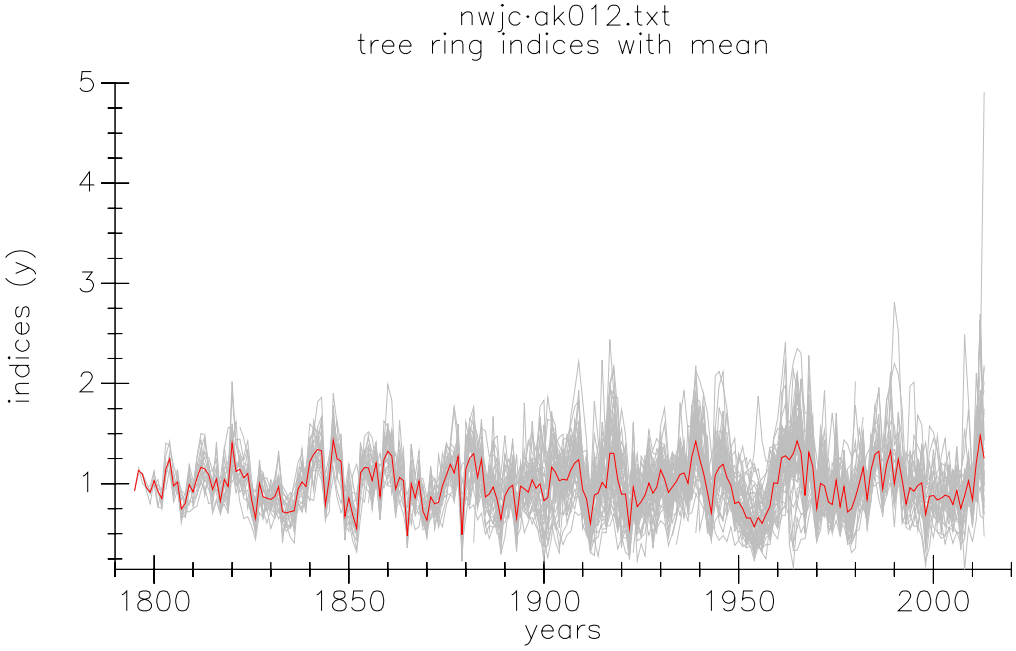


Figure18: ARSTAN output displaying tree ring indices with mean.

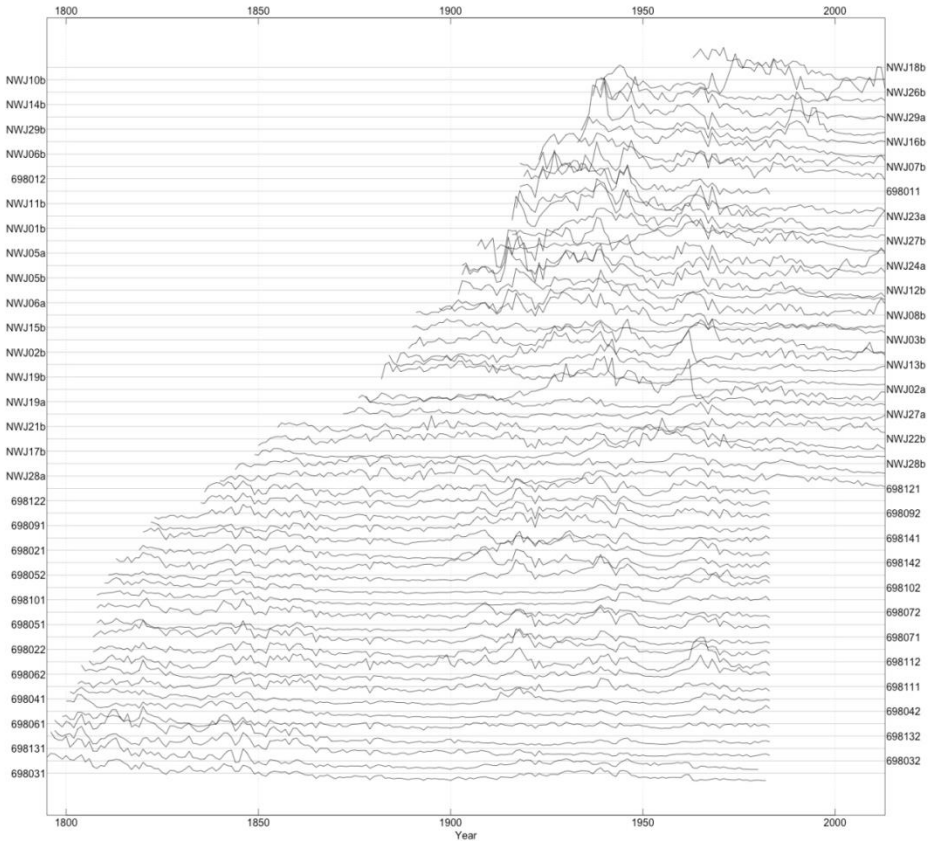


Figure 19: Spaghetti plot of the variation in growth which can help detect disturbances and overall trends in the data. Contains both the author's and Schweingruber's chronologies (abruptly ending around 1980).

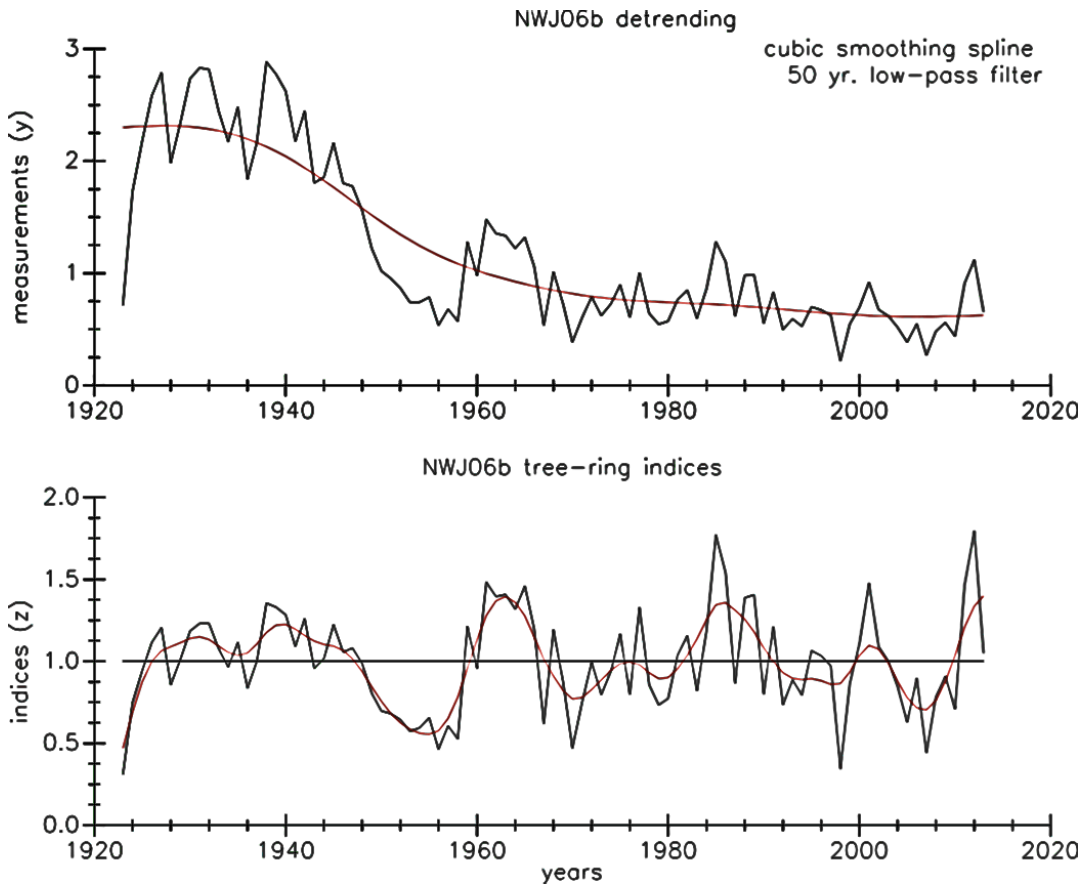


Figure 20: Representative ARSTAN output for sample NWJ06b showing raw, ring-width measurements (above) and corresponding, post-50-year cubic smoothing spline processing.

Data generated in COFECHA were then run through ARSTAN and a series of chronologies were generated including raw, standard, residual, and ARSTAN chronologies (Appendix E).

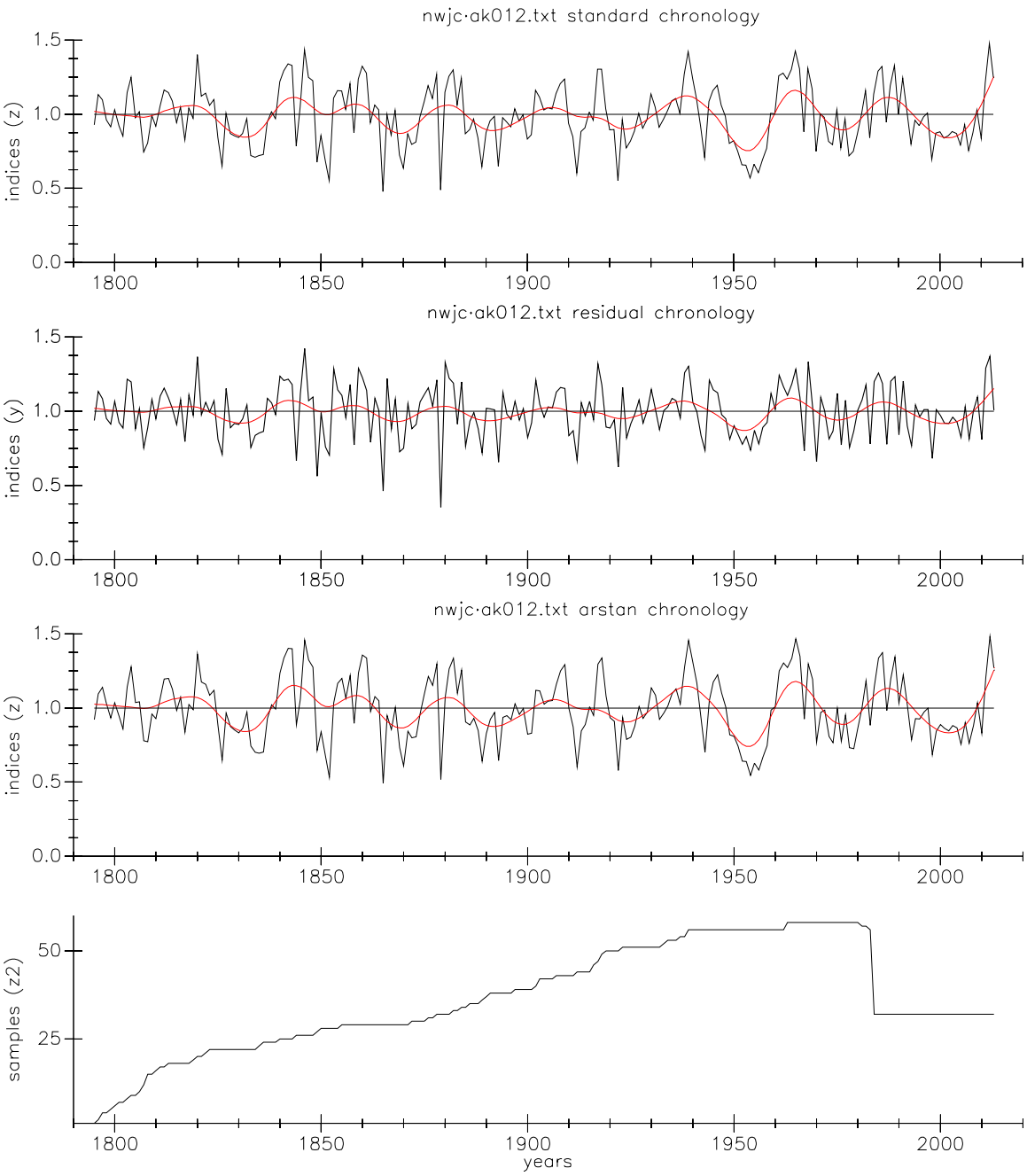


Figure 21: Top graph is the standard chronology that is a chronology with considerable autocorrelation. The second graph is the residual chronology, which shows autoregressive modeling on individual series, resulting in no low-frequency trends whatsoever. The third graph is the ARSTAN chronology, which shows pooled autoregression property derived from all series, assumed to be climatic in origin, then placed back into the residual series. The bottom graph shows the sample density (how many sticks/year). Note the end of the Schweingruber chronology in 1983, characterized by the drop–off in the bottom graph.

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Spectral Analysis

We used MTMCohere to find overarching frequencies in the data. The combined data of Schweingruber and Heinrich showed 20- and 24-year cycles at a 99% confidence interval (Figure 22). This technique of finding frequencies is used for signal detection that accounts for the nature of the climatic system.

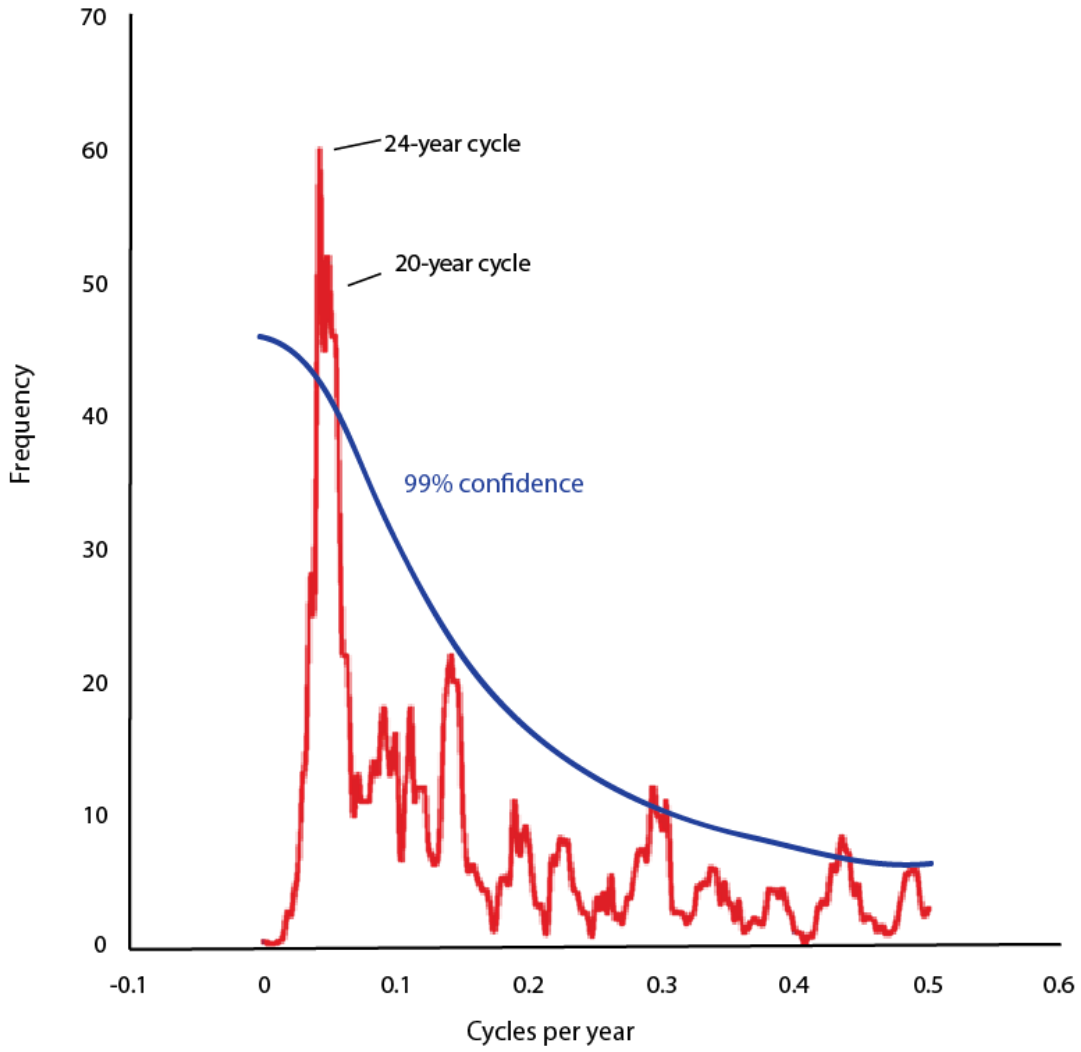


Figure 22: Spectral analysis generated with MTMCohere for combined NWJ data using confidence limits (Mann, 1996). Note the x-axis (power) is an inverse function and indicates cycles per year. The blue curve represents a 99% confidence limit at a 20-24 year cycles

After using MTMCohere to find overarching frequencies bound in the data, we used DENDROCLIM2002 (Biondi and Waikul, 2004) to perform classic climate response analyses. Using the Northway Junction Airport meteorological data set (1949-2014), we tested mean temperature, mean minimum and maximum temperatures along with mean precipitation, snowfall and snowpack during previous- and current-growth years as controls on growth. The only significant correlation was the mean maximum temperature during the previous growth season (June and July) (Figure 23).

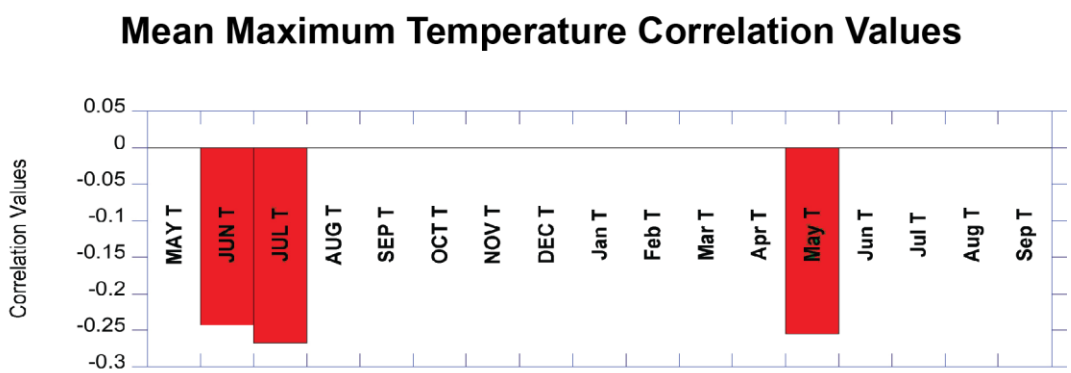
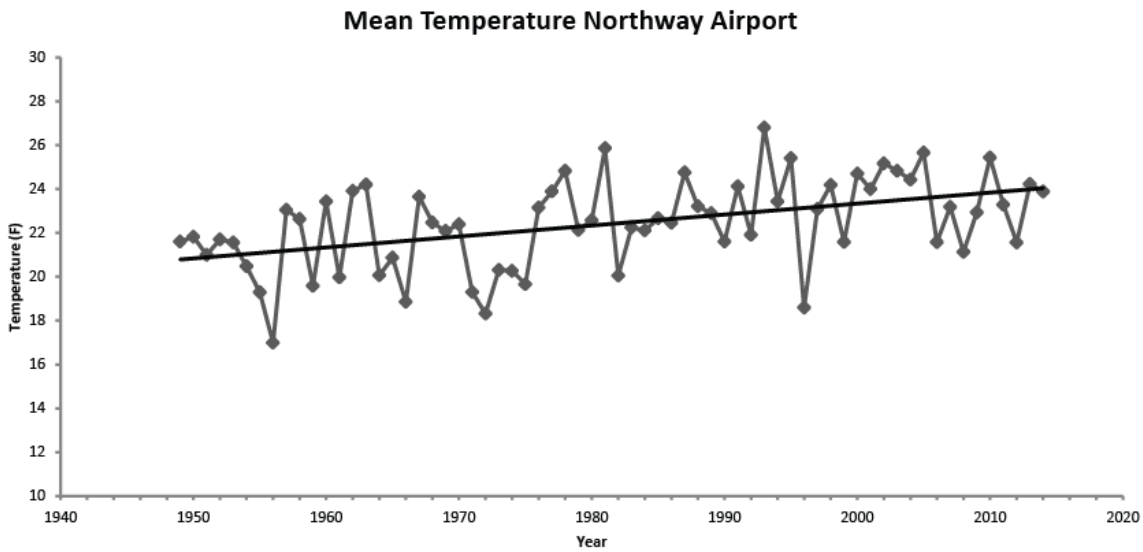


Figure 23: Negative correlation with *mean maximum temperature* values for present and previous growing season (June-July) and current May (possibly root elongation growth).

Northway Junction Climate Analysis

The climate data we obtained from NOAA were graphed in Excel to show trends in average yearly temperature, snow depth, and precipitation from the beginning of the data set in 1949 until June 2014 (Appendix F). Figures 24 and 25 depict average annual trends.



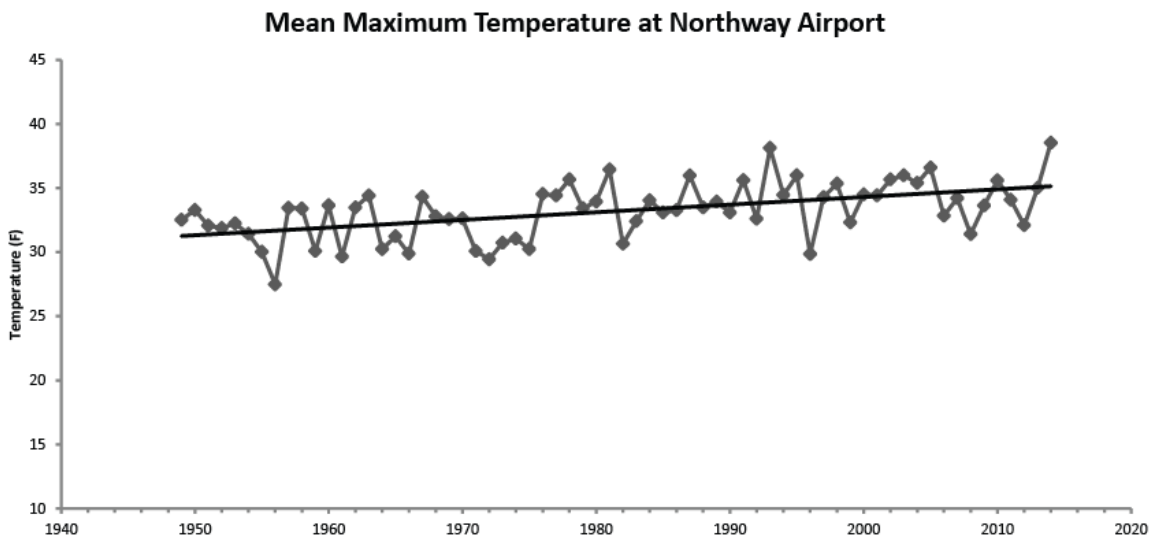


Figure 24: Excel line plots of Northway Airport climate data. The top graph shows the mean yearly temperature with a black linear trendline that shows the overall trend in the data. The bottom graph shows the mean maximum temperature at Northway Airport and it also has a black linear trendline.

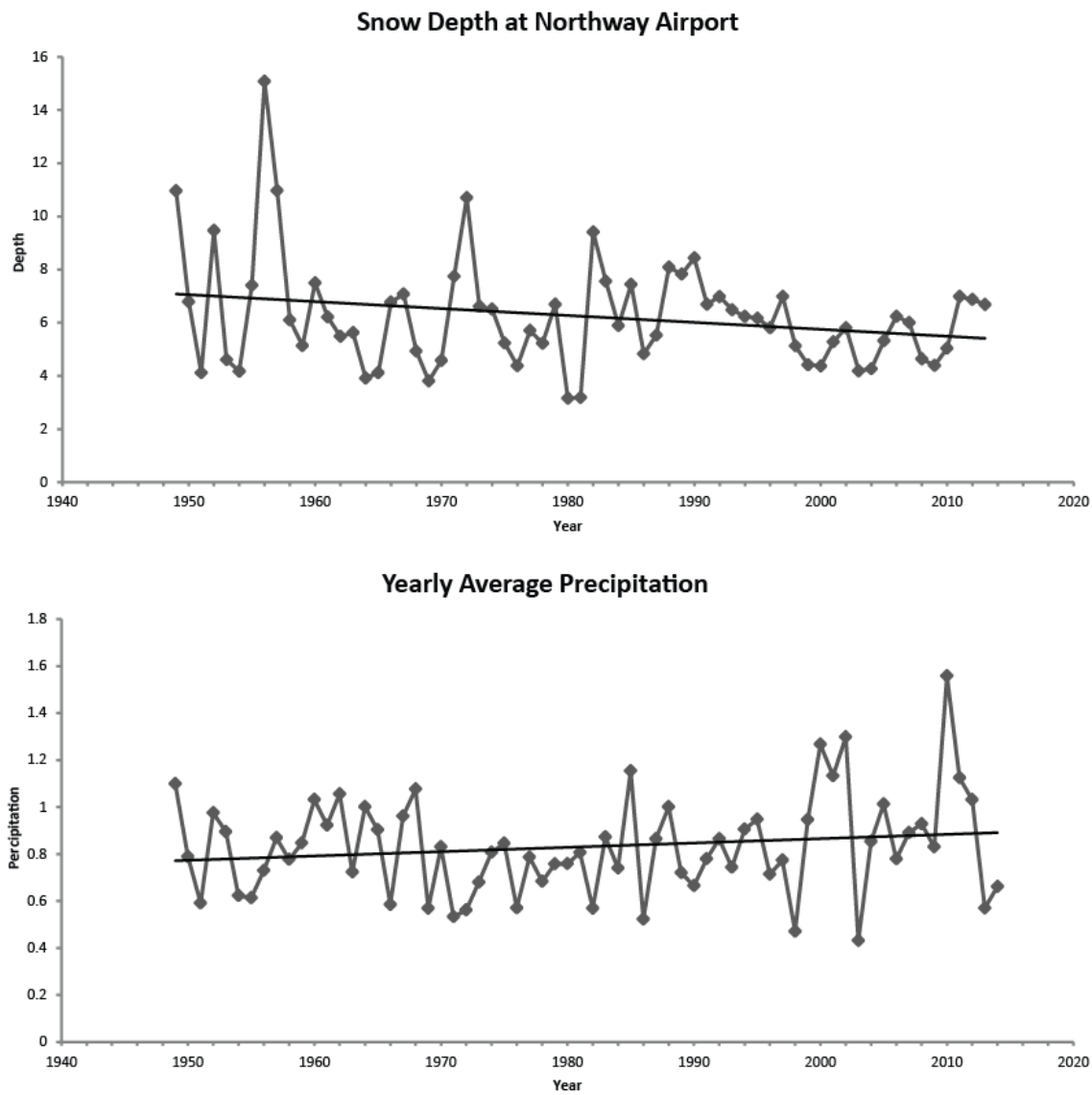


Figure 25: The top graph plots the average yearly snow depth (not snowfall) at Northway Airport, while the bottom graph shows average precipitation each year. Each graph has a black linear trendline.

Spatial Analysis

Images generated with Surfer11 and GIS allowed us to get a feel for our data. Surfer11 was used to simulate a likely map of active-layer-depth (ALD) distribution. These images helped to visually display the spatial relations of our data including factors such as tilt angle (Figure 26) and DHB (Figure 27) over contour maps of ALD thickness. GIS was used to create a map spatially representing the amount of tilt in each location to

see if certain areas were more prone to higher tilt angles (Figure 28). GIS was also used to visualize the direction of tilt as along with the angle of tilt. By using symbol sizes (circles) that were proportionate to the amount of tilt (the more tilting the bigger the circle) while also using arrows to represent the degree direction of the tilt we are able to see if there is a trend based on various factors such as gradient or ALD (Figure 29). GIS tools were used to create a raster data set out of our ALD data. By using inverse distance weighted interpolation (IDW) a reasonably accurate estimation of ALD was generated. IDW is used for high variation in data because when it is creating contours the further the point the less weight it has in the calculation of the cell's value, which, as we found, was characteristic in our sampling depths of ALD. GIS was then used to represent the onset of reaction wood both spatially and temporally. By creating layers of different yearly responses to reaction wood we were able to see if the responses in growth had spatial and temporal relationships (Figure 30). Given high resolution elevation data we were able to create a slope map, which shows the floodplain as well as little pockets of flat surface water mimicking what we observed in the field (Figure 31).

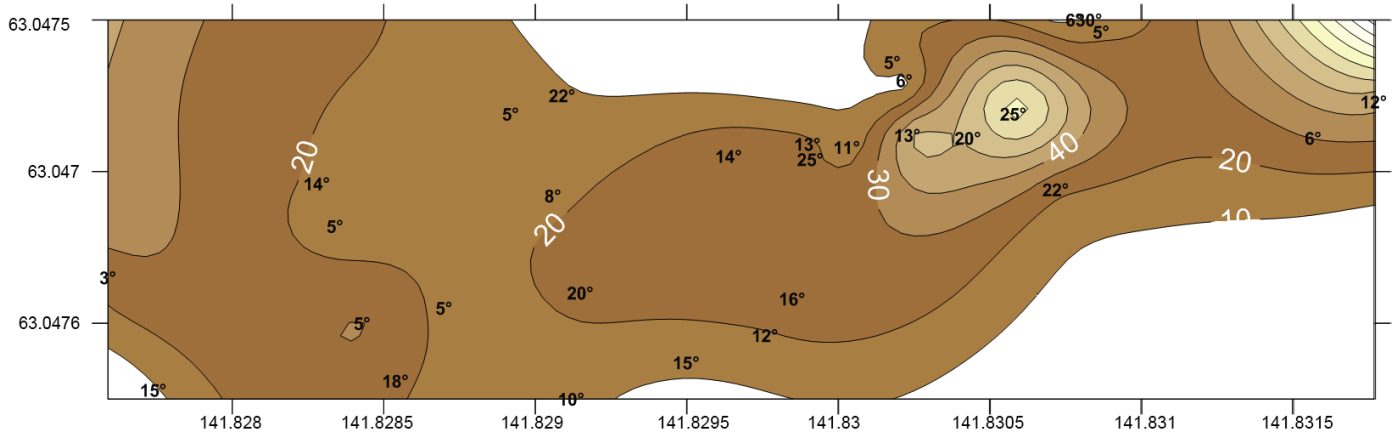


Figure 26: This surfer generated image is a minimum curvature graph where the x-axis equals longitude coordinates and the y-axis equals latitude coordinates. The average Active Layer Depth of permafrost is represented by the contour lines. The degree measurements show the degree of tree tilt at each sampling location. The contour interval is 10cm and labeled in white. The tree angles are in black and located in their respective locations.

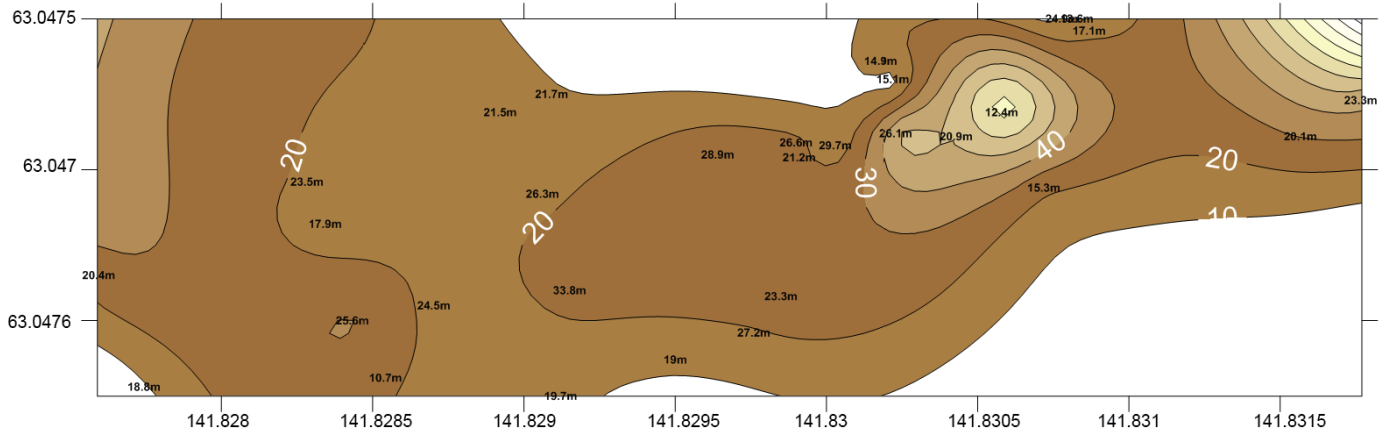


Figure 27: This surfer generated image is a minimum curvature graph where the x-axis equals longitude and the y-axis equals latitude coordinates. The average Active Layer Depth of permafrost is represented by the contour lines. The degree measurements show the height at each sampling location. The contour interval is 10cm and labeled in white. The tree heights are in black and located in their respective locations.

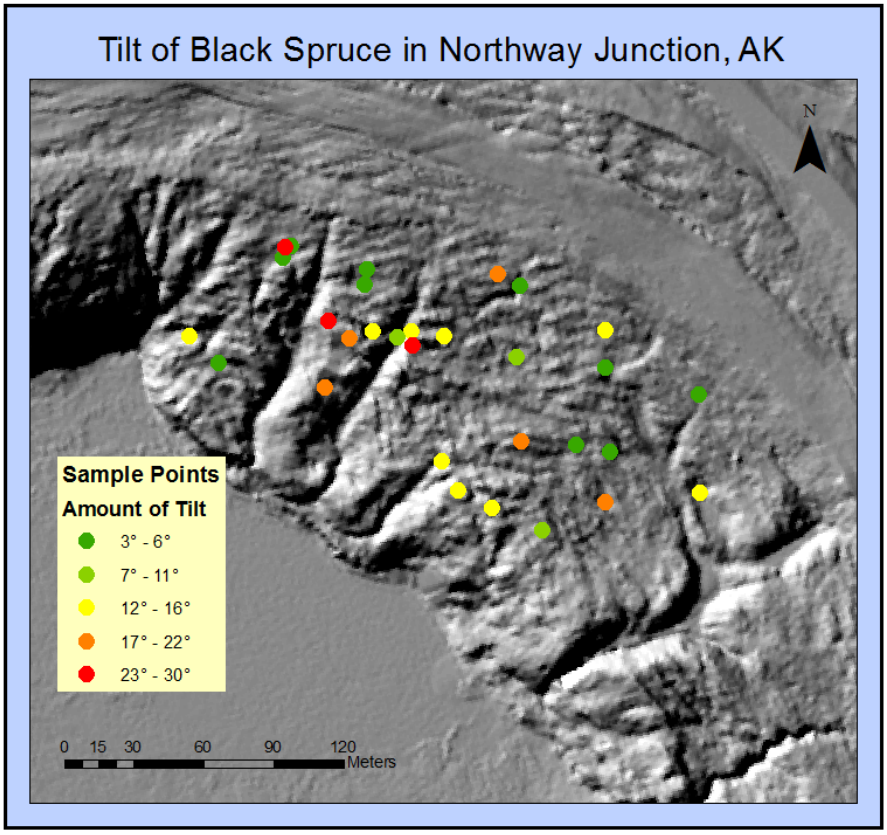


Figure 28: Shows the amount of tilt of each tree in degrees. The three trees with tilt values above 22° are clustered in the Northwest section of the site. Created with LiDAR data courtesy of Trent Hubbard DGGS.

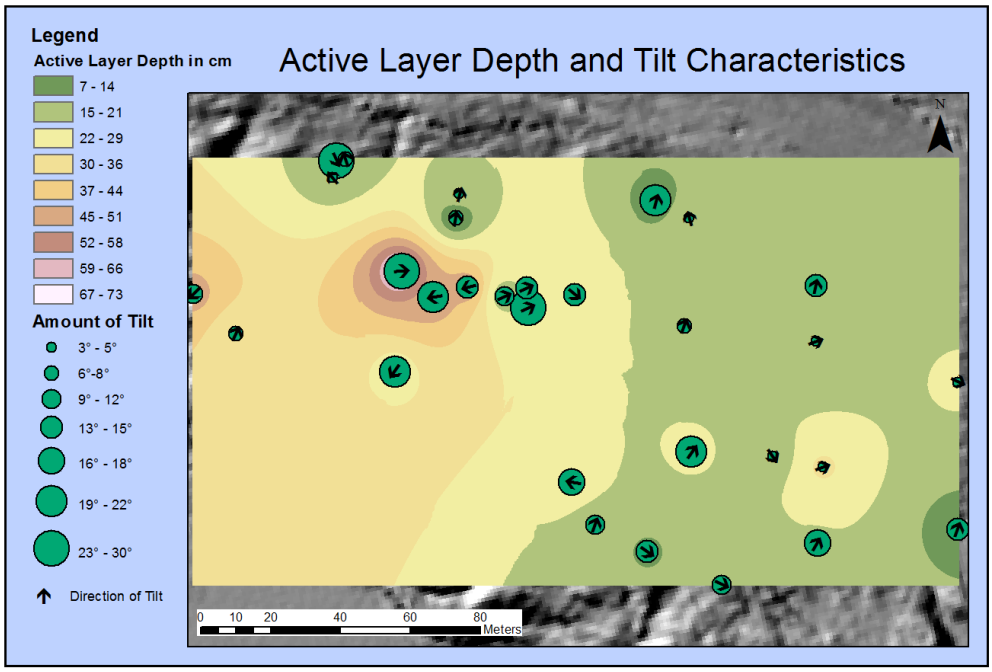


Figure 29: Shows the direction and amount of tilt over IDW map of active layer depth. Larger circles represent more tilting which tend to overlie areas of deeper ALD. Created with LiDAR data courtesy of Trent Hubbard DGGS.

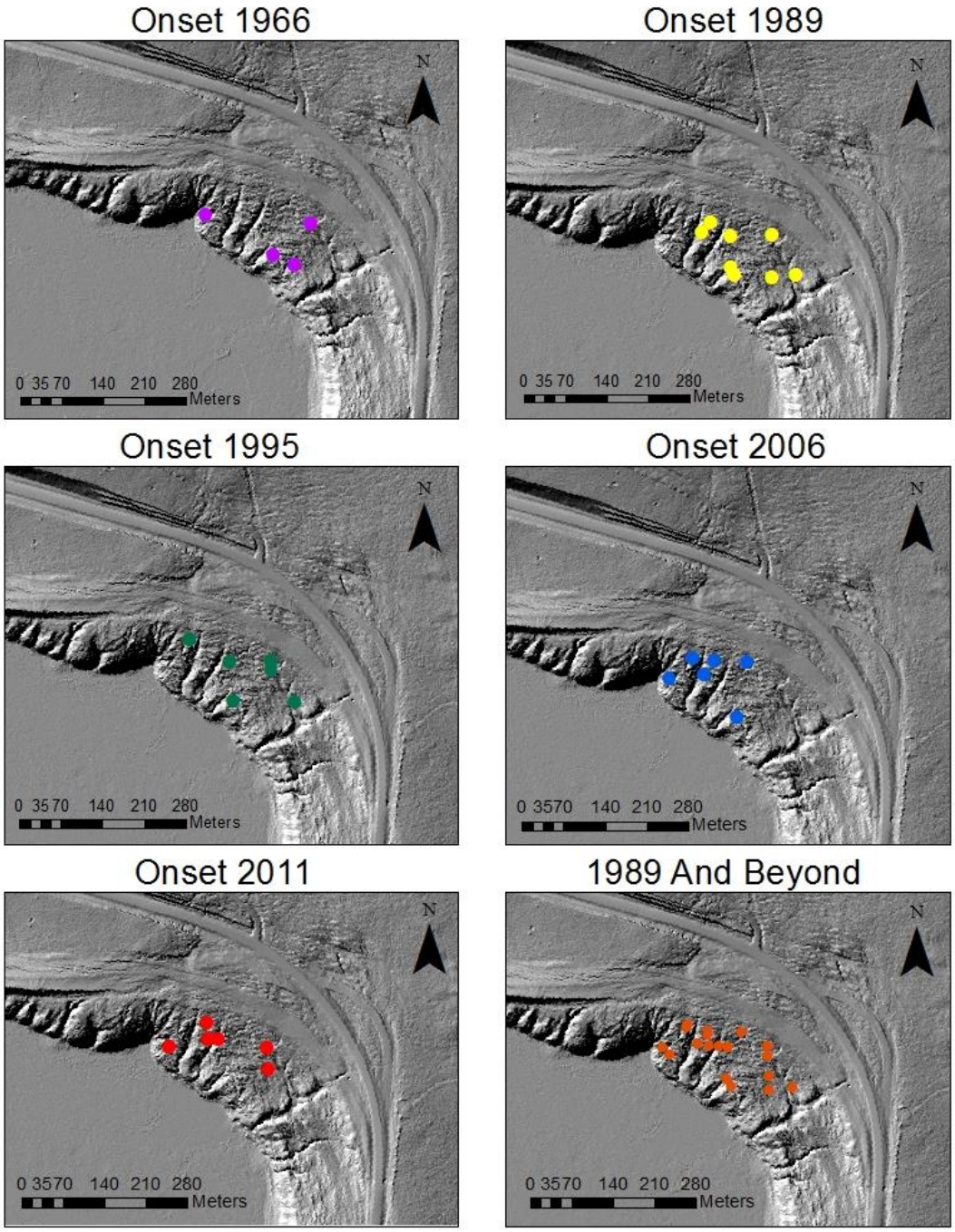


Figure 30: Series of maps showing the location of onset of reaction wood in each prominent year. The last map shows the large onset of reaction wood occurring in 1989 and further. Created with LiDAR data courtesy of Trent Hubbard DGGS.

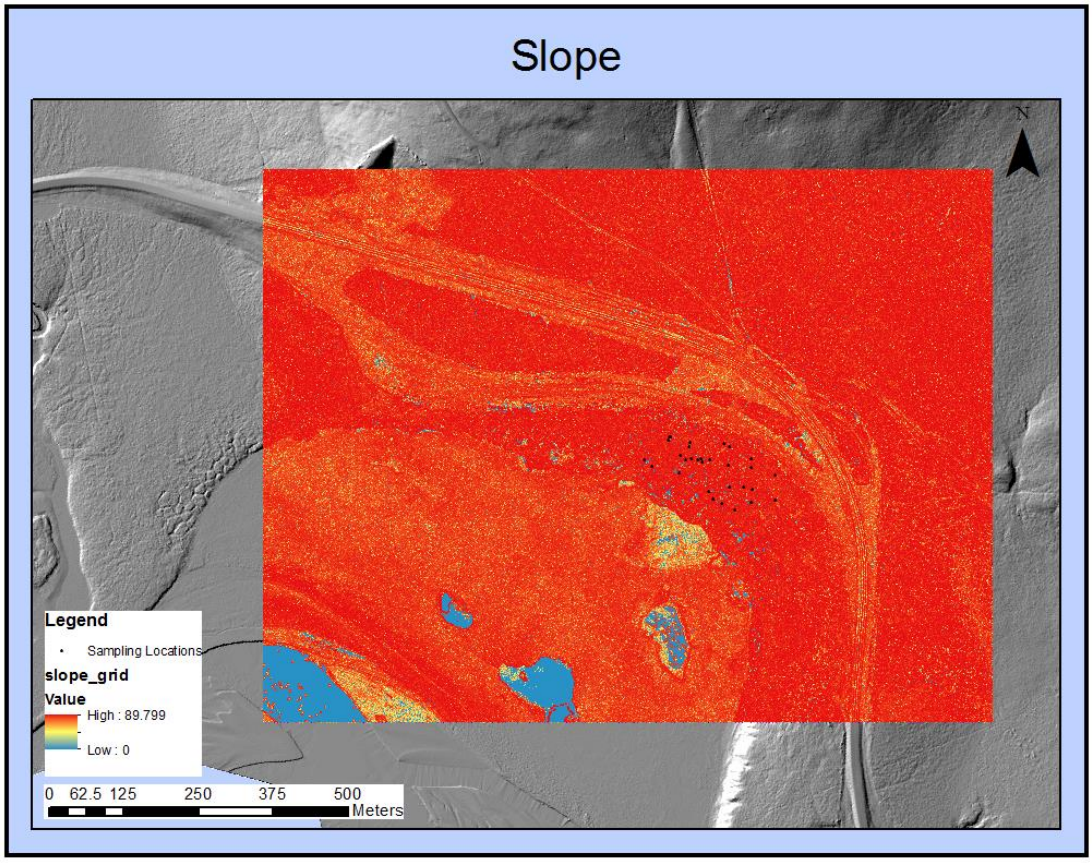


Figure 31: Red shows the highest amount of slope while blue shows zero amount of slope. The blue represents water because it is perfectly flat. The importance of this mostly red image is that it represents the many small ponds of water at our sampling location.

INTERPRETATION

Growth Responses

The positive correlation (0.297) between tilt angle and active layer depth, as well as GIS spatial analysis, both suggest that the deeper the active layer the more tilting occurs. These data do not suggest that there is a correlation (0.0067 at 99% confidence) between the direction of the tilt of the tree and the direction of the slope, suggesting the tilting of the trees is not slope related. In order to determine the onset of instability we looked largely at reaction wood percentages each year along with the sudden onset of

reaction wood. Generally, from 1900-1988 the area was relatively stable with reaction wood accounting for only 5.2% of recorded radial growth. The onset of instability, however, occurs in 1989 where, from 1989-2013, reaction wood accounts for 32.7% of recorded radial growth. Looking at the reaction wood plotted against time (Figure 9), it is apparent that most of the reaction wood in this stand has an onset in 1989. Other prominent onset years occurred in 1966, 1995, 2006 and 2011 (Figure 9). The onset of reaction wood starting in the late 1980's could be caused by a general increase in average yearly precipitation. The large jump in recorded reaction wood in 1989 may be due to above average precipitation starting in 1987. The average during May is 0.92" (σ+/- 0.58). In 1987, 1988 and 1989, during May it rained a total of 2.17", 2.21", and 2.06" respectively. This could have triggered a large onset of tilting and thus reaction wood because water has a high heat capacity, which could cause earlier and deeper thickening of the active layer early in the season. This increase in precipitation could have caused a thickening of the active layer. With climate data showing general increases in average annual precipitation and temperature and a general decrease in snow depth, these warmer wetter conditions may have caused an increase in ALD by an increase in the water flowing down gradient to the floodplain and marginal lake, which are absent of permafrost (Reger et al., 2012).

Ring Widths

The climate response analyses using the Northway Junction Airport meteorological data set showed that there was a significant correlation between the mean maximum temperatures during the previous year's May. This means that when May

temperature, during the previous growth year (i.e., 1999), was hotter than average there was a negative correlation to ring-width or growth the following year (i.e., 2000). This means that both the author's and Schweingruber's trees put on less mass (grew narrower rings) during Mays that had warmer maximum temperatures (the year prior). Auto correlation or hysteresis refers to previous year(s) conditions affect growth in the subsequent year(s), so increased precipitation and/or temperature from a previous season can affect current growth. This could mean that the trees in both stands (Schweingruber, 1983, Heinrich et al., 2014) prefer cooler mean maximum temperatures. This may be due to the high vapor deficit and increased evapotranspiration occurring during these exceptionally warm Mays. If it is too warm there may be increased evapotranspiration, which would decrease the amount of water available for uptake and growth of early-root elongation by the tree. This may however be counteracted by the general increase in precipitation. Bonan and Sirois (1992), suggest that the climate response of increasing temperature doesn't necessarily cause decreased growth. The physiological conditions allow black spruce to grow over a wider range of air temperatures than is reflected in its geographic distribution. Data suggest that the northern range limit of black spruce is not caused by the direct effects of cold-growing season air temperature on tree growth and that growth is optimal with respect to temperature at the southern range limit" (Bonan and Sirois, 1992, p. 495). If growth is optimal with respect to temperature at the southern range limit while considering a general increase in precipitation then the negative correlation may be due to an increase in ALD depth. Because there is no correlation between slope and the direction of tilt the negative effects of a deeper active layer can also be applied to Schweingruber's data. The negative effect of high mean maximum

May temperature may cause a deepening of the active layer, which could lower the accessible water table during critical early-season growth and/or decrease stability and affect the trees negatively the next year as they continue to adjust by growing reaction wood to realign with the vertical after being tilted.

DISCUSSION

The recent increase in reaction wood growth at Northway Junction is related to an increase of mass-wasting. Because mass wasting causes damage to infrastructure we can conclude that this damage has increased with the increase in mass-wasting. In order to better understand physical effects on black spruce growth we examined the effects of climate and environment on tree growth. High mean maximum temperatures negatively affect black spruce growth in May of the previous growing season. This does not mean that the warmer temperature has a negative effect on black spruce growth but rather that the *highest mean maximum temperature* has a negative effect on growth. Bonan and Sirois (1992), for example, found that while pollen data indicate large geographic changes in spruce abundance with past climatic changes, the current analyses suggest that the direct effect of air temperature on individual tree growth has not caused these changes (p. 495). Because there is a positive correlation between the depth of the active layer and the amount of tilt and there is no correlation between the direction of the tilt and the gradient of the slope we can conclude that the deeper the active layer depth of permafrost the more solifluction occurs causing the tilting of black spruce at Northway Junction. The increased precipitation in the years before the large onset of reaction wood in 1989 may have caused an increase in ALD depth due to the high heat capacity of water, causing an

increase in solifluction. The instability of these trees and thus the instability of the Northway Junction site can be seen via reaction wood from 1989 onward.

The ring-width data of both Schweingruber and Heinrich et al. both show that conditions are becoming more equitable for black spruce. There is a strong visual correlation between the ARSTAN chronology and the amount of reaction wood each year (Figure 32). As climate conditions favor growth and cause trees to grow wider rings there is also more reaction wood and thus more tilting, which suggests more mass wasting. The visual correlation with the recorded amount of reaction wood and with the ring-width from the ARSTAN chronology shows that when reaction wood is not present, ring widths are smaller (Figure 22).

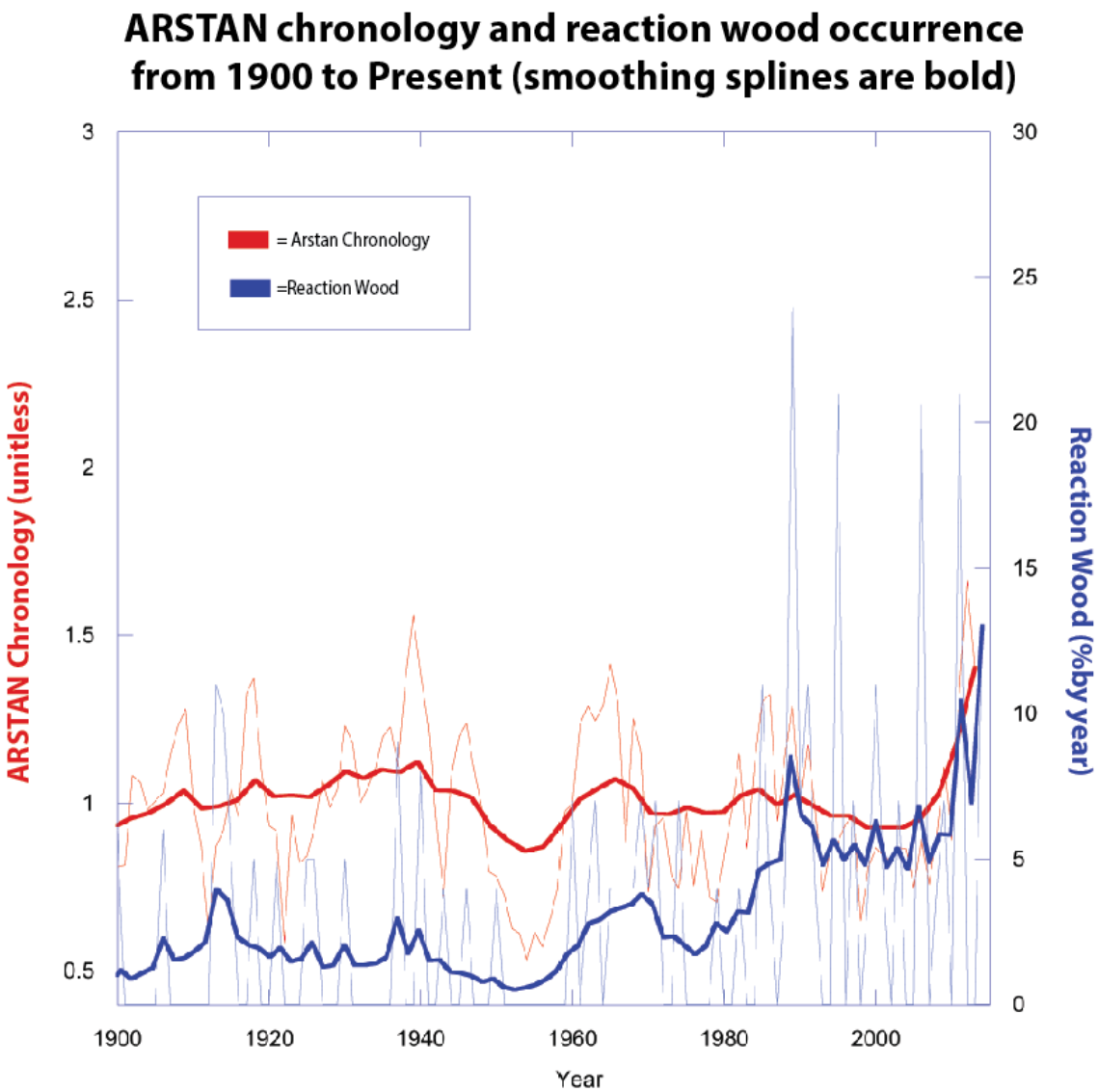


Figure 32: Line plot comparing our ARSTAN master chronology with reaction wood occurrence by year. Bold lines are smoothing splines.

CONCLUSIONS

Mass wasting damage to the ALCAN at Northway Junction reflects need to replace transportation infrastructure throughout Alaska. In order to efficiently and effectively repair and replace Alaskan infrastructure we need to understand the processes that cause damage. Based on tree-ring evidence it appears that mass-wasting processes were intermittent until widespread movement began in 1989, where reaction wood

accounts for 32.7% of recorded radial growth. Statistically, a high mean maximum temperature negatively affects growth, which deepens the active layer depth, lowering the accessible water table during critical early-season growth and/or decrease stability. Increased precipitation is another likely cause of increased reaction wood due to slumping and increased thawing of the active layer caused by the high heat capacity of water. Combined, climate and tree-tilting data, suggest that as these high-latitude sites become more equitable for black spruce growth, the more mass-wasting will occur. This could mean that other places along the ALCAN may begin experiencing an increase in mass wasting and slumping due to the deepening of the active layer. The degradation of ice-rich permafrost can destroy the physical foundation on which boreal forest ecosystems rest causing dramatic changes in ecosystem processes, forest and wetland distribution, biodiversity, contributions of boreal forests to global atmospheric processes, forest productivity and land use (Osterkamp et al., 2000). The tilting at this site has low to moderate ice content (Reger, et al., 2012), thus, the effects of a thicker ALD at locations with higher ice content will be even more unstable if those locations experience similar temperature and precipitation occurrences. Due to the remote nature of Alaskan transportation routes and the effect of temperature and precipitation on permafrost, areas underlain by high ice content should be given priority. Even if the increase in precipitation and temperature is gradual, the negative impact of mass wasting in areas of permafrost will become more devastating as climate continues to show a similar trend.

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Appendix A: Complete field data set with “year” added post-lab-analysis

Sample	Latitude	Longitude	Elevation	DBH (cm)	Sample Height (m)	Tree height (m)	Slope Directio n (°)	Slope Angle (°)	Avg ALD (cm)	Crown Density	Year	Pith, Close, Far
NWJ01A	63.0475	141.8308	560	46	1.2	24.8	200	5	14.6	high	1880	F
NWJ01B											1916	F
NWJ02A	63.04746	141.8309	564	38.5	1	17	250	8	18.3	avg-high	1978	P
NWJ02B											1886	C
NWJ03A	63.0475	141.8308	560	41	1.2	11.8	235	7	18.3	avg	1876	C
NWJ03B											1889	C
NWJ04A	63.04719	141.8306	559	19	1.2	11.2	175	5	73.3	avg	1942	C
NWJ04B											1944	C
NWJ05A	63.04711	141.8304	556	49	0.9	19.6	190	5	50.6	high	1907	F
NWJ05B											1903	F
NWJ06A	63.04712	141.8302	555	33	1	25.4	205	2.5	50	avg	1897	P
NWJ06B											1923	C
NWJ07A	63.04709	141.8299	557	41	1.2	26	150	10	21.6	avg	1917	C
NWJ07B											1919	C
NJW08A	63.04708	141.83	554	42	1.3	29.2	220	12	15.6	avg - low	1866	C
NWJ08B											1819	F
NWJ09A	63.04704	141.8299	554	27	1.4	19.24	220	12	21.6	low	1931	C
NWJ09B											1889	C
NWJ10A	63.04694	141.8307	546	24	1	14.2	220	20	25	avg-high	1963	P
NWJ10B											1963	P
NWJ11A	63.04658	141.8299	546	36.5	1.2	22.4	255	15	26	avg	1912	C
NWJ11B											1917	C
NWJ12A	63.04646	141.8298	552	32	1.3	26.6	265	10	19	avg	1878	C
NWJ12B											1902	F
NWJ13A	63.04637	141.8295	550	35	1.3	18.4	125	15	13	avg	1864	F
NWJ13B											1884	F
NWJ14A	63.04625	141.8291	561	28	1.1	19.4	265	15	16.6	low	1938	C
NWJ14B											1939	C
NWJ15A	63.04631	141.8285	567	23	1.3	10.2	160	7.5	21.3	very low	1869	C
NWJ15B											1890	C

Sample	Latitude	Longitude	Elevation	DBH (cm)	Sample Height (m)	Tree height (m)	Slope Directio n (°)	Slope Angle (°)	Avg ALD (cm)	Crown Density	Year	Pith, Close, Far
NWJ16A	63.04628	141.8277	549	25	1.4	18.2	255	12	10.6	low	1937	P
NWJ16B											1933	P
NWJ17A	63.04682	141.8283	557	22	1	17.8	195	15	15	low	1871	F
NWJ17B											1849	P
NWJ18A	63.04696	141.8283	552	46	1.5	22.8	190	15	19	very high	1890	F
NWJ18B											1963	F
NWJ19A	63.04719	141.8289	557	33	1.2	21.4	215	20	17.3	avg-low	1876	F
NWJ19B											1882	F
NWJ20A	63.04725	141.8291	562	19	1.6	20.1	185	20	11		1883	P
NWJ20B											1901	F
NWJ21A	63.0466	141.8292	556	39	1.3	31.8	120	5	22.3	avg	1856	F
NWJ21B											1855	F
NWJ22A	63.04705	141.8296	560	40	1.1	28	190	15	26.6	avg	1909	F
NWJ22B											1850	F
NJW23A	63.04711	141.8316	555	33	1.2	20	250	25	31.6	avg- high	1916	C
NWJ23B											1914	C
NWJ24A	63.04723	141.8318	550	35	1	22.8	178	30	46	avg	1903	C
NWJ24B											1898	C
NWJ25A	63.04736	141.8302	563	15.5	1	14.8	270	3	18.6	low	1946	P
NWJ25B											1947	C
NWJ26A	63.0473	141.8302	561	21	1.3	15	250	3	6.6	avg	1939	P
NWJ26B											1939	P
NWJ27A	63.04692	141.8291	561	30	1.2	26	180	20	18.6	low	1872	C
NWJ27B											1912	F
NWJ28A	63.04655	141.8287	552	39	1.1	24.4	175	12	18.3	avg	1839	P
NWJ28B											1844	C
NWJ29A	63.0465	141.8284	551	32	1	25.5	150	15	30	avg- high	1901	C
NWJ29B											1891	C
NWJ30A	63.04665	141.8276	556	29	1.2	20.4	310	12	22.3	avg- low	1937	C
NWJ30B											1934	C

Appendix B: Correlation values of effects on growth from physical environment factors gathered onsite.

	Sample	Height of tree (m)	Elevation (m)	DBH (cm)	Direction of tilt (°)	Angle of tilt (°)	Direction of slope (°)	Angle of slope (°)	Average ALD (cm)	Age
Sample	1									
Height of tree (m)	0.195549	1								
Elevation (m)	-0.04488	-0.28415	1							
DBH (cm)	-0.31059	0.543324	-0.21432	1						
Direction of tilt (°)	-0.44666	0.021521	-0.12649	0.433009	1					
Angle of tilt (°)	-0.4884	-0.28284	-0.0916	-0.00144	-0.08048	1				
Direction of slope (°)	0.011365	-0.2573	0.03379	-0.23767	0.066028	-0.2602	1			
Angle of slope (°)	0.393401	0.148834	-0.38065	-0.03058	0.006659	-0.12206	-0.05279	1		
Average ALD (cm)	-0.234	-0.0848	-0.11299	0.044767	0.236911	0.296652	-0.19809	-0.06524	1	
Age	0.155915	0.400676	-0.05526	0.341649	-0.10497	0.013691	-0.56361	0.099695	-0.21407	1

Confidence Interval	T-Distribution	Correlation Coefficient
99%	2.757	0.251783
95%	2.045	0.196146
90%	1.699	0.166237

Appendix C: COFECHA input tree ring-width data from Heinrich et al., 2014 and Schweingruber, 1983

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NWJ01b 1916 676 679 997 776
NWJ01b 1920 717 611 574 790 658 539 618 1026 1076 1420
NWJ01b 1930 1659 1757 1848 1577 1927 1806 2150 2037 2691 2788
NWJ01b 1940 2770 2549 2382 1801 2308 2035 2002 2390 2002 1482
NWJ01b 1950 1384 1448 1100 962 1201 1278 1371 1349 1351 1280
NWJ01b 1960 1966 2297 2124 1618 1846 1537 1107 786 993 1038
NWJ01b 1970 799 923 841 733 886 1150 937 927 1085 819
NWJ01b 1980 870 811 1118 804 1110 1075 1075 776 823 932
NWJ01b 1990 818 842 713 561 722 638 744 785 546 617
NWJ01b 2000 477 444 481 413 653 500 476 452 523 579
NWJ01b 2010 448 404 652 597 -9999
NWJ02a 1878 709 223
NWJ02a 1880 402 578 961 877 682 482 715 823 765 545
NWJ02a 1890 596 612 534 277 485 618 576 650 509 584
NWJ02a 1900 417 547 852 806 695 739 835 841 861 745
NWJ02a 1910 539 589 378 468 483 582 657 911 1128 761
NWJ02a 1920 886 1093 1115 1210 1312 1451 1998 2495 1940 1923
NWJ02a 1930 3334 2239 2354 2709 2840 2729 2926 2869 3756 3565
NWJ02a 1940 3915 2767 3803 1526 2171 2267 2780 2715 2516 1721
NWJ02a 1950 2290 1948 1910 1221 966 1621 1562 1670 1978 2483
NWJ02a 1960 2447 2955 3716 1094 514 512 654 647 933 1196
NWJ02a 1970 1172 1230 1230 816 1495 1372 1125 1248 1342 1372
NWJ02a 1980 1610 993 1478 1102 1163 1336 1518 746 1143 1185
NWJ02a 1990 711 943 861 675 956 681 959 846 439 568
NWJ02a 2000 506 512 530 615 447 736 629 405 583 632
NWJ02a 2010 403 671 1056 1036 -9999
NWJ02b 1886 430 1206 1249 877
NWJ02b 1890 954 1069 991 522 716 925 997 990 927 934
NWJ02b 1900 621 924 1117 1163 1084 987 1067 953 1097 988
NWJ02b 1910 726 1067 451 824 1019 912 899 1157 1792 1193
NWJ02b 1920 1234 1603 1296 1794 1633 2241 2202 2983 2587 2593
NWJ02b 1930 2847 2198 2066 2275 2022 2167 2096 2398 2663 2970
NWJ02b 1940 2185 1722 2360 1095 1641 1552 1488 1274 1478 1031
NWJ02b 1950 1250 1171 1194 1009 869 1011 983 1086 1527 1944
NWJ02b 1960 2155 2605 3046 1310 496 667 806 815 861 978
NWJ02b 1970 908 821 741 716 1192 1168 925 980 990 1135
NWJ02b 1980 1241 1030 1409 886 1102 1387 1633 807 1338 1435
NWJ02b 1990 819 1013 1017 742 994 997 1288 1183 653 923
NWJ02b 2000 883 762 787 868 672 891 1315 1308 1572 2101
NWJ02b 2010 1238 1283 1343 1044 -9999
NWJ03b 1889 521
NWJ03b 1890 844 961 1437 726 1057 1043 1114 1361 1182 932
NWJ03b 1900 962 997 1369 1341 1358 1215 1480 1575 1929 1903
NWJ03b 1910 1606 1056 939 1447 1004 887 755 774 941 807
NWJ03b 1920 787 864 754 1253 1158 1706 1781 2359 1951 2009
NWJ03b 1930 2339 2291 1959 1735 1997 2024 2047 1820 2385 2672
NWJ03b 1940 1959 1779 1888 1042 1518 2430 2885 1770 1762 1275
NWJ03b 1950 1457 1035 589 802 651 540 677 791 807 951
NWJ03b 1960 1029 1584 2093 2363 2421 2851 2620 2048 2916 1854
NWJ03b 1970 1130 1288 1384 1044 1063 1280 858 1186 1379 974
NWJ03b 1980 1134 1110 1278 1283 1131 1334 1259 978 1094 1210
NWJ03b 1990 727 844 843 470 490 637 595 680 394 477
NWJ03b 2000 414 410 219 331 293 173 244 214 598 383
NWJ03b 2010 187 128 195 158 -9999
NWJ05a 1907 2441 2965 2191
NWJ05a 1910 2688 3095 786 703 1798 3754 3649 3683 2395 2722
NWJ05a 1920 1936 1923 1250 3112 2062 3808 3627 3540 3397 3204
NWJ05a 1930 3942 3722 2737 2581 2730 3451 3556 3707 4768 4619
NWJ05a 1940 3588 3179 2086 2365 2857 3029 3353 2319 1807 1743
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NWJ05a 1950 1974 1677 1495 1520 1280 1591 1423 1609 1393 2445
NWJ05a 1960 1793 2754 2461 2523 2462 2442 1787 1314 2515 1878
NWJ05a 1970 1129 1374 1267 1069 1410 1531 936 1549 1087 1085
NWJ05a 1980 1289 1319 1125 812 1563 1445 1677 1088 1373 1375
NWJ05a 1990 1055 1323 841 737 666 828 914 695 366 580
NWJ05a 2000 644 550 481 417 450 354 366 135 264 316
NWJ05a 2010 253 385 682 328 -9999
NWJ05b 1903 1977 2724 2022 2332 2192 2617 2607
NWJ05b 1910 2153 2354 1366 1445 2432 4260 3540 3172 3233 2740
NWJ05b 1920 2326 2259 1378 2957 1593 3278 2988 2898 3136 3456
NWJ05b 1930 3878 3256 3779 3059 3210 3308 3239 3098 4056 4457
NWJ05b 1940 3159 2699 2158 2446 2867 2838 2573 2317 2055 1883
NWJ05b 1950 1916 1341 1654 1428 893 1577 1237 1213 1112 2166
NWJ05b 1960 1552 2483 2079 2000 2102 2288 1449 1023 1667 1563
NWJ05b 1970 802 1248 1186 987 1067 1285 763 1105 746 687
NWJ05b 1980 709 855 841 630 1145 1170 1393 814 1001 1071
NWJ05b 1990 762 931 597 532 479 487 662 471 195 336
NWJ05b 2000 394 413 390 343 413 272 288 148 212 274
NWJ05b 2010 172 328 517 176 -9999
NWJ06a 1897 941 744 910
NWJ06a 1900 866 1296 1618 1340 1485 1269 1141 1265 1339 1412
NWJ06a 1910 1045 825 466 702 1543 2487 2264 2409 1992 2139
NWJ06a 1920 1848 1760 842 1351 1245 1820 2489 2167 2139 2234
NWJ06a 1930 2488 2605 2464 2497 2465 2566 2570 2249 2835 4037
NWJ06a 1940 3348 2981 2389 2251 1940 2633 2765 2135 1780 1539
NWJ06a 1950 1639 1406 1231 868 1019 1055 703 873 837 1719
NWJ06a 1960 1396 1888 2201 2226 2050 2042 1707 794 1657 1067
NWJ06a 1970 496 820 1106 960 659 832 551 968 708 498
NWJ06a 1980 747 906 1250 767 1085 1318 1241 743 1258 1094
NWJ06a 1990 684 1026 445 415 435 521 361 642 297 554
NWJ06a 2000 699 676 710 730 778 525 668 461 388 844
NWJ06a 2010 478 1269 1734 1318 -9999
NWJ06b 1923 715 1732 2179 2581 2788 1986 2341
NWJ06b 1930 2732 2832 2817 2446 2172 2481 1841 2163 2884 2776
NWJ06b 1940 2623 2176 2445 1806 1855 2161 1803 1775 1560 1222
NWJ06b 1950 1019 955 869 742 740 787 538 679 572 1278
NWJ06b 1960 978 1480 1356 1335 1220 1320 1061 538 1012 727
NWJ06b 1970 384 602 789 624 726 894 607 1001 642 547
NWJ06b 1980 572 766 848 600 864 1280 1107 617 980 984
NWJ06b 1990 555 830 499 594 527 699 672 626 220 546
NWJ06b 2000 694 920 676 620 520 386 550 271 479 559
NWJ06b 2010 438 909 1117 655 -9999
NWJ07b 1919 942
NWJ07b 1920 1467 741 1017 845 1536 1343 1255 1174 1558 1933
NWJ07b 1930 2046 1717 1753 1393 2020 1910 1338 2253 3760 2748
NWJ07b 1940 2267 2189 1694 1406 1789 3274 3039 3869 2952 2412
NWJ07b 1950 2550 2169 1577 1685 1725 1871 1563 1311 1469 2010
NWJ07b 1960 1795 1861 2441 2115 2786 3034 2873 1637 2763 2762
NWJ07b 1970 2035 2053 2291 2487 1838 2049 1556 1839 1479 828
NWJ07b 1980 1280 1481 1746 1311 2125 1954 1989 1642 1797 1929
NWJ07b 1990 1405 1652 1320 1294 1324 1402 1460 1446 1369 1427
NWJ07b 2000 1491 1381 1273 1343 1229 1084 1164 966 1185 1134
NWJ07b 2010 776 1207 1129 663 -9999
NWJ08b 1891 1510 1579 1381 1342 1519 1531 1521 1862 2014
NWJ08b 1900 2023 1609 1852 1997 1769 1742 1787 1961 2256 2276
NWJ08b 1910 1813 2209 1459 1893 2011 2241 1714 3042 2522 1924
NWJ08b 1920 1506 1776 1209 2040 1486 2176 2717 2781 2641 3178
NWJ08b 1930 3059 2850 2571 2506 2203 2437 3000 2200 1906 3054
NWJ08b 1940 2185 2286 2128 1324 1786 1749 2059 1611 1630 1346
NWJ08b 1950 1921 1582 915 730 563 517 455 683 628 818
NWJ08b 1960 806 1335 1354 1152 1393 1417 1218 501 969 869
NWJ08b 1970 556 668 586 500 664 667 602 546 618 510
NWJ08b 1980 666 613 695 363 544 672 563 409 505 568
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NWJ08b 1990 360 520 547 288 480 392 444 489 541 388
NWJ08b 2000 455 186 160 165 261 207 340 359 282 403
NWJ08b 2010 304 357 443 418 -9999
NWJ10b 1963 626 946 1365 1256 1366 2599 1516
NWJ10b 1970 913 1355 2196 3106 4142 3194 2960 3669 3593 3278
NWJ10b 1980 3468 3145 2559 2479 3714 2940 2857 2427 3160 2286
NWJ10b 1990 1240 2340 1296 1340 1335 1079 1063 837 325 1016
NWJ10b 2000 1251 1421 2035 1980 1988 1604 1272 1011 1724 2256
NWJ10b 2010 1517 3092 3054 1340 -9999
NWJ11b 1917 1053 2480 1654
NWJ11b 1920 1390 937 723 1644 1963 1635 1636 2189 1940 1929
NWJ11b 1930 2247 2326 2451 2224 2457 2714 2503 2374 2870 3062
NWJ11b 1940 2734 2362 2117 1359 1693 2597 1948 1990 1636 1555
NWJ11b 1950 1508 1603 1278 1059 949 946 884 892 1197 1328
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```

Appendix D: COFECHA output

```
[]  Dendrochronology Program Library
Run ZZ     Program COF  08:15  Tue 23 Sep 2014  Page   1
[]
[]  P R O G R A M      C O F E C H A
Version 6.06P    29122
----------------------------------------------------------------------
-------------------------------------------------------------

 QUALITY CONTROL AND DATING CHECK OF TREE-RING MEASUREMENTS
COF12K.for

 File of DATED series:   nwjc_ak012.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 not transformed to logarithms            N
         5  CORRELATION is Pearson (parametric, quantitative)
            Critical correlation, 99% confidence level  0.3281
         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  1795 to  2013   219 years
 Continuous time span is               1795 to  2013   219 years
 Portion with two or more series is    1796 to  2013   218 years



****************************************
                                         *C* Number of dated series
```

61 *C*

O Master series 1795 2013

219 yrs *O*

F Total rings in all series

8022 *F*

E Total dated rings checked

8021 *E*

C Series intercorrelation

0.661 *C*

H Average mean sensitivity

0.233 *H*

A Segments, possible

problems 14 *A*

*** Mean length of series

131.0 ***

****

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

No ring measurements of zero value

PART 2: TIME PLOT OF TREE-RING SERIES:
08:15 Tue 23 Sep 2014 Page 2

```
-----------------------------------------------------------------------
-------------------------------------------------------------
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1750 1800 1850 1900 1950 2000 2050 Ident   Seq Time-span  Yrs
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:    :    :    :    :    :    : -------- --- ---- ---- ----
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.    <=================> .    . 698071    46 1807 1983  177
   .    .    .    .    .    .    .    .    .    .    .    .    .    .
.    <=================> .    . 698072    47 1808 1983  176
   .    .    .    .    .    .    .    .    .    .    .    .    .    .
.    . <===============> .    . 698091    48 1822 1983  162
   .    .    .    .    .    .    .    .    .    .    .    .    .    .
.    . <===============> .    . 698092    49 1823 1983  161
   .    .    .    .    .    .    .    .    .    .    .    .    .    .
.    <=================> .    . 698101    50 1808 1983  176
   :    :    :    :    :    :    :    :    :    :    :    :    :    :
:    :    :    :    :    :    :
 1050 1100 1150 1200 1250 1300 1350 1400 1450 1500 1550 1600 1650 1700
1750 1800 1850 1900 1950 2000 2050

PART 2:  TIME PLOT OF TREE-RING SERIES:
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-----------------------------------------------------------------------
-------------------------------------------------------------
 1050 1100 1150 1200 1250 1300 1350 1400 1450 1500 1550 1600 1650 1700
1750 1800 1850 1900 1950 2000 2050 Ident   Seq Time-span  Yrs
   :    :    :    :    :    :    :    :    :    :    :    :    :    :
:    :    :    :    :    :    : -------- --- ---- ---- ----
   .    .    .    .    .    .    .    .    .    .    .    .    .    .
.    .<=====>  .    .    .    . 698102    51 1810 1878   69
   .    .    .    .    .    .    .    .    .    .    .    .    .    .
.    .    .  <==>   .    .    . 698102    52 1880 1912   33
   .    .    .    .    .    .    .    .    .    .    .    .    .    .
.    .    .    . <=====> .    . 698102    53 1920 1983   64
```

```
   .    .    .    .    .    .    .    .    .    .    .    .    .    .
.    <=================> .    . 698111    54 1803 1983  181
   .    .    .    .    .    .    .    .    .    .    .    .    .    .
.    <=================> .    . 698112    55 1806 1983  178
   .    .    .    .    .    .    .    .    .    .    .    .    .    .
.    .  <===============> .    . 698121    56 1836 1983  148
   .    .    .    .    .    .    .    .    .    .    .    .    .    .
.    .  <===============> .    . 698122    57 1835 1983  149
   .    .    .    .    .    .    .    .    .    .    .    .    .    .
.   <===================> .    . 698131    58 1797 1983  187
   .    .    .    .    .    .    .    .    .    .    .    .    .    .
.   <===================> .    . 698132    59 1797 1983  187
   .    .    .    .    .    .    .    .    .    .    .    .    .    .
.    . <================> .    . 698141    60 1820 1983  164
   .    .    .    .    .    .    .    .    .    .    .    .    .    .
.    .<================>  .    . 698142    61 1813 1979  167
   :    :    :    :    :    :    :    :    :    :    :    :    :    :
:    :    :    :    :    :    :
 1050 1100 1150 1200 1250 1300 1350 1400 1450 1500 1550 1600 1650 1700
1750 1800 1850 1900 1950 2000 2050
```

PART 3: Master Dating Series:
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Year	Value	No Ab	Year	Value	No Ab	Year	Value	No Ab	Year	Value	No Ab	Year	Value	No Ab
									1800	0.402	6				1850	-0.726	28
1900	-0.965	39				1950	-0.446	57				2000	-0.216	33
									1801	-0.785	7				1851	-1.535	28
1901	-0.793	39				1951	-0.675	57				2001	-0.518	33
									1802	-1.269	7				1852	-2.082	28
1902	0.961	40				1952	-1.145	57				2002	-0.562	33
									1803	1.315	8				1853	0.414	28
1903	0.676	42				1953	-1.058	57				2003	-0.304	33
									1804	2.314	9				1854	0.717	28
1904	0.103	42				1954	-1.425	57				2004	-0.384	33
									1805	-0.119	9				1855	0.675	29
1905	0.031	42				1955	-1.009	57				2005	-0.859	33
									1806	0.225	10				1856	0.086	29
1906	0.044	42				1956	-1.400	57				2006	-0.003	33
									1807	-1.849	12				1857	0.937	29
1907	0.626	43				1957	-1.093	57				2007	-1.047	33
									1808	-1.586	15				1858	-0.712	29
1908	1.006	43				1958	-0.721	57				2008	-0.153	33
									1809	0.059	15				1859	1.214	29
1909	1.181	43				1959	0.316	57				2009	0.469	33

			1810	−0.721	16				1860	1.720	29
1910	−0.312	43	1960	0.169	57	2010	−0.785	33			
			1811	0.334	17				1861	1.420	29
1911	−0.600	43	1961	1.196	57	2011	0.817	33			
			1812	1.207	17				1862	−0.293	29
1912	−1.871	44	1962	1.282	57	2012	1.784	33			
			1813	1.027	18				1863	0.463	29
1913	−0.404	43	1963	0.761	59	2013	0.582	33			
			1814	0.504	18				1864	0.177	29
1914	−0.415	43	1964	0.939	59						
			1815	−0.555	18				1865	−2.765	29
1915	0.230	43	1965	1.543	59						
			1816	0.391	18				1866	0.183	29
1916	−0.202	45	1966	1.073	59						
			1817	−1.264	18				1867	−0.713	29
1917	1.434	46	1967	−0.827	59						
			1818	0.301	18				1868	0.353	29
1918	1.480	48	1968	1.300	59						
			1819	−0.386	19				1869	−1.208	29
1919	0.189	49	1969	0.617	59						
			1820	2.818	20				1870	−1.866	29
1920	−0.226	50	1970	−1.258	59						
			1821	1.102	20				1871	−0.355	29
1921	−0.266	50	1971	−0.075	59						
			1822	0.991	21				1872	−0.826	30
1922	−2.030	50	1972	−0.099	59						
			1823	0.467	22				1873	−0.779	30
1923	0.190	51	1973	−0.898	59						
			1824	0.755	22				1874	0.139	30
1924	−0.838	51	1974	−0.900	59						
			1825	−0.882	22				1875	0.675	30
1925	−0.758	51	1975	0.361	59						
			1826	−2.251	22				1876	1.186	31
1926	−0.410	51	1976	−1.063	59						
			1827	0.548	22				1877	0.844	31
1927	0.374	51	1977	0.044	59						
			1828	−0.368	22				1878	1.497	32
1928	−0.466	51	1978	−1.323	59						
			1829	−0.504	22				1879	−2.324	31
1929	−0.163	51	1979	−1.307	59						
			1830	−0.608	22				1880	0.754	32
1930	0.933	51	1980	−0.407	58						
			1831	−0.324	22				1881	1.228	32
1931	0.355	51	1981	0.198	57						
			1832	0.464	22				1882	1.459	33
1932	−0.707	51	1982	1.208	57						
			1833	−1.403	22				1883	0.432	33
1933	−0.437	52	1983	−0.809	56						

```
                        1834 -1.505  22       1884  1.395  34
1934 -0.123  53       1984  0.757  33
                        1835 -1.461  23       1885 -0.588  34
1935  0.471  53       1985  1.656  33
                        1836 -1.390  24       1886 -0.396  35
1936  0.457  53       1986  1.713  33
                        1837 -0.075  24       1887  0.071  35
1937 -0.293  54       1987 -0.468  33
                        1838  0.223  24       1888 -0.632  35
1938  1.281  55       1988  0.855  33
                        1839 -0.133  24       1889 -1.742  36
1939  2.066  57       1989  1.732  33

                        1840  1.111  25       1890 -0.267  37
1940  1.126  57       1990  0.165  33
                        1841  1.331  25       1891  0.110  38
1941  0.466  57       1991  1.422  33
                        1842  1.556  25       1892  0.491  38
1942 -0.546  57       1992  0.115  33
                        1843  1.438  25       1893 -1.942  38
1943 -1.590  57       1993 -1.204  33
                        1844 -1.146  26       1894  0.185  38
1944  0.418  57       1994 -0.080  33
  1795 -1.691   1       1845  0.099  26       1895  0.161  38
1945  0.735  57       1995 -0.203  33
  1796  1.743   2       1846  1.895  26       1896 -0.239  38
1946  0.916  57       1996  0.126  33
  1797  1.016   4       1847  0.932  26       1897  0.496  39
1947  0.611  57       1997  0.280  33
  1798 -0.313   4       1848  0.771  26       1898 -0.117  39
1948  0.198  57       1998 -1.640  33
  1799 -0.908   5       1849 -1.611  27       1899  0.126  39
1949 -0.618  57       1999 -0.377  33
-----------------------------------------------------------------------
-------------------------------------------------------------

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
                  1800-------B    1850--c         1900-d
1950---b        2000----a
                  1801--c         1851f           1901--c
1951--c         2001---b
                  1802-e          1852h           1902--------D
1952-e          2002---b
                  1803---------E  1853-------B    1903--------C
1953-d          2003----a
```

1804----------I
1954f
2004---b
1805----@
1955-d
2005--c
1806------A
1956-f
2006-----@
1807g
1957-d
2007-d
1808f
1958--c
2008----a
1809-----@
1959------A
2009-------B
1810--c
1960------A
2010--c
1811------A
1961---------E
2011--------C
1812---------E
1962---------E
2012----------G
1813---------D
1963--------C
2013-------B
1814-------B
1964--------D
1815---b
1965----------F
1816-------B
1966---------D
1817-e
1967--c
1818------A
1968---------E
1819---b
1969-------B
1820----------K
1970-e
1821---------D
1971-----@
1822---------D
1972----@
1823-------B
1973--d
1824--------C
1974--d
1825--d
1975-------A
1826i
1976-d
1827-------B
1977-----@
1828---a
1978-e

1854--------C
1855--------C
1856-----@
1857--------D
1858--c
1859---------E
1860----------G
1861---------F
1862----a
1863-------B
1864------A
1865k
1866------A
1867--c
1868-------A
1869-e
1870g
1871---a
1872--c
1873--c
1874-----A
1875--------C
1876---------E
1877--------C
1878----------F

1904-----@
1905-----@
1906-----@
1907--------C
1908---------D
1909---------E
1910----a
1911---b
1912g
1913---b
1914---b
1915------A
1916----a
1917----------F
1918----------F
1919------A
1920----a
1921----a
1922h
1923------A
1924--c
1925--c
1926---b
1927-------A
1928---b

```
                    1829---b        1879i           1929----a
1979-e
                    1830--b         1880--------C   1930--------D
1980---b
                    1831----a       1881---------E  1931-------A
1981------A
                    1832-------B    1882----------F 1932--c
1982---------E
                    1833-f          1883-------B    1933---b
1983--c
                    1834f           1884---------F  1934----@
1984--------C
                    1835f           1885---b        1935-------B
1985----------G
                    1836-f          1886---b        1936-------B
1986----------G
                    1837-----@      1887-----@      1937----a
1987---b
                    1838------A     1888--c         1938---------E
1988--------C
                    1839----a       1889g           1939----------H
1989----------G
                    1840---------D  1890----a       1940---------E
1990------A
                    1841---------E  1891-----@      1941-------B
1991---------F
                    1842----------F 1892-------B    1942---b
1992-----@
                    1843----------F 1893h           1943f
1993-e
                    1844-e          1894------A     1944-------B
1994-----@
   1795g            1845-----@      1895------A     1945--------C
1995----a
   1796----------G 1846----------H 1896----a       1946--------D
1996-----A
   1797---------D  1847--------D   1897-------B    1947-------B
1997------A
   1798----a       1848--------C   1898----@       1948------A
1998g
   1799--d         1849f           1899-----A      1949--b
1999---b
```

PART 5: CORRELATION OF SERIES BY SEGMENTS:
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 Correlations of 50-year dated segments, lagged 25 years
 Flags: A = correlation under 0.3281 but highest as dated; B = correlation higher at other than dated position

Seq	Series	Time_span		1775 1824	1800 1849	1825 1874	1850 1899	1875 1924	1900 1949	1925 1974	1950 1999	1975 2024
1	NWJ01b	1916	2013						.63	.62	.68	.61
2	NWJ02a	1878	2013					.62	.58	.40	.46	.44
3	NWJ02b	1886	2013					.57	.57	.39	.58	.50
4	NWJ03b	1889	2013					.64	.60	.73	.70	.56
5	NWJ05a	1907	2013						.62	.76	.82	.80
6	NWJ05b	1903	2013						.56	.70	.82	.82
7	NWJ06a	1897	2013					.58	.59	.72	.85	.83
8	NWJ06b	1923	2013						.55	.67	.85	.78
9	NWJ07b	1919	2013						.38	.52	.71	.70
10	NWJ08b	1891	2013					.51	.59	.62	.63	.58
11	NWJ10b	1963	2013								.39	.40
12	NWJ11b	1917	2013						.68	.74	.71	.59
13	NWJ12b	1902	2013						.47	.60	.61	.56
14	NWJ13b	1884	2013					.58	.51	.55	.77	.75
15	NWJ14b	1939	2013							.71	.80	.79
16	NWJ15b	1890	2013					.68	.77	.82	.77	.72
17	NWJ16b	1933	2013							.67	.71	.66
18	NWJ17b	1849	2013			.14B	.11B	.30A	.44	.24B	.33B	.45
19	NWJ18b	1963	2013								.51	.52
20	NWJ19a	1876	2013					.45	.28B	.24B	.54	.55
21	NWJ19b	1882	2013					.40	.42	.55	.66	.57
22	NWJ21b	1855	2013				.09B	.32A	.61	.46	.47	.42
23	NWJ22b	1850	2013				.56	.61	.48	.54	.72	.68
24	NWJ23a	1916	2013						.62	.66	.79	.76
25	NWJ24a	1903	2013						.58	.74	.75	.67
26	NWJ26b	1939	2013							.46	.68	.65
27	NWJ27a	1872	2013				.31A	.26B	.15B	.39	.71	.66
28	NWJ27b	1912	2013						.16B	.31A	.65	.68
29	NWJ28a	1840	2013			.48	.55	.59	.54	.46	.42	.42
30	NWJ28b	1844	2013			.65	.70	.72	.57	.48	.61	.63
31	NWJ29a	1937	2013							.64	.61	.60
32	NWJ29b	1934	2013							.60	.75	.76
33	NWJ30a	1938	2013							.59	.59	.58
34	698011	1918	1983						.47	.54	.64	
35	698012	1918	1983						.51	.66	.76	
36	698021	1819	1983		.89	.89	.90	.76	.54	.61	.68	
37	698022	1807	1983		.83	.90	.94	.84	.70	.71	.75	
38	698031	1795	1982	.82	.82	.86	.87	.76	.74	.60	.60	
39	698032	1796	1980	.71	.74	.84	.86	.69	.50	.40	.37	
40	698041	1801	1983		.72	.82	.82	.60	.55	.59	.68	
41	698042	1800	1983		.71	.80	.83	.74	.67	.63	.72	
42	698051	1808	1983		.67	.88	.84	.75	.74	.76	.80	
43	698052	1811	1983		.77	.83	.83	.77	.74	.75	.79	
44	698061	1799	1983	.80	.81	.82	.85	.75	.59	.68	.65	
45	698062	1804	1983		.81	.82	.84	.82	.75	.79	.80	

```
  46 698071   1807 1983        .82  .91  .90  .82  .70  .74  .79
  47 698072   1808 1983        .71  .90  .89  .80  .72  .74  .78
  48 698091   1822 1983        .83  .84  .88  .81  .67  .70  .71
  49 698092   1823 1983        .66  .71  .86  .85  .84  .82  .83
  50 698101   1808 1983        .83  .87  .81  .64  .49  .59  .70
  51 698102   1810 1878        .87  .90  .91
  52 698102   1880 1912                        .59
  53 698102   1920 1983                             .53  .64  .67
  54 698111   1803 1983        .79  .88  .83  .72  .68  .75  .79
  55 698112   1806 1983        .81  .89  .84  .79  .75  .68  .70
  56 698121   1836 1983             .85  .78  .69  .73  .70  .75
  57 698122   1835 1983             .85  .79  .80  .79  .81  .84
  58 698131   1797 1983   .81  .81  .88  .79  .75  .73  .65  .74
  59 698132   1797 1983   .85  .86  .90  .84  .56  .51  .71  .67
  60 698141   1820 1983        .79  .88  .86  .77  .73  .77  .72
  61 698142   1813 1979        .84  .87  .76  .67  .75  .82  .79
 Av segment correlation  0.80 0.79 0.81 0.76 0.65 0.59 0.62 0.68 0.63

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

 NWJ01b    1916 to  2013      98 years
Series   1

 [B] Entire series, effect on correlation ( 0.619) is:
       Lower   1978>-0.033   2004>-0.029   2011<-0.021   1968<-0.013
```

1966<-0.009 1932>-0.008 Higher 2012 0.015 1998 0.014

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

NWJ02a 1878 to 2013 136 years
Series 2

[B] Entire series, effect on correlation (0.530) is:
Lower 1942>-0.023 1965<-0.017 2005>-0.014 1880<-0.013
1968<-0.012 1974>-0.012 Higher 1893 0.022 1879 0.015

[E] Outliers 1 3.0 SD above or -4.5 SD below mean for year
1942 +3.3 SD
==========
==========

NWJ02b 1886 to 2013 128 years
Series 3

[B] Entire series, effect on correlation (0.545) is:
Lower 1942>-0.021 1968<-0.015 1964<-0.014 1965<-0.013
1974>-0.010 1917<-0.010 Higher 1893 0.019 1912 0.019

[E] Outliers 1 3.0 SD above or -4.5 SD below mean for year
2009 +3.7 SD
==========
==========

NWJ03b 1889 to 2013 125 years
Series 4

[B] Entire series, effect on correlation (0.611) is:
Lower 2008>-0.043 1917<-0.020 2011<-0.016 1978>-0.015
1983>-0.015 1892>-0.007 Higher 1893 0.021 1998 0.011

[E] Outliers 2 3.0 SD above or -4.5 SD below mean for year
1892 +3.0 SD; 2008 +5.4 SD
==========
==========

NWJ05a 1907 to 2013 107 years
Series 5

[B] Entire series, effect on correlation (0.732) is:
Lower 1925>-0.018 1982<-0.016 1918<-0.014 1913<-0.010
1909<-0.009 1911>-0.009 Higher 1998 0.014 1912 0.011

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

```
 NWJ05b    1903 to  2013     111 years
Series   6

 [B] Entire series, effect on correlation ( 0.706) is:
       Lower   1932>-0.022   1904>-0.017   1925>-0.013   1915>-0.011
1982<-0.010   1913<-0.008  Higher   1998 0.015   1939 0.013

 [E] Outliers     1   3.0 SD above or -4.5 SD below mean for year
       1915 +3.1 SD
=====================================================================
==============================================================

 NWJ06a    1897 to  2013     117 years
Series   7

 [B] Entire series, effect on correlation ( 0.719) is:
       Lower   1901>-0.020   1944<-0.015   1926>-0.009   1996<-0.008
2008<-0.007   1918<-0.006  Higher   1922 0.013   1998 0.011

 [E] Outliers     1   3.0 SD above or -4.5 SD below mean for year
       1939 +3.4 SD
=====================================================================
==============================================================

 NWJ06b    1923 to  2013      91 years
Series   8

 [B] Entire series, effect on correlation ( 0.662) is:
       Lower   1923<-0.052   2001>-0.031   1942>-0.023   1936<-0.023
1932>-0.016   1993>-0.008  Higher   1998 0.021   1985 0.013

 [E] Outliers     1   3.0 SD above or -4.5 SD below mean for year
       2001 +3.7 SD
=====================================================================
==============================================================

 NWJ07b    1919 to  2013      95 years
Series   9

 [B] Entire series, effect on correlation ( 0.504) is:
       Lower   1924>-0.026   1923<-0.024   1920>-0.024   1973>-0.018
1936<-0.015   1922>-0.013  Higher   1938 0.022   1968 0.016

 [E] Outliers     1   3.0 SD above or -4.5 SD below mean for year
       1920 +3.3 SD
=====================================================================
==============================================================

 NWJ08b    1891 to  2013     123 years
```

Series 10

 [B] Entire series, effect on correlation (0.569) is:
      Lower   1998>-0.043   1938<-0.028   1900>-0.020   1894<-0.018
1950>-0.010   1978>-0.010 Higher   1939 0.018   1922 0.016

 [E] Outliers   2   3.0 SD above or -4.5 SD below mean for year
      1900 +3.2 SD;   1998 +4.0 SD
==
==

 NWJ10b   1963 to 2013   51 years
Series 11

 [B] Entire series, effect on correlation (0.388) is:
      Lower   1974>-0.047   1978>-0.029   1973>-0.029   2002>-0.027
1982<-0.027   1989<-0.023 Higher   1998 0.055   1968 0.043

 [E] Outliers   1   3.0 SD above or -4.5 SD below mean for year
      1974 +3.9 SD
==
==

 NWJ11b   1917 to 2013   97 years
Series 12

 [B] Entire series, effect on correlation (0.620) is:
      Lower   1993>-0.031   2005>-0.027   1917<-0.023   2006<-0.016
1985<-0.012   1932>-0.012 Higher   1998 0.018   1943 0.014

 [E] Outliers   1   3.0 SD above or -4.5 SD below mean for year
      1993 +3.1 SD
==
==

 NWJ12b   1902 to 2013   112 years
Series 13

 [B] Entire series, effect on correlation (0.535) is:
      Lower   1902<-0.032   1991<-0.024   1942>-0.022   1923<-0.014
1990>-0.013   1940<-0.010 Higher   1912 0.019   1917 0.019

 [E] Outliers   1   3.0 SD above or -4.5 SD below mean for year
      1990 +3.0 SD
==
==

 NWJ13b   1884 to 2013   130 years
Series 14

```
 [B] Entire series, effect on correlation ( 0.607) is:
       Lower   1944<-0.022   1941>-0.014   1899>-0.012   1945<-0.007
1911>-0.007   1942>-0.006  Higher   1939 0.014   1912 0.012

 [E] Outliers     3   3.0 SD above or -4.5 SD below mean for year
       1899 +3.2 SD;    1941 +3.0 SD;    1942 +3.2 SD
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 NWJ14b    1939 to  2013      75 years
Series  15

 [B] Entire series, effect on correlation ( 0.693) is:
       Lower   1948>-0.054   1995>-0.023   1955>-0.012   1944<-0.011
1981<-0.008   1943>-0.007  Higher   1998 0.021   1968 0.013

 [E] Outliers     1   3.0 SD above or -4.5 SD below mean for year
       1948 +3.7 SD
=========================================================================
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 NWJ15b    1890 to  2013     124 years
Series  16

 [B] Entire series, effect on correlation ( 0.717) is:
       Lower   2008<-0.019   1892<-0.012   1894<-0.011   1996>-0.011
1988<-0.010   1909<-0.010  Higher   1912 0.009   2012 0.009

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 NWJ16b    1933 to  2013      81 years
Series  17

 [B] Entire series, effect on correlation ( 0.631) is:
       Lower   1988<-0.033   1992>-0.024   1943>-0.020   2013>-0.020
1996<-0.018   1973>-0.012  Higher   1998 0.025   1968 0.018

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 NWJ17b    1849 to  2013     165 years
Series  18

 [A] Segment   High   -10   -9   -8   -7   -6   -5   -4   -3   -2   -1
0   +1   +2   +3   +4   +5   +6   +7   +8   +9  +10
    ---------  ----   ---  ---  ---  ---  ---  ---  ---  ---  ---  ---
---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---
    1849 1898    2   -.09  .08  .12 -.16  .02 -.07 -.24 -.01  .21  .
03  .14| .07  .32*-.02  .08  .17 -.03  .05  .14 -.20 -.38
```

```
    1850 1899    2   -.11  .10  .14 -.14  .02 -.10 -.23  .03  .22  .
04  .11| .05  .29*-.05  .11  .18 -.02  .05  .17 -.21 -.35
    1875 1924    0   -.05  .02  .16  .03  .23 -.14 -.29 -.11  .22 -.
12  .30* .07  .11 -.03  .09  .01 -.19  .04  .21 -.17 -.04
    - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
    1925 1974  -10    .35* .27 -.09 -.06  .04 -.21 -.30  .03 -.24 -.
25  .24|-.13 -.21  .00  .03 -.10  .27  .02  .06  .19  .25
    1950 1999   -3    .19  .22 -.13 -.03  .15 -.07 -.17  .36*-.28 -.
28  .33|-.26 -.05  .03  .01 -.12  .19 -.04 -.03  .02  .00

 [B] Entire series, effect on correlation ( 0.291) is:
       Lower   1879>-0.034   1955>-0.018   1900>-0.017   1881<-0.017
1954>-0.009   1851>-0.009  Higher   1893 0.021   1912 0.013
     1849 to 1898 segment:
       Lower   1879>-0.089   1881<-0.045   1851>-0.023   1858>-0.021
1852>-0.020   1866<-0.020  Higher   1893 0.076   1865 0.052
     1850 to 1899 segment:
       Lower   1879>-0.090   1881<-0.045   1851>-0.024   1858>-0.021
1866<-0.020   1852>-0.020  Higher   1893 0.085   1865 0.059
     1875 to 1924 segment:
       Lower   1879>-0.113   1881<-0.056   1900>-0.054   1883>-0.015
1889>-0.015   1897<-0.015  Higher   1893 0.074   1912 0.046
     1925 to 1974 segment:
       Lower   1955>-0.063   1954>-0.034   1945<-0.024   1974>-0.023
1964<-0.022   1965<-0.017  Higher   1967 0.047   1970 0.036
     1950 to 1999 segment:
       Lower   1955>-0.057   1954>-0.027   1964<-0.021   1981<-0.019
1971>-0.019   1974>-0.019  Higher   1998 0.039   1967 0.034

 [C] Year-to-year changes diverging by over 4.0 std deviations:
       1878 1879   4.5 SD

 [E] Outliers     7   3.0 SD above or -4.5 SD below mean for year
       1852 +3.0 SD;    1879 +4.1 SD;    1890 +3.1 SD;    1900 +3.4
SD;    1955 +5.5 SD;    1956 +3.3 SD;    1971 +4.7 SD
=====================================================================
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 NWJ18b    1963 to  2013      51 years
Series  19

 [B] Entire series, effect on correlation ( 0.505) is:
       Lower   1998>-0.036   2007>-0.026   1990>-0.023   1963<-0.019
1992>-0.016   2000<-0.015  Higher   1968 0.031   1993 0.027

 [E] Outliers     1   3.0 SD above or -4.5 SD below mean for year
       1971 +3.2 SD
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```
 NWJ19a    1876 to  2013     138 years
Series  20

 [A] Segment   High   -10   -9   -8   -7   -6   -5   -4   -3   -2   -1
0   +1   +2   +3   +4   +5   +6   +7   +8   +9  +10
    ---------  ----   ---  ---  ---  ---  ---  ---  ---  ---  ---  ---
---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---
    1900 1949    8   -.06 -.12 -.02 -.06  .03 -.08  .09 -.23 -.07 -.
08  .28|-.09  .12  .10  .00  .06  .15  .01  .28* .17  .27
    1925 1974    3   -.04 -.10 -.15 -.28 -.23 -.31  .03 -.15 -.17  .
16  .24|-.04  .25  .50* .06  .15  .02  .05  .05  .18  .06

 [B] Entire series, effect on correlation ( 0.444) is:
       Lower   1938<-0.022   1976>-0.015   1940<-0.014   1880<-0.012
1881<-0.012   1944<-0.011  Higher   2012 0.013   1939 0.013
     1900 to 1949 segment:
       Lower   1938<-0.064   1940<-0.037   1944<-0.032   1918<-0.029
1945<-0.022   1928>-0.019  Higher   1939 0.060   1912 0.033
     1925 to 1974 segment:
       Lower   1938<-0.073   1940<-0.043   1944<-0.038   1945<-0.026
1966<-0.024   1970>-0.020  Higher   1967 0.069   1939 0.068

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 NWJ19b    1882 to  2013     132 years
Series  21

 [B] Entire series, effect on correlation ( 0.503) is:
       Lower   1882<-0.023   1941>-0.016   1917<-0.014   1911>-0.012
1975<-0.012   1976>-0.012  Higher   1893 0.021   1991 0.012

 [E] Outliers     1   3.0 SD above or -4.5 SD below mean for year
       1941 +3.4 SD
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 NWJ21b    1855 to  2013     159 years
Series  22

 [A] Segment   High   -10   -9   -8   -7   -6   -5   -4   -3   -2   -1
0   +1   +2   +3   +4   +5   +6   +7   +8   +9  +10
    ---------  ----   ---  ---  ---  ---  ---  ---  ---  ---  ---  ---
---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---
    1855 1904   -1   -.25 -.15  .12 -.09 -.16  .05 -.12  .18 -.01  .
43* .09| .11 -.10 -.04  .17 -.05 -.11  .04 -.07 -.09  .04
    1875 1924    0   -.08 -.03  .10 -.03 -.09 -.04 -.31 -.06 -.05  .
15  .32* .10 -.01 -.09  .26 -.01 -.06  .03 -.02 -.03  .07
```

```
 [B] Entire series, effect on correlation ( 0.316) is:
       Lower   1893>-0.025   1993>-0.023   1866<-0.020   2012<-0.018
1879>-0.016   1894<-0.013  Higher   1968 0.021   1922 0.016
     1855 to 1904 segment:
       Lower   1893>-0.054   1866<-0.047   1894<-0.030   1862>-0.027
1880<-0.025   1879>-0.023  Higher   1865 0.045   1889 0.031
     1875 to 1924 segment:
       Lower   1893>-0.076   1879>-0.053   1894<-0.039   1895>-0.034
1880<-0.033   1918<-0.025  Higher   1922 0.048   1917 0.041

 [E] Outliers     6   3.0 SD above or -4.5 SD below mean for year
       1879 +3.2 SD;    1893 +3.5 SD;    1895 +3.8 SD;    1952 +3.6
SD;    1993 +3.6 SD;    2008 +3.4 SD
=====================================================================
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 NWJ22b    1850 to  2013     164 years
Series  23

 [B] Entire series, effect on correlation ( 0.567) is:
       Lower   1869>-0.011   1868<-0.009   1904>-0.009   1912>-0.009
1944<-0.008   1859<-0.008  Higher   1879 0.018   1893 0.015

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 NWJ23a    1916 to  2013      98 years
Series  24

 [B] Entire series, effect on correlation ( 0.677) is:
       Lower   1934>-0.019   1983>-0.017   2001>-0.011   1947<-0.009
1933<-0.008   1952>-0.007  Higher   1998 0.016   1917 0.013

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 NWJ24a    1903 to  2013     111 years
Series  25

 [B] Entire series, effect on correlation ( 0.647) is:
       Lower   1993>-0.016   2002>-0.015   2010>-0.011   1905<-0.010
2003>-0.008   1915>-0.008  Higher   1968 0.015   1989 0.012

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 NWJ26b    1939 to  2013      75 years
Series  26

 [B] Entire series, effect on correlation ( 0.533) is:
```

```
       Lower   1939<-0.082   1943>-0.041   1998>-0.013   2000>-0.013
1988<-0.010   2013<-0.008  Higher   2012 0.024   1989 0.023

 [E] Outliers     3   3.0 SD above or -4.5 SD below mean for year
       1939 -4.7 SD;    1943 +3.3 SD;    2000 +3.1 SD
=========================================================================
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 NWJ27a    1872 to  2013     142 years
Series  27

 [A] Segment   High   -10   -9   -8   -7   -6   -5   -4   -3   -2   -1
0   +1   +2   +3   +4   +5   +6   +7   +8   +9  +10
    ---------  ----   ---  ---  ---  ---  ---  ---  ---  ---  ---  ---
---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---
    1872 1921    0   -.12  .01  .17 -.13  .07  .07 -.12 -.28  .02 -.
06  .31*-.10  .10 -.25  .19  .12  .24  .10 -.02 -.33  .20
    1875 1924    6   -.13  .04  .17 -.17  .12  .09 -.13 -.35 -.04 -.
09  .26|-.13  .09 -.23  .21  .16  .27* .09  .02 -.32  .22
    1900 1949   10   -.16  .04  .07 -.15 -.08  .10  .22 -.09 -.15 -.
18  .15|-.08  .05 -.03  .18 -.04  .27  .03  .10 -.10  .34*

 [B] Entire series, effect on correlation ( 0.418) is:
       Lower   1945<-0.020   1946<-0.017   1922>-0.015   1918<-0.012
1954>-0.012   2005>-0.012  Higher   1998 0.021   1938 0.016
     1872 to 1921 segment:
       Lower   1918<-0.029   1911>-0.022   1878<-0.019   1917<-0.018
1889>-0.017   1915<-0.017  Higher   1912 0.035   1885 0.030
     1875 to 1924 segment:
       Lower   1922>-0.029   1918<-0.029   1878<-0.019   1917<-0.018
1911>-0.018   1915<-0.017  Higher   1912 0.038   1885 0.030
     1900 to 1949 segment:
       Lower   1945<-0.045   1946<-0.038   1922>-0.036   1918<-0.029
1911>-0.021   1924>-0.018  Higher   1938 0.083   1912 0.049

 [E] Outliers     2   3.0 SD above or -4.5 SD below mean for year
       1903 +3.1 SD;    1946 -4.6 SD
=========================================================================
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 NWJ27b    1912 to  2013     102 years
Series  28

 [A] Segment   High   -10   -9   -8   -7   -6   -5   -4   -3   -2   -1
0   +1   +2   +3   +4   +5   +6   +7   +8   +9  +10
    ---------  ----   ---  ---  ---  ---  ---  ---  ---  ---  ---  ---
---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---
    1912 1961   10   -.13  .17 -.15 -.16 -.05  .19  .08  .07 -.27 -.
31  .16|-.13 -.12  .09  .18 -.06 -.06  .06  .11  .04  .21*
    1925 1974    0   -.20  .11 -.29 -.18 -.23  .03  .10  .21 -.09 -.
```

```
15  .31*-.04 -.19  .22  .13 -.27  .10  .01 -.06  .23  .06

 [B] Entire series, effect on correlation ( 0.452) is:
       Lower   1917<-0.028   1946<-0.024   1945<-0.022   1949>-0.016
1954>-0.015   1939<-0.013  Higher   2012 0.021   1989 0.020
     1912 to 1961 segment:
       Lower   1917<-0.052   1946<-0.045   1945<-0.041   1949>-0.028
1954>-0.026   1939<-0.018  Higher   1923 0.044   1930 0.043
     1925 to 1974 segment:
       Lower   1946<-0.049   1945<-0.045   1949>-0.032   1954>-0.030
1939<-0.027   1932>-0.020  Higher   1968 0.055   1967 0.046

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 NWJ28a    1840 to  2013     174 years
Series  29

 [B] Entire series, effect on correlation ( 0.466) is:
       Lower   1982<-0.017   1970>-0.011   1861<-0.010   2000>-0.010
1945<-0.010   1862>-0.009  Higher   1879 0.015   1893 0.013

 [E] Outliers     2   3.0 SD above or -4.5 SD below mean for year
       2000 +3.4 SD;    2006 +3.2 SD
=========================================================================
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 NWJ28b    1844 to  2013     170 years
Series  30

 [B] Entire series, effect on correlation ( 0.604) is:
       Lower   1849>-0.014   1925>-0.012   1987>-0.009   1958>-0.009
1971<-0.009   1922>-0.007  Higher   1879 0.013   1893 0.011

 [E] Outliers     2   3.0 SD above or -4.5 SD below mean for year
       1936 +3.4 SD;    1958 +3.0 SD
=========================================================================
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 NWJ29a    1937 to  2013      77 years
Series  31

 [B] Entire series, effect on correlation ( 0.586) is:
       Lower   1990>-0.051   1986<-0.021   1947>-0.018   2013>-0.014
1996<-0.011   1946<-0.011  Higher   1968 0.025   1967 0.016

 [E] Outliers     1   3.0 SD above or -4.5 SD below mean for year
       1990 +4.0 SD
=========================================================================
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 NWJ29b    1934 to  2013      80 years
Series  32

 [B] Entire series, effect on correlation ( 0.639) is:
       Lower   1937>-0.030   1990>-0.022   1939<-0.014   1941<-0.013
1948<-0.010   1944<-0.009  Higher   1968 0.019   1967 0.013

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 NWJ30a    1938 to  2013      76 years
Series  33

 [B] Entire series, effect on correlation ( 0.555) is:
       Lower   1990>-0.051   1986<-0.022   1947>-0.017   1941<-0.016
1982<-0.013   1953>-0.012  Higher   1968 0.027   1967 0.017

 [E] Outliers     1   3.0 SD above or -4.5 SD below mean for year
       1990 +4.0 SD
=====================================================================
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 698011    1918 to  1983      66 years
Series  34

 [B] Entire series, effect on correlation ( 0.575) is:
       Lower   1924>-0.038   1939<-0.031   1938<-0.024   1932>-0.021
1930<-0.012   1979>-0.012  Higher   1922 0.044   1968 0.032

 [E] Outliers     1   3.0 SD above or -4.5 SD below mean for year
       1927 +3.6 SD
=====================================================================
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 698012    1918 to  1983      66 years
Series  35

 [B] Entire series, effect on correlation ( 0.631) is:
       Lower   1924>-0.070   1938<-0.016   1928>-0.013   1953>-0.009
1926>-0.008   1955>-0.007  Higher   1970 0.022   1982 0.014

 [E] Outliers     1   3.0 SD above or -4.5 SD below mean for year
       1924 +4.0 SD
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 698021    1819 to  1983     165 years
Series  36
```

```
 [B] Entire series, effect on correlation ( 0.775) is:
       Lower   1931>-0.012   1902<-0.012   1939<-0.010   1920>-0.007
1941>-0.006   1906<-0.005  Higher   1879 0.012   1865 0.012

 [E] Outliers     1   3.0 SD above or -4.5 SD below mean for year
       1931 +3.6 SD
=====================================================================
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 698022    1807 to  1983     177 years
Series  37

 [B] Entire series, effect on correlation ( 0.821) is:
       Lower   1920>-0.006   1908<-0.006   1967>-0.005   1818>-0.005
1821<-0.004   1899<-0.004  Higher   1820 0.011   1865 0.007

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 698031    1795 to  1982     188 years
Series  38

 [*] Early part of series cannot be checked from 1795 to 1795 -- not
matched by another series

 [B] Entire series, effect on correlation ( 0.753) is:
       Lower   1964<-0.010   1963<-0.010   1920>-0.007   1979>-0.006
1980>-0.005   1965<-0.004  Higher   1865 0.010   1879 0.007

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 698032    1796 to  1980     185 years
Series  39

 [B] Entire series, effect on correlation ( 0.651) is:
       Lower   1963<-0.015   1964<-0.014   1938<-0.012   1980>-0.012
1939<-0.007   1840<-0.007  Higher   1879 0.014   1865 0.014

 [E] Outliers     2   3.0 SD above or -4.5 SD below mean for year
       1964 -4.6 SD;    1980 +4.3 SD
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 698041    1801 to  1983     183 years
Series  40

 [B] Entire series, effect on correlation ( 0.701) is:
       Lower   1885>-0.008   1967>-0.006   1913>-0.006   1938<-0.006
1920>-0.006   1807>-0.006  Higher   1820 0.015   1865 0.013
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 698042    1800 to  1983     184 years
Series  41

 [B] Entire series, effect on correlation ( 0.726) is:
       Lower   1809<-0.007   1902<-0.007   1933>-0.006   1967>-0.006
1828>-0.006   1961<-0.005  Higher   1865 0.012   1820 0.012

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 698051    1808 to  1983     176 years
Series  42

 [B] Entire series, effect on correlation ( 0.756) is:
       Lower   1819>-0.012   1905>-0.006   1916>-0.006   1902<-0.006
1822<-0.006   1959<-0.005  Higher   1879 0.015   1865 0.011

 [E] Outliers     1   3.0 SD above or -4.5 SD below mean for year
       1819 +3.5 SD
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 698052    1811 to  1983     173 years
Series  43

 [B] Entire series, effect on correlation ( 0.772) is:
       Lower   1811<-0.015   1972>-0.009   1873>-0.009   1902<-0.008
1903<-0.008   1968<-0.006  Higher   1879 0.013   1820 0.008

 [E] Outliers     1   3.0 SD above or -4.5 SD below mean for year
       1972 +3.1 SD
=================================================================
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 698061    1799 to  1983     185 years
Series  44

 [B] Entire series, effect on correlation ( 0.743) is:
       Lower   1902<-0.011   1979>-0.010   1935<-0.008   1949>-0.007
1976>-0.007   1860<-0.007  Higher   1820 0.014   1879 0.009

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 698062    1804 to  1983     180 years
Series  45
```

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 [B] Entire series, effect on correlation ( 0.803) is:
       Lower   1906>-0.006   1979>-0.005   1807>-0.005   1926>-0.004
1931<-0.004   1961<-0.004  Higher   1820 0.011   1879 0.006

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 698071    1807 to  1983     177 years
Series  46

 [B] Entire series, effect on correlation ( 0.817) is:
       Lower   1813<-0.007   1902<-0.006   1817>-0.006   1935<-0.006
1885>-0.006   1928<-0.005  Higher   1820 0.011   1879 0.008

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 698072    1808 to  1983     176 years
Series  47

 [B] Entire series, effect on correlation ( 0.772) is:
       Lower   1821>-0.022   1972>-0.009   1817>-0.007   1968<-0.007
1813<-0.007   1928<-0.007  Higher   1879 0.010   1865 0.010

 [E] Outliers     1   3.0 SD above or -4.5 SD below mean for year
       1821 +3.9 SD
=====================================================================
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 698091    1822 to  1983     162 years
Series  48

 [B] Entire series, effect on correlation ( 0.776) is:
       Lower   1938<-0.013   1846<-0.006   1903<-0.006   1933>-0.006
1939<-0.005   1827<-0.004  Higher   1879 0.009   1893 0.008

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 698092    1823 to  1983     161 years
Series  49

 [B] Entire series, effect on correlation ( 0.766) is:
       Lower   1832<-0.013   1824<-0.012   1826>-0.011   1825>-0.009
1841<-0.007   1886>-0.006  Higher   1879 0.010   1893 0.008

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 698101    1808 to  1983     176 years
Series  50

 [B] Entire series, effect on correlation ( 0.728) is:
       Lower   1901>-0.017   1965<-0.012   1892<-0.010   1930<-0.007
1900>-0.007   1818<-0.006  Higher   1820 0.013   1865 0.012

 [E] Outliers     1   3.0 SD above or -4.5 SD below mean for year
       1901 +3.9 SD
=====================================================================
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 698102    1810 to  1878      69 years
Series  51

 [B] Entire series, effect on correlation ( 0.883) is:
       Lower   1874<-0.009   1811<-0.007   1844>-0.007   1815<-0.005
1828<-0.005   1825>-0.005  Higher   1865 0.013   1820 0.010

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 698102    1880 to  1912      33 years
Series  52

 [B] Entire series, effect on correlation ( 0.593) is:
       Lower   1901>-0.069   1887>-0.055   1900>-0.031   1882<-0.016
1892<-0.016   1894<-0.010  Higher   1893 0.063   1889 0.053

 [E] Outliers     2   3.0 SD above or -4.5 SD below mean for year
       1887 +3.2 SD;    1901 +3.2 SD
=====================================================================
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 698102    1920 to  1983      64 years
Series  53

 [B] Entire series, effect on correlation ( 0.561) is:
       Lower   1920>-0.075   1979>-0.028   1927<-0.020   1965<-0.018
1935<-0.012   1971<-0.011  Higher   1968 0.033   1939 0.020

 [E] Outliers     1   3.0 SD above or -4.5 SD below mean for year
       1920 +4.0 SD
=====================================================================
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 698111    1803 to  1983     181 years
Series  54

 [B] Entire series, effect on correlation ( 0.766) is:
```

```
       Lower   1813<-0.012   1803<-0.010   1923>-0.006   1921>-0.005
1967>-0.005   1815>-0.005  Higher   1820 0.011   1879 0.010

 [E] Outliers     1   3.0 SD above or -4.5 SD below mean for year
       1923 +3.7 SD
=========================================================================
==============================================================

 698112    1806 to  1983     178 years
Series  55

 [B] Entire series, effect on correlation ( 0.778) is:
       Lower   1819>-0.008   1813<-0.006   1897>-0.006   1938<-0.005
1930<-0.005   1912>-0.005  Higher   1879 0.012   1865 0.007

 [E] Outliers     1   3.0 SD above or -4.5 SD below mean for year
       1899 +3.3 SD
=========================================================================
==============================================================

 698121    1836 to  1983     148 years
Series  56

 [B] Entire series, effect on correlation ( 0.764) is:
       Lower   1893>-0.012   1958>-0.010   1900>-0.009   1896>-0.007
1841<-0.007   1899>-0.007  Higher   1865 0.011   1849 0.007

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

 698122    1835 to  1983     149 years
Series  57

 [B] Entire series, effect on correlation ( 0.812) is:
       Lower   1841<-0.012   1893>-0.008   1903<-0.007   1934>-0.006
1896>-0.006   1930<-0.005  Higher   1879 0.011   1849 0.006

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

 698131    1797 to  1983     187 years
Series  58

 [B] Entire series, effect on correlation ( 0.772) is:
       Lower   1896>-0.008   1893>-0.007   1947<-0.007   1930<-0.006
1968<-0.006   1882<-0.005  Higher   1879 0.009   1865 0.008

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

```
 698132    1797 to  1983     187 years
Series  59

 [B] Entire series, effect on correlation ( 0.724) is:
       Lower   1900>-0.021   1979>-0.011   1967>-0.010   1899>-0.009
1915<-0.007   1917<-0.006  Higher   1879 0.011   1865 0.009

 [E] Outliers     2   3.0 SD above or -4.5 SD below mean for year
       1899 +3.2 SD;    1900 +4.6 SD
=========================================================================
==============================================================

 698141    1820 to  1983     164 years
Series  60

 [B] Entire series, effect on correlation ( 0.755) is:
       Lower   1820<-0.030   1979>-0.019   1901>-0.010   1893>-0.008
1931>-0.007   1830>-0.006  Higher   1865 0.013   1879 0.010

 [E] Outliers     1   3.0 SD above or -4.5 SD below mean for year
       1931 +3.1 SD
=========================================================================
==============================================================

 698142    1813 to  1979     167 years
Series  61

 [B] Entire series, effect on correlation ( 0.772) is:
       Lower   1893>-0.016   1979>-0.013   1900>-0.011   1896<-0.007
1897<-0.006   1835>-0.006  Higher   1865 0.008   1922 0.006

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

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 NWJ01b   1916 2013     98      4      0   0.619   1.16   2.79
0.619  0.927  0.164   0.53  0.228 -0.053   1
   2 NWJ02a   1878 2013    136      5      0   0.530   1.26   3.92
```

0.866 0.856 0.239 0.95 0.336 −0.005 1
3 NWJ02b 1886 2013 128 5 0 0.545 1.30 3.05
0.584 0.789 0.214 0.84 0.324 −0.013 1
4 NWJ03b 1889 2013 125 5 0 0.611 1.23 2.92
0.658 0.866 0.221 1.40 0.341 −0.006 1
5 NWJ05a 1907 2013 107 4 0 0.732 1.87 4.77
1.117 0.850 0.251 0.85 0.322 0.014 1
6 NWJ05b 1903 2013 111 4 0 0.706 1.73 4.46
1.101 0.889 0.248 0.88 0.324 −0.012 1
7 NWJ06a 1897 2013 117 5 0 0.719 1.39 4.04
0.763 0.872 0.264 1.26 0.319 0.009 1
8 NWJ06b 1923 2013 91 4 0 0.662 1.19 2.88
0.746 0.906 0.270 0.73 0.312 −0.003 1
9 NWJ07b 1919 2013 95 4 0 0.504 1.76 3.87
0.640 0.720 0.199 0.70 0.248 0.004 1
10 NWJ08b 1891 2013 123 5 0 0.569 1.30 3.18
0.825 0.910 0.212 0.75 0.269 −0.005 1
11 NWJ10b 1963 2013 51 2 0 0.388 2.05 4.14
0.963 0.738 0.296 0.62 0.323 0.028 1
12 NWJ11b 1917 2013 97 4 0 0.620 1.43 3.06
0.609 0.845 0.169 0.58 0.234 0.018 1
13 NWJ12b 1902 2013 112 4 0 0.535 1.05 2.82
0.591 0.896 0.159 0.73 0.235 −0.006 2
14 NWJ13b 1884 2013 130 5 0 0.607 0.68 2.31
0.458 0.900 0.234 0.78 0.314 −0.055 1
15 NWJ14b 1939 2013 75 3 0 0.693 1.42 3.68
0.971 0.925 0.207 0.79 0.267 −0.007 1
16 NWJ15b 1890 2013 124 5 0 0.717 0.53 1.21
0.250 0.751 0.304 0.96 0.373 0.025 1
17 NWJ16b 1933 2013 81 3 0 0.631 1.31 3.32
0.836 0.919 0.227 1.02 0.466 −0.034 1
18 NWJ17b 1849 2013 165 7 5 0.291 0.68 3.37
0.600 0.927 0.213 1.03 0.275 0.002 1
19 NWJ18b 1963 2013 51 2 0 0.505 1.63 3.24
0.778 0.890 0.158 0.42 0.193 −0.048 1
20 NWJ19a 1876 2013 138 5 2 0.444 0.62 1.22
0.276 0.797 0.238 0.70 0.296 0.010 3
21 NWJ19b 1882 2013 132 5 0 0.503 0.74 2.01
0.536 0.912 0.221 0.74 0.279 −0.001 1
22 NWJ21b 1855 2013 159 6 2 0.316 0.96 1.82
0.250 0.474 0.196 0.77 0.246 −0.026 1
23 NWJ22b 1850 2013 164 6 0 0.567 1.09 2.10
0.446 0.831 0.204 0.66 0.253 −0.027 1
24 NWJ23a 1916 2013 98 4 0 0.677 1.42 4.42
1.008 0.885 0.263 0.96 0.326 0.075 1
25 NWJ24a 1903 2013 111 4 0 0.647 1.29 3.66
0.724 0.756 0.298 1.04 0.395 0.038 1
26 NWJ26b 1939 2013 75 3 0 0.533 1.19 3.37
0.745 0.943 0.175 0.55 0.233 −0.008 1
27 NWJ27a 1872 2013 142 6 3 0.418 0.74 1.69

```
0.272  0.794  0.191   0.68  0.237  0.009   1
  28 NWJ27b   1912 2013    102      4      2   0.452   1.23   3.00
0.594  0.876  0.166   0.45  0.201 -0.022   1
  29 NWJ28a   1840 2013    174      7      0   0.466   1.13   1.99
0.364  0.778  0.178   0.47  0.204 -0.012   1
  30 NWJ28b   1844 2013    170      7      0   0.604   1.03   1.82
0.331  0.792  0.167   0.50  0.206  0.005   1
  31 NWJ29a   1937 2013     77      3      0   0.586   1.78   4.84
1.228  0.903  0.234   1.20  0.419  0.010   1
  32 NWJ29b   1934 2013     80      3      0   0.639   1.40   5.23
1.063  0.872  0.221   1.00  0.310 -0.067   1
  33 NWJ30a   1938 2013     76      3      0   0.555   1.76   4.87
1.216  0.904  0.236   1.16  0.424  0.006   1
  34 698011   1918 1983     66      3      0   0.575   2.46   5.77
1.529  0.889  0.289   1.05  0.381  0.021   1
  35 698012   1918 1983     66      3      0   0.631   1.75   3.91
0.945  0.897  0.217   0.60  0.270  0.003   1
  36 698021   1819 1983    165      7      0   0.775   0.88   2.42
0.470  0.861  0.220   0.69  0.285 -0.021   1
  37 698022   1807 1983    177      7      0   0.821   0.87   2.52
0.402  0.804  0.216   0.99  0.283 -0.032   1
  38 698031   1795 1982    188      8      0   0.753   0.66   2.26
0.515  0.935  0.268   0.76  0.330  0.022   1
  39 698032   1796 1980    185      8      0   0.651   0.74   3.07
0.640  0.926  0.261   1.09  0.416 -0.003   2
  40 698041   1801 1983    183      7      0   0.701   0.57   1.51
0.349  0.911  0.199   0.80  0.265 -0.024   1
  41 698042   1800 1983    184      7      0   0.726   0.62   1.99
0.416  0.929  0.211   0.74  0.279 -0.008   1
  42 698051   1808 1983    176      7      0   0.756   0.61   2.02
0.417  0.866  0.287   0.79  0.354 -0.026   1
  43 698052   1811 1983    173      7      0   0.772   0.56   2.22
0.360  0.820  0.310   1.11  0.400 -0.044   1
  44 698061   1799 1983    185      8      0   0.743   0.65   2.05
0.306  0.797  0.227   0.91  0.277 -0.003   1
  45 698062   1804 1983    180      7      0   0.803   0.68   2.22
0.342  0.806  0.229   0.97  0.298 -0.022   1
  46 698071   1807 1983    177      7      0   0.817   0.75   2.09
0.418  0.821  0.276   1.07  0.324 -0.023   1
  47 698072   1808 1983    176      7      0   0.772   0.72   1.85
0.356  0.789  0.267   1.07  0.339  0.000   2
  48 698091   1822 1983    162      7      0   0.776   0.72   1.80
0.374  0.788  0.257   0.60  0.304 -0.012   1

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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  ()
 --- -------- ---------  -----  -----  -----   ------ -----  -----
-----  -----  -----  -----  -----  -----  --
  49 698092   1823 1983    161      7      0   0.766   0.87   2.11
0.367  0.692  0.260   0.66  0.294 -0.010   1
  50 698101   1808 1983    176      7      0   0.728   0.48   1.36
0.346  0.912  0.254   0.89  0.330  0.006   2
  51 698102   1810 1878     69      3      0   0.883   0.69   1.33
0.316  0.836  0.212   0.62  0.276  0.001   1
  52 698102   1880 1912     33      1      0   0.593   0.14   0.24
0.047  0.536  0.272   0.82  0.334  0.058   1
  53 698102   1920 1983     64      3      0   0.561   0.64   1.64
0.399  0.917  0.221   1.17  0.374 -0.052   1
  54 698111   1803 1983    181      7      0   0.766   0.72   1.66
0.305  0.717  0.249   0.93  0.322  0.004   2
  55 698112   1806 1983    178      7      0   0.778   1.01   2.99
0.453  0.737  0.260   0.80  0.340  0.003   3
  56 698121   1836 1983    148      6      0   0.764   1.00   1.98
0.382  0.741  0.247   0.66  0.305  0.008   1
  57 698122   1835 1983    149      6      0   0.812   0.87   1.94
0.299  0.674  0.217   0.65  0.272  0.016   1
  58 698131   1797 1983    187      8      0   0.772   0.74   2.53
0.590  0.931  0.242   0.77  0.299  0.027   1
  59 698132   1797 1983    187      8      0   0.724   0.79   2.93
0.724  0.935  0.261   0.82  0.323 -0.018   1
  60 698141   1820 1983    164      7      0   0.755   0.78   1.59
0.328  0.778  0.229   0.63  0.299 -0.032   1
  61 698142   1813 1979    167      7      0   0.772   0.92   2.02
0.364  0.749  0.227   0.69  0.269  0.003   4
 --- -------- ---------  -----  -----  -----   ------ -----  -----
-----  -----  -----  -----  -----  -----  --
 Total or mean:           8022    323     14   0.661   0.96   5.77
0.533  0.832  0.233   1.40  0.303 -0.006

                                                  - = [  COFECHA ZZ
COF  ] = -
```

Appendix E: ARSTAN output

```
                          ***********************************
                          ***********************************
                          ***                             ***
                          ***       Program ARSTAN        ***
                          ***                             ***
                          ***       Creation Date:        ***
                          ***          02/10/13           ***
                          ***                             ***
                          ***       Programmed by:        ***
                          ***     Dr. Edward R. Cook      ***
                          ***       Paul J. Krusic        ***
                          ***    Tree-Ring Laboratory     ***
                          ***  Lamont-Doherty Earth Obs.  ***
                          ***    Palisades, N.Y. 10964    ***
                          *** drdendro@ldeo.columbia.edu ***
                          ***    pjk@ldeo.columbia.edu    ***
                          ***  www.ldeo.columbia.edu/trl  ***
                          ***                             ***
                          ********** Version 44h2 **********
                          ***********************************

 |
==================================================================
========|

 overall run title:

 file names file processed:       arstan_files.txt
 data file processed:             nwjc_ak012.txt
 log file processed:              nwjc_ak012_log.txt

                        opt          plt
 tree-ring data type    1                 !tucson ring-width format
 missing data in gap   -9            0   !missing values estimated (no
plots)
 data transformation    0            0   !no data transformation (no
plots)
 first detrending      50      0     1   !1st-spline curve (fixed 50%
cutoff)
 second detrending      0      0     0   !2nd-no detrending performed
 robust detrending      1                 !non-robust detrending
methods used
 interactive detrend    0                 !no interactive detrending
 index calculation      1                 !tree-ring indices or ratios
(rt/gt)
 ar modeling method     1            0   !non-robust autoregressive
modeling
 pooled ar order        0            0   !minimum aic pooled ar model
order fit
```

```
 series ar order        0                !pooled ar order fit to all
series
 mean chronology        2   0    0   0   !robust (biweight) mean
chronology
 stabilize variance     0                !no variance stabilization
performed
 common period years        0    0       !no common period analysis
performed
 site-tree-core mask       SSSTTCC       !site-tree-core separation
mask
 running rbar              50   25   0   !running rbar window/overlap
(no plots)
 printout option        2                !summary & series statistics
printed
 core series save       0                !no individual core series
saved
 summary plot displays  3                !spaghetti and mean
chronology plots

 stand dynamics stuf    0            0   !no stand dynamics analyses
done
 running mean window    0                !running mean window width
 percent growth change  0                !percent growth change
threshold
 std error threshold    0                !standard error limit
threshold

 |======================== raw data statistical analyses
========================|

 |-------------------- tree-ring series read in for processing
------------------|

  data header lines:

 |------------ series gaps found based on any negative number found
------------|

        series      ident      results of scans for gaps or missing
values
          50       698102         missing values found:   2 in   2
gaps
             / 1879  1879 / 1913  1913 /

-----------------------------------------------------------------------

 |------------------ statistics of raw tree-ring measurements
------------------|

 series   ident   frst   last   year    mean   stdev   skew   kurt
```

									sens	ac(1)
1	NWJ01b	1916	2013	98	1.161	0.619	1.026	3.068	0.166	0.930
2	NWJ02a	1878	2013	136	1.260	0.866	1.400	4.090	0.241	0.860
3	NWJ02b	1886	2013	128	1.296	0.584	1.332	4.034	0.216	0.788
4	NWJ03b	1889	2013	125	1.226	0.658	0.582	2.858	0.222	0.859
5	NWJ05a	1907	2013	107	1.872	1.117	0.513	2.438	0.254	0.849
6	NWJ05b	1903	2013	111	1.728	1.101	0.437	2.257	0.250	0.888
7	NWJ06a	1897	2013	117	1.393	0.763	0.814	3.162	0.266	0.878
8	NWJ06b	1923	2013	91	1.188	0.746	1.041	2.747	0.273	0.911
9	NWJ07b	1919	2013	95	1.763	0.640	1.088	4.261	0.201	0.710
10	NWJ08b	1891	2013	123	1.300	0.825	0.441	2.116	0.214	0.913
11	NWJ10b	1963	2013	51	2.050	0.963	0.383	2.151	0.302	0.732
12	NWJ11b	1917	2013	97	1.429	0.609	0.825	2.675	0.171	0.848
13	NWJ12b	1902	2013	112	1.054	0.591	0.759	2.702	0.160	0.896
14	NWJ13b	1884	2013	130	0.679	0.458	1.296	4.638	0.235	0.897
15	NWJ14b	1939	2013	75	1.419	0.971	0.631	2.211	0.210	0.897
16	NWJ15b	1890	2013	124	0.528	0.250	0.468	2.747	0.307	0.748
17	NWJ16b	1933	2013	81	1.312	0.836	0.303	2.283	0.230	0.920
18	NWJ17b	1849	2013	165	0.681	0.600	1.703	5.789	0.215	0.930
19	NWJ18b	1963	2013	51	1.632	0.778	0.310	2.208	0.161	0.884

series	ident	frst	last	year	mean	stdev	skew	kurt	sens	ac(1)
20	NWJ19a	1876	2013	138	0.620	0.276	0.223	2.003	0.240	0.797
21	NWJ19b	1882	2013	132	0.740	0.536	0.747	2.310	0.223	0.914
22	NWJ21b	1855	2013	159	0.956	0.250	0.418	3.157	0.197	0.471
23	NWJ22b	1850	2013	164	1.085	0.446	0.131	2.393	0.205	0.823

24	NWJ23a	1916	2013	98	1.420	1.008	1.016	3.287	0.265	0.893
25	NWJ24a	1903	2013	111	1.291	0.724	1.117	4.087	0.300	0.757
26	NWJ26b	1939	2013	75	1.192	0.745	1.207	3.571	0.177	0.950
27	NWJ27a	1872	2013	142	0.736	0.272	0.921	4.168	0.192	0.800
28	NWJ27b	1912	2013	102	1.229	0.594	0.903	3.349	0.168	0.870
29	NWJ28a	1840	2013	174	1.127	0.364	-0.061	2.456	0.179	0.766
30	NWJ28b	1844	2013	170	1.029	0.331	-0.158	3.166	0.168	0.778
31	NWJ29a	1937	2013	77	1.778	1.228	0.719	2.705	0.237	0.897
32	NWJ29b	1934	2013	80	1.395	1.063	1.804	6.541	0.224	0.878
33	698011	1918	1983	66	2.465	1.529	0.341	1.975	0.294	0.889
34	698012	1918	1983	66	1.753	0.945	0.498	2.179	0.220	0.885
35	698021	1819	1983	165	0.877	0.470	0.719	3.050	0.221	0.865
36	698022	1807	1983	177	0.867	0.402	0.910	4.648	0.217	0.806
37	698031	1795	1982	188	0.663	0.515	1.209	3.843	0.270	0.921
38	698032	1796	1980	185	0.741	0.640	1.561	4.856	0.262	0.893
39	698041	1801	1983	183	0.574	0.349	0.714	2.479	0.200	0.908

series	ident	frst	last	year	mean	stdev	skew	kurt	sens	ac(1)
40	698042	1800	1983	184	0.620	0.416	0.848	2.961	0.212	0.923
41	698051	1808	1983	176	0.608	0.417	1.217	4.028	0.289	0.870
42	698052	1811	1983	173	0.557	0.360	1.547	6.188	0.312	0.824
43	698061	1799	1983	185	0.652	0.306	1.538	5.802	0.229	0.792
44	698062	1804	1983	180	0.683	0.342	1.391	5.865	0.230	0.800
45	698071	1807	1983	177	0.748	0.418	0.738	2.923	0.278	0.823
46	698072	1808	1983	176	0.724	0.356	0.858	3.183	0.268	0.788
47	698091	1822	1983	162	0.722	0.374	1.149	3.462		

```
0.259   0.790
    48   698092   1823   1983    161   0.872   0.367  0.896  3.379
0.262   0.693
    49   698101   1808   1983    176   0.479   0.346  0.647  2.259
0.256   0.915
    50   698102   1810   1983    174   0.545   0.384  0.503  2.197
0.224   0.922
    51   698111   1803   1983    181   0.718   0.305  0.653  2.853
0.250   0.717
    52   698112   1806   1983    178   1.011   0.453  1.615  7.213
0.262   0.740
    53   698121   1836   1983    148   0.997   0.382  0.152  2.407
0.248   0.740
    54   698122   1835   1983    149   0.871   0.299  0.597  3.594
0.219   0.676
    55   698131   1797   1983    187   0.744   0.590  0.946  2.697
0.243   0.918
    56   698132   1797   1983    187   0.788   0.724  1.090  2.970
0.263   0.931
    57   698141   1820   1983    164   0.783   0.328  0.473  2.556
0.230   0.778
    58   698142   1813   1983    171   0.913   0.361  0.756  3.460
0.230   0.749

       number of series read in:   58   from   1795  to   2013     219
years

 |---------------- summary of raw tree-ring series statistics
------------------|

                                 year    mean   stdev   skew   kurt
sens   ac(1)
 arithmetic mean                  137   1.061   0.589  0.826  3.356
0.233   0.836
 standard deviation                41   0.435   0.283  0.445  1.229
0.038   0.087
 median (50th quantile)           145   0.977   0.525  0.787  3.010
0.230   0.863
 interquartile range               74   0.578   0.385  0.619  1.590
0.050   0.109
 minimum value                     51   0.479   0.250 -0.158  1.975
0.160   0.471
 lower hinge (25th quantile)      102   0.722   0.361  0.498  2.438
0.212   0.788
 upper hinge (75th quantile)      176   1.300   0.746  1.117  4.028
0.262   0.897
 maximum value                    188   2.465   1.529  1.804  7.213
0.312   0.950

 |-------------------- all possible series rbar statistics
```

```
---------------------|

   total    mean   standard   standard  skewess   kurtosis   minimum
maximum
   corrs    rbar   deviation    error    coeff      coeff      corr
corr
    1649   0.361     0.348      0.009   -0.553      2.674    -0.768
0.957

   minimum correlation: -0.768   series  NWJ10b     and  698112
21 years
   maximum correlation:  0.957   series  698031     and  698032
185 years

       percent of all possible correlations used (n>20 years):
99.76
       percent of all possible tree-ring years used in rbar:
45.45

 |--------------------------- running rbar statistics
-------------------------|

    year   1850.  1875.  1900.  1925.  1950.  1975.
    corr    231.   378.   435.   741.  1275.   435.
    rbar  0.713  0.633  0.323  0.234  0.329  0.530
    sdev  0.158  0.300  0.382  0.335  0.401  0.272
    serr  0.010  0.015  0.018  0.012  0.011  0.013
    eps   0.985  0.982  0.950  0.938  0.965  0.982
    nss    26.4   32.0   40.0   49.3   55.3   49.1

 |======================== raw data chronology statistics
======================|

 |----------------- robust mean raw data chronology statistics
-----------------|

  first    last    total    mean    stdrd    skew    kurtosis    mean
serial
   year    year    years   index     dev     coeff     coeff     sens
corr
   1795    2013     219    0.912   0.382    1.125      5.071    0.172
0.856

  mean indices vs their standard deviations       robust mean
efficiency results
      correlation    slope    intercept             # improved    #
unimproved
        0.491        0.301      0.171                    118
101
```

```
 |---------------- robust mean efficiency gain and loss results
----------------|

   median      interquartile      minimum       lower       upper
maximum
    gain           range            gain        hinge       hinge
gain
    1.05            1.12            0.09         0.51        1.63
4.62

   median      interquartile      minimum       lower       upper
maximum
    loss           range            loss        hinge       hinge
loss
    0.92            0.06            0.00         0.89        0.96
1.00

 |---------------------- segment length summary statistics
----------------------|

   median      interquartile      minimum       lower       upper
maximum
   length          range           length       hinge       hinge
length
     145.            74.             51.         102.        176.
188.

 |----------- raw data chronology auto and partial autocorrelations
------------|

 lag           t-1    t-2    t-3    t-4    t-5    t-6    t-7    t-8
t-9   t-10
 acf         0.852  0.742  0.671  0.605  0.544  0.501  0.470  0.423
0.371  0.315
 pacf        0.852  0.055  0.098  0.010  0.003  0.046  0.040 -0.045
-0.040 -0.057
 95% c.l.    0.135  0.212  0.255  0.285  0.308  0.325  0.339  0.350
0.360  0.367

 |------------------ raw data chronology autoregressive model
------------------|

 ord    rsq    t-1    t-2    t-3    t-4    t-5    t-6    t-7    t-8
t-9   t-10
  3   0.767  0.699  0.085  0.121

 |================== detrended data curve fits and statistics
==================|

 |------------------------ results of first detrending
```

```
-------------------------|

 |--------------- growth curve used for detrending tree-ring data
--------------|
   option
     -5: variable span smoother         f(i) = variable span smooth
     -4: lowess robust smoother         f(i) = lowess robust smooth
     -3: median smoothing               f(i) = median sharp/smooth
    -2:  regional curve detrending      f(i) = one age-aligned curve
    -1:  first-differences              f(i) = y(i) - y(i-1)
     1:  neg expon curve, no = opt 4    f(i) = a*exp(-b*t(i)) + d
(d>0)
     2:  neg expon curve, no = opt 5    f(i) = a*exp(-b*t(i)) + d
(d>0)
     3:  neg expon curve  (general)     f(i) = a*exp(-b*t(i)) + d
(any d)
     4:  linear regression (any slope)  f(i) = +/-c*t(i) + d
     5:  linear regression (neg slope)  f(i) = -c*t(i) + d
     6:  horizontal line through mean   f(i) = mean(y(i)) = d
     7:  hugershoff growth function     f(i) = a*t(i+p)**b * exp(-
c*t(i+p)) + d
     8:  general exponential (b = 1)    f(i) = a*t(i+p)**b * exp(-
c*t(i+p)) + d
    >9:  cubic smoothing spline         fixed 50 pct variance cutoff
   <-9:  cubic smoothing spline         pct n 50 pct variance cutoff

   (a, b, c are coefficients, d is intercept or asymptote, p is pith
offset)

 series   ident     option       a           b           c           d
p
     1   NWJ01b     50   50         smoothing spline curve and window
width
     2   NWJ02a     50   50         smoothing spline curve and window
width
     3   NWJ02b     50   50         smoothing spline curve and window
width
     4   NWJ03b     50   50         smoothing spline curve and window
width
     5   NWJ05a     50   50         smoothing spline curve and window
width
     6   NWJ05b     50   50         smoothing spline curve and window
width
     7   NWJ06a     50   50         smoothing spline curve and window
width
     8   NWJ06b     50   50         smoothing spline curve and window
width
     9   NWJ07b     50   50         smoothing spline curve and window
width
    10   NWJ08b     50   50         smoothing spline curve and window
```

```
width
    11   NWJ10b     50   50         smoothing spline curve and window
width
    12   NWJ11b     50   50         smoothing spline curve and window
width
    13   NWJ12b     50   50         smoothing spline curve and window
width
    14   NWJ13b     50   50         smoothing spline curve and window
width
    15   NWJ14b     50   50         smoothing spline curve and window
width
    16   NWJ15b     50   50         smoothing spline curve and window
width
    17   NWJ16b        1   --> curve fit option failed and changed to:
4
    17   NWJ16b        4     0.000000    0.000000   -0.031829
2.617481       0
    18   NWJ17b     50   50         smoothing spline curve and window
width
    19   NWJ18b     50   50         smoothing spline curve and window
width

 series   ident     option       a           b           c           d
p
    20   NWJ19a     50   50         smoothing spline curve and window
width
    21   NWJ19b     50   50         smoothing spline curve and window
width
    22   NWJ21b     50   50         smoothing spline curve and window
width
    23   NWJ22b     50   50         smoothing spline curve and window
width
    24   NWJ23a     50   50         smoothing spline curve and window
width
    25   NWJ24a     50   50         smoothing spline curve and window
width
    26   NWJ26b     50   50         smoothing spline curve and window
width
    27   NWJ27a     50   50         smoothing spline curve and window
width
    28   NWJ27b     50   50         smoothing spline curve and window
width
    29   NWJ28a     50   50         smoothing spline curve and window
width
    30   NWJ28b     50   50         smoothing spline curve and window
width
    31   NWJ29a     50   50         smoothing spline curve and window
width
    32   NWJ29b     50   50         smoothing spline curve and window
width
```

33	698011	50	50	smoothing spline curve and window width			
34	698012	50	50	smoothing spline curve and window width			
35	698021	50	50	smoothing spline curve and window width			
36	698022	50	50	smoothing spline curve and window width			
37	698031	50	50	smoothing spline curve and window width			
38	698032	50	50	smoothing spline curve and window width			
39	698041	50	50	smoothing spline curve and window width			

series	ident	option		a	b	c	d p
40	698042	50	50	smoothing spline curve and window width			
41	698051	50	50	smoothing spline curve and window width			
42	698052	50	50	smoothing spline curve and window width			
43	698061	50	50	smoothing spline curve and window width			
44	698062	50	50	smoothing spline curve and window width			
45	698071	50	50	smoothing spline curve and window width			
46	698072	50	50	smoothing spline curve and window width			
47	698091	50	50	smoothing spline curve and window width			
48	698092	50	50	smoothing spline curve and window width			
49	698101	50	50	smoothing spline curve and window width			
50	698102	50	50	smoothing spline curve and window width			
51	698111	50	50	smoothing spline curve and window width			
52	698112	50	50	smoothing spline curve and window width			
53	698121	50	50	smoothing spline curve and window width			
54	698122	50	50	smoothing spline curve and window width			
55	698131	50	50	smoothing spline curve and window width			
56	698132	50	50	smoothing spline curve and window			

```
width
    57   698141     50   50         smoothing spline curve and window
width
    58   698142     50   50         smoothing spline curve and window
width

 |-------------------- statistics of single tree-ring series
-------------------|

 series   ident   frst   last   year    mean   stdev   skew   kurt
sens   ac(1)
     1  NWJ01b    1916   2013     98   0.993   0.238  0.231  2.664
0.164   0.636
     2  NWJ02a    1878   2013    136   0.991   0.318  0.532  4.057
0.237   0.492
     3  NWJ02b    1886   2013    128   0.993   0.305  1.305  6.632
0.214   0.520
     4  NWJ03b    1889   2013    125   1.003   0.354  0.957  4.823
0.217   0.593
     5  NWJ05a    1907   2013    107   1.002   0.325  1.290  8.761
0.251   0.440
     6  NWJ05b    1903   2013    111   1.002   0.305  1.590  9.613
0.247   0.364
     7  NWJ06a    1897   2013    117   0.992   0.335  0.333  2.748
0.262   0.560
     8  NWJ06b    1923   2013     91   0.995   0.304  0.167  3.017
0.267   0.433
     9  NWJ07b    1919   2013     95   0.996   0.232  0.609  4.109
0.199   0.388
    10  NWJ08b    1891   2013    123   0.997   0.253 -0.220  2.972
0.211   0.461
    11  NWJ10b    1963   2013     51   0.973   0.371  0.218  2.587
0.291   0.555
    12  NWJ11b    1917   2013     97   0.995   0.238  0.074  2.829
0.170   0.550
    13  NWJ12b    1902   2013    112   0.992   0.260  0.333  3.334
0.159   0.647
    14  NWJ13b    1884   2013    130   0.975   0.402  0.716  3.009
0.231   0.721
    15  NWJ14b    1939   2013     75   1.001   0.271  0.066  2.581
0.209   0.559
    16  NWJ15b    1890   2013    124   0.981   0.390  0.546  3.170
0.302   0.626
    17  NWJ16b    1933   2013     81   1.026   0.536  5.307 37.642
0.235   0.369
    18  NWJ17b    1849   2013    165   1.004   0.289  0.760  4.071
0.212   0.529
    19  NWJ18b    1963   2013     51   1.004   0.200  0.074  2.394
0.158   0.477
```

series	ident	frst	last	year	mean	stdev	skew	kurt	sens	ac(1)
20	NWJ19a	1876	2013	138	0.983	0.353	0.192	2.403	0.236	0.643
21	NWJ19b	1882	2013	132	0.994	0.283	0.165	2.808	0.219	0.497
22	NWJ21b	1855	2013	159	0.996	0.218	0.387	3.430	0.195	0.282
23	NWJ22b	1850	2013	164	0.994	0.245	0.395	4.675	0.202	0.443
24	NWJ23a	1916	2013	98	0.983	0.435	0.679	2.668	0.262	0.709
25	NWJ24a	1903	2013	111	0.987	0.419	0.829	3.595	0.294	0.569
26	NWJ26b	1939	2013	75	0.998	0.225	0.460	2.590	0.173	0.489
27	NWJ27a	1872	2013	142	0.994	0.232	0.511	3.406	0.189	0.453
28	NWJ27b	1912	2013	102	0.996	0.202	0.590	3.214	0.159	0.451
29	NWJ28a	1840	2013	174	0.991	0.200	0.068	2.668	0.175	0.414
30	NWJ28b	1844	2013	170	0.997	0.204	-0.185	2.953	0.165	0.519
31	NWJ29a	1937	2013	77	0.984	0.472	1.790	6.603	0.236	0.691
32	NWJ29b	1934	2013	80	0.993	0.402	1.232	3.923	0.217	0.691
33	698011	1918	1983	66	0.994	0.359	1.143	5.263	0.286	0.439
34	698012	1918	1983	66	0.999	0.259	0.483	3.045	0.218	0.457
35	698021	1819	1983	165	0.976	0.300	0.545	3.984	0.219	0.587
36	698022	1807	1983	177	0.983	0.284	0.569	3.428	0.216	0.519
37	698031	1795	1982	188	0.998	0.297	0.378	3.846	0.269	0.343
38	698032	1796	1980	185	0.990	0.292	0.540	3.861	0.262	0.344
39	698041	1801	1983	183	0.974	0.336	0.813	3.902	0.197	0.721

series	ident	frst	last	year	mean	stdev	skew	kurt	sens	ac(1)
40	698042	1800	1983	184	0.987	0.276	0.560	4.204	0.210	0.573
41	698051	1808	1983	176	0.980	0.385	0.455	2.603	0.285	0.618
42	698052	1811	1983	173	0.979	0.398	0.716	3.678		

```
0.308   0.559
    43  698061    1799   1983    185   0.995   0.255  0.328  3.294
0.226   0.328
    44  698062    1804   1983    180   0.993   0.289  0.622  3.982
0.228   0.451
    45  698071    1807   1983    177   0.990   0.305  0.314  3.227
0.275   0.396
    46  698072    1808   1983    176   0.991   0.334  0.652  3.784
0.266   0.528
    47  698091    1822   1983    162   0.992   0.283  0.153  2.544
0.256   0.331
    48  698092    1823   1983    161   0.992   0.269  0.114  2.573
0.259   0.302
    49  698101    1808   1983    176   0.994   0.335  0.629  3.917
0.255   0.535
    50  698102    1810   1983    174   0.994   0.314  0.279  2.788
0.233   0.585
    51  698111    1803   1983    181   0.992   0.322  0.576  3.565
0.247   0.515
    52  698112    1806   1983    178   0.989   0.377  0.857  4.264
0.259   0.644
    53  698121    1836   1983    148   0.993   0.306 -0.199  2.497
0.246   0.580
    54  698122    1835   1983    149   0.995   0.278  0.139  2.809
0.216   0.536
    55  698131    1797   1983    187   0.995   0.280  0.034  2.585
0.243   0.386
    56  698132    1797   1983    187   0.988   0.327  0.441  3.576
0.260   0.513
    57  698141    1820   1983    164   0.991   0.311  0.133  2.845
0.227   0.615
    58  698142    1813   1983    171   0.993   0.302  0.141  2.167
0.227   0.593

 |---------------- summary of single tree-ring series statistics
---------------|

                                year    mean   stdev   skew   kurt
sens   ac(1)
 arithmetic mean                 137   0.992   0.308  0.576  4.210
0.230   0.513
 standard deviation               41   0.009   0.069  0.755  4.680
0.038   0.111
 median (50th quantile)          145   0.993   0.303  0.471  3.314
0.230   0.519
 interquartile range              74   0.007   0.076  0.512  1.233
0.049   0.147
 minimum value                    50   0.973   0.200 -0.220  2.167
0.158   0.282
 lower hinge (25th quantile)     102   0.989   0.260  0.167  2.748
```

```
0.210   0.440
 upper hinge (75th quantile)     176   0.996   0.336  0.679  3.982
0.259   0.587
 maximum value                   188   1.026   0.536  5.307 37.642
0.308   0.721

 |-------------------- all possible series rbar statistics
---------------------|

   total    mean   standard   standard  skewess   kurtosis   minimum
maximum
   corrs    rbar   deviation    error    coeff      coeff      corr
corr
    1649   0.401     0.221      0.005   -0.945      4.602    -0.641
0.901

   minimum correlation: -0.641   series  NWJ10b     and  698112
21 years
   maximum correlation:  0.901   series  NWJ05a     and  NWJ05b
107 years

       percent of all possible correlations used (n>20 years):
99.76
       percent of all possible tree-ring years used in rbar:
45.45

 |---------------------------- running rbar statistics
--------------------------|

    year   1850.  1875.  1900.  1925.  1950.  1975.
    corr    231.   378.   435.   741.  1275.   435.
    rbar  0.757  0.595  0.393  0.329  0.453  0.482
    sdev  0.087  0.183  0.251  0.244  0.266  0.225
    serr  0.006  0.009  0.012  0.009  0.007  0.011
    eps   0.988  0.979  0.963  0.960  0.979  0.979
    nss    26.4   32.0   40.0   49.3   55.3   49.1

 |======================== standard chronology statistics
======================|

 |----------------- robust mean standard chronology statistics
-----------------|

  first    last    total    mean    stdrd    skew    kurtosis    mean
serial
   year    year    years   index     dev     coeff     coeff     sens
corr
   1795    2013     219    0.986   0.201    0.024      2.674    0.166
0.470
```

```
  mean indices vs their standard deviations       robust mean
efficiency results
      correlation    slope    intercept             # improved    #
unimproved
        0.333        0.120      0.079                    101
118

 |---------------- robust mean efficiency gain and loss results
----------------|

   median      interquartile      minimum       lower       upper
maximum
    gain           range            gain        hinge       hinge
gain
    1.09            0.46            0.47         0.94        1.40
4.91

   median      interquartile      minimum       lower       upper
maximum
    loss           range            loss        hinge       hinge
loss
    0.93            0.07            0.00         0.90        0.96
1.00

 |----------- standard chronology auto and partial autocorrelations
------------|

 lag           t-1    t-2    t-3    t-4    t-5    t-6    t-7    t-8
t-9   t-10
 acf         0.468  0.289  0.177  0.063 -0.048 -0.055 -0.071 -0.183
-0.213 -0.253
 pacf        0.468  0.090  0.015 -0.056 -0.098  0.001 -0.020 -0.159
-0.090 -0.117
 95% c.l.    0.135  0.162  0.171  0.175  0.175  0.175  0.176  0.176
0.180  0.184

 |------------------ standard chronology autoregressive model
------------------|

 ord    rsq    t-1    t-2    t-3    t-4    t-5    t-6    t-7    t-8
t-9   t-10
  2   0.229  0.424  0.097

 |======================= pooled autoregression analysis
=======================|

 pooled autocorrelations:

 lag     t= -1  t= -2  t= -3  t= -4  t= -5  t= -6  t= -7  t= -8  t= -9
t=-10
```

```
        0.543  0.356  0.266  0.125 -0.020 -0.036 -0.112 -0.246 -0.252
-0.296

 yule-walker estimates of autoregression:

 order   t= -1  t= -2  t= -3  t= -4  t= -5  t= -6  t= -7  t= -8  t= -9
t=-10
    1    0.543
    2    0.496  0.087
    3    0.490  0.057  0.060
    4    0.495  0.062  0.101 -0.083
    5    0.485  0.075  0.109 -0.019 -0.129
    6    0.487  0.075  0.107 -0.021 -0.137  0.018
    7    0.489  0.063  0.105 -0.011 -0.130  0.061 -0.090
    8    0.472  0.074  0.081 -0.013 -0.111  0.073 -0.001 -0.183
    9    0.463  0.074  0.085 -0.018 -0.112  0.077  0.003 -0.160 -0.048
   10    0.457  0.054  0.085 -0.009 -0.126  0.074  0.014 -0.151  0.010
-0.125

 last term in each row above equals the partial autocorrelation
coefficient

 akaike information criterion:

      ar( 0)      ar( 1)      ar( 2)      ar( 3)      ar( 4)
ar( 5)
     2097.09     2022.67     2023.02     2024.22     2024.71
2023.05

      ar( 6)      ar( 7)      ar( 8)      ar( 9)      ar(10)
     2024.98     2025.20     2019.74     2021.23     2019.78

 selected autoregression order:   1

 ar order selection criterion: ipp=0  first-minimum aic selection

 the aic trace should be checked to see if ar order selection
criterion <ipp>
 is adequate. e.g. if ar-orders of the first-minimum and the full-
minimum aic
 are close, an arstan run with full-minimum aic order selection might
be tried

 autoregression coefficients:

  t= -1   t= -2   t= -3   t= -4   t= -5   t= -6   t= -7   t= -8   t=
-9   t=-10
  0.543

 r-squared due to pooled autoregression:   29.46 pct
```

```
 variance inflation from autoregression:  141.76 pct

 impulse response function weights for this ar ( 1) process out to
order 50:

  1.0000   0.543   0.295   0.160   0.087   0.047   0.026   0.014
0.008   0.004
  0.0022   0.001   0.001   0.000   0.000   0.000   0.000   0.000
0.000   0.000
  0.0000   0.000   0.000   0.000   0.000   0.000   0.000   0.000
0.000   0.000
  0.0000   0.000   0.000   0.000   0.000   0.000   0.000   0.000
0.000   0.000
  0.0000   0.000   0.000   0.000   0.000   0.000   0.000   0.000
0.000   0.000

 |================== individual series autoregression analyses
=================|

 |---------------- individual series autoregressive coefficients
---------------|

     series    ident    order     rsq     t-1     t-2     t-3   .....
t-ip
         1   NWJ01b       1     0.421   0.645
         2   NWJ02a       1     0.252   0.502
         3   NWJ02b       1     0.277   0.526
         4   NWJ03b       1     0.367   0.605
         5   NWJ05a       1     0.198   0.444
         6   NWJ05b       1     0.134   0.364
         7   NWJ06a       1     0.322   0.564
         8   NWJ06b       1     0.201   0.446
         9   NWJ07b       1     0.153   0.391
        10   NWJ08b       1     0.232   0.464
        11   NWJ10b       1     0.325   0.570
        12   NWJ11b       1     0.309   0.555
        13   NWJ12b       1     0.434   0.656
        14   NWJ13b       1     0.555   0.743
        15   NWJ14b       1     0.316   0.562
        16   NWJ15b       1     0.398   0.631
        17   NWJ16b       1     0.309   0.555
        18   NWJ17b       1     0.306   0.553
        19   NWJ18b       1     0.293   0.500

     series    ident    order     rsq     t-1     t-2     t-3   .....
t-ip
        20   NWJ19a       1     0.444   0.647
        21   NWJ19b       1     0.265   0.511
        22   NWJ21b       1     0.108   0.285
        23   NWJ22b       1     0.207   0.447
```

```
        24   NWJ23a       1     0.553   0.738
        25   NWJ24a       1     0.324   0.569
        26   NWJ26b       1     0.256   0.506
        27   NWJ27a       1     0.224   0.472
        28   NWJ27b       1     0.225   0.457
        29   NWJ28a       1     0.194   0.418
        30   NWJ28b       1     0.275   0.524
        31   NWJ29a       1     0.535   0.722
        32   NWJ29b       1     0.512   0.716
        33   698011       1     0.200   0.440
        34   698012       1     0.218   0.459
        35   698021       1     0.359   0.587
        36   698022       1     0.284   0.520
        37   698031       1     0.124   0.348
        38   698032       1     0.134   0.356
        39   698041       1     0.529   0.722

     series    ident    order     rsq     t-1     t-2     t-3   .....
t-ip
        40   698042       1     0.332   0.573
        41   698051       1     0.387   0.619
        42   698052       1     0.321   0.559
        43   698061       1     0.120   0.330
        44   698062       1     0.221   0.453
        45   698071       1     0.178   0.397
        46   698072       1     0.308   0.530
        47   698091       1     0.120   0.336
        48   698092       1     0.098   0.302
        49   698101       1     0.305   0.536
        50   698102       1     0.344   0.585
        51   698111       1     0.289   0.516
        52   698112       1     0.434   0.645
        53   698121       1     0.344   0.585
        54   698122       1     0.292   0.538
        55   698131       1     0.150   0.387
        56   698132       1     0.274   0.513
        57   698141       1     0.378   0.615
        58   698142       1     0.359   0.593

 |------------- summary statistics for autoregressive coefficients
-------------|

                        order     rsq     t-1     t-2     t-3   .....
t-ip
   arithmetic mean        1     0.294   0.523
   standard deviation     0     0.116   0.112
   median                 1     0.292   0.528
   interquartile range    0     0.152   0.140
   minimum value          1     0.098   0.285
   lower hinge            1     0.207   0.447
```

```
   upper hinge            1     0.359   0.587
   maximum value          1     0.555   0.743

 |------------------- statistics of prewhitened tree-ring data
-----------------|

 series   ident   frst   last   year    mean   stdev   skew   kurt
sens   ac(1)
     1  NWJ01b    1916   2013     98   1.000   0.182  0.562  2.854
0.211  -0.055
     2  NWJ02a    1878   2013    136   1.000   0.275 -0.071  4.187
0.308   0.013
     3  NWJ02b    1886   2013    128   1.000   0.259  0.261  4.204
0.273   0.016
     4  NWJ03b    1889   2013    125   1.000   0.281  1.689 10.695
0.281   0.010
     5  NWJ05a    1907   2013    107   1.000   0.291  1.368  9.396
0.299   0.016
     6  NWJ05b    1903   2013    111   1.000   0.284  1.343  8.317
0.287  -0.014
     7  NWJ06a    1897   2013    117   1.000   0.276  0.329  3.124
0.303  -0.036
     8  NWJ06b    1923   2013     91   1.000   0.270  0.131  2.960
0.308  -0.036
     9  NWJ07b    1919   2013     95   1.000   0.213  0.642  4.427
0.232   0.007
    10  NWJ08b    1891   2013    123   1.000   0.224 -0.193  2.986
0.263  -0.061
    11  NWJ10b    1963   2013     51   1.000   0.302  0.387  3.412
0.309  -0.002
    12  NWJ11b    1917   2013     97   1.000   0.198  0.398  4.420
0.197  -0.022
    13  NWJ12b    1902   2013    112   1.000   0.195  1.108  6.156
0.209  -0.058
    14  NWJ13b    1884   2013    130   1.000   0.268  0.235  3.123
0.315  -0.043
    15  NWJ14b    1939   2013     75   1.000   0.224 -0.007  3.120
0.253   0.003
    16  NWJ15b    1890   2013    124   1.000   0.302  0.374  3.195
0.350  -0.001
    17  NWJ16b    1933   2013     81   1.000   0.444  5.430 38.245
0.278   0.191
    18  NWJ17b    1849   2013    165   1.000   0.241  0.525  3.358
0.263   0.007
    19  NWJ18b    1963   2013     51   1.000   0.173 -0.031  2.448
0.215  -0.098

 series   ident   frst   last   year    mean   stdev   skew   kurt
sens   ac(1)
    20  NWJ19a    1876   2013    138   1.000   0.269  0.046  3.561
```

0.316 -0.136
21 NWJ19b 1882 2013 132 1.000 0.242 0.363 3.013
0.270 -0.038
22 NWJ21b 1855 2013 159 1.000 0.209 0.660 4.420
0.217 -0.046
23 NWJ22b 1850 2013 164 1.000 0.219 0.677 6.480
0.238 -0.046
24 NWJ23a 1916 2013 98 1.000 0.292 0.623 3.767
0.289 0.110
25 NWJ24a 1903 2013 111 1.000 0.345 0.970 4.815
0.361 -0.001
26 NWJ26b 1939 2013 75 1.000 0.193 0.249 2.789
0.212 -0.021
27 NWJ27a 1872 2013 142 1.000 0.205 0.479 3.786
0.218 0.000
28 NWJ27b 1912 2013 102 1.000 0.180 0.774 3.591
0.191 -0.056
29 NWJ28a 1840 2013 174 1.000 0.182 0.030 3.073
0.204 -0.061
30 NWJ28b 1844 2013 170 1.000 0.174 -0.280 3.439
0.199 -0.008
31 NWJ29a 1937 2013 77 1.000 0.326 1.060 5.713
0.310 0.143
32 NWJ29b 1934 2013 80 1.000 0.278 0.565 4.028
0.288 -0.015
33 698011 1918 1983 66 1.000 0.322 1.220 6.407
0.338 -0.040
34 698012 1918 1983 66 1.000 0.230 0.032 2.810
0.261 -0.040
35 698021 1819 1983 165 1.000 0.243 0.017 3.328
0.274 -0.086
36 698022 1807 1983 177 1.000 0.242 0.258 4.019
0.271 -0.070
37 698031 1795 1982 188 1.000 0.279 0.118 3.892
0.305 0.026
38 698032 1796 1980 185 1.000 0.273 0.497 4.370
0.290 0.042
39 698041 1801 1983 183 1.000 0.232 0.682 4.712
0.260 -0.094

series ident frst last year mean stdev skew kurt
sens ac(1)
40 698042 1800 1983 184 1.000 0.226 0.478 3.767
0.260 -0.037
41 698051 1808 1983 176 1.000 0.302 -0.263 3.312
0.351 -0.044
42 698052 1811 1983 173 1.000 0.329 0.228 3.662
0.379 -0.060
43 698061 1799 1983 185 1.000 0.241 0.406 3.822
0.261 -0.035

```
    44  698062    1804   1983    180   1.000   0.257  0.712  4.624
0.272  -0.061
    45  698071    1807   1983    177   1.000   0.280  0.288  3.341
0.326  -0.063
    46  698072    1808   1983    176   1.000   0.283  0.213  3.132
0.339  -0.101
    47  698091    1822   1983    162   1.000   0.267  0.162  3.047
0.293  -0.035
    48  698092    1823   1983    161   1.000   0.257  0.092  2.889
0.294  -0.025
    49  698101    1808   1983    176   1.000   0.283  0.680  4.907
0.314  -0.084
    50  698102    1810   1983    174   1.000   0.255  0.188  3.591
0.282  -0.029
    51  698111    1803   1983    181   1.000   0.276  0.358  3.864
0.323  -0.090
    52  698112    1806   1983    178   1.000   0.288  0.262  3.295
0.345  -0.115
    53  698121    1836   1983    148   1.000   0.247 -0.248  2.815
0.291   0.017
    54  698122    1835   1983    149   1.000   0.234  0.243  3.051
0.252   0.024
    55  698131    1797   1983    187   1.000   0.258  0.031  3.511
0.279  -0.004
    56  698132    1797   1983    187   1.000   0.281  0.203  3.486
0.315  -0.062
    57  698141    1820   1983    164   1.000   0.245  0.040  2.978
0.282   0.006
    58  698142    1813   1983    171   1.000   0.243 -0.044  3.056
0.282  -0.061

 |------------- summary of prewhitened tree-ring series statistics
-------------|

                                 year    mean   stdev   skew   kurt
sens   ac(1)
 arithmetic mean                  137   1.000   0.257  0.475  4.634
0.279  -0.025
 standard deviation                41   0.000   0.048  0.784  4.756
0.045   0.057
 median (50th quantile)           145   1.000   0.258  0.308  3.576
0.282  -0.035
 interquartile range               74   0.000   0.055  0.550  1.300
0.049   0.064
 minimum value                     50   1.000   0.173 -0.280  2.448
0.191  -0.136
 lower hinge (25th quantile)      102   1.000   0.226  0.092  3.120
0.260  -0.061
 upper hinge (75th quantile)      176   1.000   0.281  0.642  4.420
0.309   0.003
```

```
 maximum value                    188   1.000   0.444  5.430 38.245
0.379   0.191

 |-------------------- all possible series rbar statistics
---------------------|

   total    mean   standard   standard  skewess   kurtosis   minimum
maximum
   corrs    rbar   deviation    error    coeff      coeff      corr
corr
    1649   0.405     0.174      0.004   -0.139      2.812    -0.279
0.892

   minimum correlation: -0.279   series  NWJ10b     and  698112
21 years
   maximum correlation:  0.892   series  NWJ05a     and  NWJ05b
107 years

       percent of all possible correlations used (n>20 years):
99.76
       percent of all possible tree-ring years used in rbar:
45.45

 |---------------------------- running rbar statistics
--------------------------|

    year   1850.  1875.  1900.  1925.  1950.  1975.
    corr    231.   378.   435.   741.  1275.   435.
    rbar  0.758  0.634  0.485  0.396  0.421  0.483
    sdev  0.070  0.219  0.206  0.178  0.197  0.169
    serr  0.005  0.011  0.010  0.007  0.006  0.008
    eps   0.988  0.982  0.974  0.970  0.976  0.979
    nss    26.4   32.0   40.0   49.3   55.3   49.1

 |======================== residual chronology statistics
======================|

 |----------------- robust mean residual chronology statistics
-----------------|

  first    last    total    mean    stdrd    skew    kurtosis    mean
serial
   year    year    years   index     dev     coeff     coeff     sens
corr
   1795    2013     219    0.994   0.176   -0.322      3.459    0.205
-0.091

  mean indices vs their standard deviations       robust mean
efficiency results
      correlation    slope    intercept             # improved    #
```

```
unimproved
        0.280        0.087      0.077                     107
112

 |---------------- robust mean efficiency gain and loss results
----------------|

   median      interquartile      minimum       lower       upper
maximum
    gain           range            gain        hinge       hinge
gain
    1.05            0.50            0.31         0.81        1.31
4.23

   median      interquartile      minimum       lower       upper
maximum
    loss           range            loss        hinge       hinge
loss
    0.93            0.06            0.00         0.89        0.96
1.00

 |----------- residual chronology auto and partial autocorrelations
------------|

 lag           t-1    t-2    t-3    t-4    t-5    t-6    t-7    t-8
t-9   t-10
 acf        -0.091  0.038  0.059  0.009 -0.082 -0.009  0.035 -0.110
-0.045 -0.064
 pacf       -0.091  0.030  0.065  0.019 -0.085 -0.029  0.038 -0.093
-0.065 -0.079
 95% c.l.    0.135  0.136  0.136  0.137  0.137  0.138  0.138  0.138
0.140  0.140

 |------------------ residual chronology autoregressive model
------------------|

 ord    rsq    t-1    t-2    t-3    t-4    t-5    t-6    t-7    t-8
t-9   t-10
  0   0.000

 |---------- rewhitened chronology auto and partial autocorrelations
-----------|

 lag           t-1    t-2    t-3    t-4    t-5    t-6    t-7    t-8
t-9   t-10
 acf         0.003  0.036  0.064  0.007 -0.084 -0.013  0.024 -0.113
-0.062 -0.081
 pacf        0.003  0.036  0.064  0.005 -0.089 -0.018  0.031 -0.102
-0.063 -0.086
 95% c.l.    0.135  0.135  0.135  0.136  0.136  0.137  0.137  0.137
```

```
0.139  0.139

 |----------------- rewhitened chronology autoregressive model
-----------------|

 ord    rsq    t-1    t-2    t-3    t-4    t-5    t-6    t-7    t-8
t-9   t-10
  1   0.001  0.003

 |========================= arstan chronology statistics
=======================|

 |----------------- robust mean arstan chronology statistics
-------------------|


  first    last    total    mean    stdrd    skew    kurtosis    mean
serial
   year    year    years   index     dev     coeff     coeff     sens
corr
   1795    2013      219   0.993   0.212    0.085      2.599    0.159
0.563

 |------------ arstan chronology auto and partial autocorrelations
-------------|

 lag           t-1    t-2    t-3    t-4    t-5    t-6    t-7    t-8
t-9   t-10
 acf         0.560  0.333  0.200  0.072 -0.042 -0.065 -0.094 -0.197
-0.231 -0.281
 pacf        0.560  0.028  0.004 -0.070 -0.091  0.007 -0.044 -0.160
-0.073 -0.132
 95% c.l.    0.135  0.172  0.184  0.188  0.188  0.188  0.189  0.190
0.193  0.198

 |------------------- arstan chronology autoregressive model
-------------------|

 ord    rsq    t-1    t-2    t-3    t-4    t-5    t-6    t-7    t-8
t-9   t-10
  1   0.317  0.562

 |================ as jim morrison would say, "this is the end"
================|
```

Appendix F: Raw climate data

Mean Temperature

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1949	-14.4	-20.5	11.7	25.1	42.3	49.4	57.3	55.6	46.7	20.9	2.3	-17.2
1950	-10.1	-23.2	9	24.1	44.2	59	58.1	56.5	45.1	22.9	-14.1	-9.7
1951	-27.4	-13.9	-3.8	32.1	46.5	53.8	61.9	57.3	44.1	16.5	-0.2	-15
1952	-32.3	-9.6	5.8	26.3	39.3	55.5	58.2	52.9	40.9	27.3	8.7	-12.6
1953	-33.6	-3.9	4.6	31.5	47.9	57.5	60.3	53.7	40.4	20.5	-7.6	-12.6
1954	-21.6	-20.6	7.1	20.3	44.9	54.9	56.3	53	39.8	22.8	10.7	-21.9
1955	-12.4	-11.3	6.6	23.5	40.2	52.8	59.3	50.8	41.2	17.8	-16.9	-20.1
1956	-28.1	-15.1	2	26.9	44	53.2	56.8	52	36.9	12.1	-6.3	-30.6
1957	-12.9	-7.8	8.8	25.4	42.4	57.9	56	53.2	42.01	20.92	9.2	-18.5
1958	-11.8	-8.7	10.6	31.6	45.6	60.7	60.1	53.2	41.1	11.3	-3.2	-19
1959	-30.2	-3	-4.5	24	43.6	57.4	54.5	51.5	41.4	17.6	-3	-14.3
1960	-12.9	-1.1	0	27.1	49.8	53.6	56.7	53.3	41.3	24	-2.6	-8
1961	-14.3	-7.6	-0.1	24.8	44.3	54.4	58.5	53.6	42.3	19.2	-8.2	-27.3
1962	-14.9	-0.5	5.3	28.1	42.4	53.4	60	56.5	38.6	26.2	3.9	-12
1963	-3.6	-3.6	7.6	26.1	45.6	51.7	58.5	55.8	44.5	26.5	-10.4	-8.3
1964	-20.1	-2.9	-0.9	26.2	35.9	55.9	57	52.9	43.7	25.8	-2.2	-30.5
1965	-26.3	-17.7	23.5	29.1	40.7	51.9	57.9	52.5	45.8	15.8	-6.5	-16.3
1966	-36	-7.1	-1.7	26.6	41.4	57.6	59.5	51.5	42.1	18.7	-6.5	-19.9
1967	-21.9	-9.7	6.6	28.5	42.5	59.2	59.1	56.6	43.1	23.4	5.3	-8.9
1968	-14.6	-5.9	10.9	25.9	45.3	55.3	61.1	54.7	40.2	19.6	-0.6	-22.3
1969	-33.6	-14.5	10.8	33.6	44.8	61.1	55.6	46.9	43.5	28.8	-4.7	-7.3
1970	-24.7	0.3	18.6	27.9	45	52.1	56.7	52.1	37.9	15.4	4.1	-16.7
1971	-37.1	-6.3	-1	25.8	41.9	58	58.9	53.7	42.7	20.6	-8.1	-17.5

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1972	-27.3	-19.6	-4.4	16.9	42.4	54.6	59.2	55.9	37.7	21.3	-3.4	-13.5
1973	-26.2	-13.4	11.2	32.5	42.9	53.8	58.7	51.4	42.3	21.2	-14.3	-16.4
1974	-30	-17.2	4.3	28.7	44	53.1	57.6	53.5	43.5	19.1	-2.3	-11.1
1975	-22.7	-15.9	7.2	27.8	44.5	54.3	60	53.2	43.5	20.4	-11.8	-24.6
1976	-17.4	-13.6	8	30.9	42.8	56	60.3	56.5	42	21.3	4.6	-13.6
1977	0.5	1.5	7.8	28.8	44.6	54.6	58.3	58.8	42.9	21.7	-10.2	-22.7
1978	-15.5	-7.1	11.2	31.8	46.1	53.8	60.4	56.5	45.8	21.2	2.4	-8.7
1979	-19.8	-36.2	14.4	30.9	46.5	54	58.6	57.4	43.7	28	8.1	-20.1
1980	-20.6	-1.5	11.7	35	47.5	56.7	58	52.3	39.3	26.3	3.1	-36.9
1981	-0.8	-1.1	17	25.7	49.8	52.1	56.9	52.9	40.4	26.9	6.1	-15.6
1982	-34.4	-13.3	5.6	24.8	42.8	56.4	60	54.3	44.3	14.8	-4.7	-10
1983	-22.2	-4.7	6.9	32.5	46.5	56.6	59	52.3	35.2	22	-0.2	-17
1984	-21.66	-10.48	8.64	28.71	44.7	55.39	58.73	54.06	41.65	21.88	-3.7	-12.6
1985	0.5	-13.7	9.8	20	46.1	50.9	58.2	51.8	39.4	19.96	-10.3	-0.7
1986	-6.2	-8.2	4.1	16.9	42.2	54.9	58.8	50.2	43.3	24.4	-7	-4
1987	-8.3	-1.8	5.4	31.1	45.7	54.3	59	53.8	39.9	25.6	2.2	-9.9
1988	-17.5	-8.3	12.6	29.8	46.9	55.8	58.9	52.9	40.8	18.1	-2.7	-8.8
1989	-26.8	-6.6	1.2	34.9	45.1	55.1	61	57.2	44.1	21.7	-9	-3.1
1990	-18.9	-21.8	12.1	33.5	49.4	56.9	60.3	55.1	42.5	18	-14.5	-13.4
1991	-12.1	-4.9	11.1	32.1	46.2	56.3	57	52	45.3	20	-2.5	-11.1
1992	-8.7	-10.7	11.8	26.2	40	55.3	60.7	54	29.2	15.1	2.4	-12.4
1993	-9.5	-2.4	12	34.5	49.9	57.4	60.9	54.5	43.1	28.1	2.9	-9.8
1994	-12.1	-14.7	10.8	35	46.8	56.4	61.1	59.6	41.2	19.9	-5.7	-17.1
1995	-13.5	-0.9	4.8	37.5	51.5	59.9	59.1	53	47.7	26	-7.1	-13.1
1996	-28.8	-4.2	9.3	28.5	44.2	53.4	58.1	50.8	37.8	9.6	-12.1	-23.5
1997	-23.9	0.2	-0.4	29	44.2	54.9	59.4	56.6	46.1	15.1	3.1	-7.3

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1998	-16.5	-0.5	10.8	34.5	47.3	57.7	59.6	52	43.5	18	-0.1	-16.1
1999	-22.2	-17.3	6.2	28.7	42.1	57.5	58.9	55.6	42.7	21.6	-5.5	-9.3
2000	-14.1	7.6	16	29	42	56.4	58.5	49	39.4	19.7	2.4	-9.5
2001	-5.4	-1.3	9	30.6	42	57.6	58	56.2	43.2	19.8	-4.3	-17.5
2002	-5.6	-7	0.7	19.8	45.1	55.1	58.9	53	43.5	29.6	12.2	-3.3
2003	-8.6	7.3	6.7	30.1	44.7	54.7	59.7	52.8	37.5	27.1	1.2	-15.3
2004	-25.3	1.4	4.4	31.5	49.8	62	60	56.9	36.1	25	1.7	-10.4
2005	-13.7	-5.6	17	32	50.2	56.4	56.2	56	44.1	24.1	-5.1	-3.7
2006	-20.3	-3.9	-0.4	26.3	45.9	55.6	58.5	51.8	44	26.2	-15.5	-9.3
2007	-10.3	-10.1	-6.3	31.1	46.9	58.6	60.3	57.2	43	19.5	3.4	-15.1
2008	-16.5	-12.4	11.8	29.2	45.4	54.5	54.2	50.5	43.2	15.6	-4	-18
2009	-19.9	-7.4	1.6	27.6	46.5	55.1	62	53.1	43.5	26	-3.5	-9.4
2010	-10.3	-0.1	8.9	31.6	49.2	54.8	58.3	56.7	42.3	21.7	8.4	-16.3
2011	-16.2	-7.9	-1.4	27.9	48.3	55.2	59.4	56.1	46.6	23.2	-9	-2.8
2012	-24.3	2.6	5.9	34.7	43.8	56.6	58.2	54.8	44.5	18.5	-11.9	-24.7
2013	-7.8	-1.9	4.6	16.2	41.5	61.1	60.2	56.9	41.5	31.2	1.1	-13.9
2014	0.4	-13.7	6.4	30.2	48	52.9	58	54.43	42.6	22.17	-2.26	-12.64

Mean Maximum Temperature

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1949	-4.7	-6.9	30.5	39.3	53.7	58.4	67.3	66.5	57.6	28.3	9	-8.8
1950	0.7	-11.4	26.5	37.8	55.9	71	68.4	69.3	56.3	31.7	-5.1	-1.7
1951	-19.9	-2.4	13.2	43.9	59.2	64.4	73.8	69.5	54.3	26.6	7.8	-5.7
1952	-21.8	2.1	19.7	38.5	50.4	66.5	68.3	63.3	49.3	36.2	15.6	-5.7
1953	-26.9	7.2	22.4	45	60.3	68.4	72	63.7	51.5	28.3	0.7	-5.8

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1954	-11.7	-7	22.5	33.2	57.4	66.6	66.3	65.5	50.2	31.6	17.2	-14.7
1955	-4.7	-1.6	22	36.5	52.2	63.1	71.5	60.5	52.3	27.6	-9.1	-10.1
1956	-19	-5.9	17.2	41.1	57.2	64	66.9	61.7	47.4	20.1	2.3	-23.2
1957	-3	3.4	23.8	38.6	52.3	69	66.4	65	52.36	28.8	16.1	-11.3
1958	-3.1	1.4	26.7	47.5	56.8	72.1	71.3	64.3	51.2	21.2	3.9	-12.6
1959	-21.1	9.2	10.5	36.4	53.9	68.8	63.7	61.3	50.2	28.2	5.7	-5.9
1960	-5.2	9.9	14.3	41.3	62.7	64	67	63.2	50.6	30.8	4.8	0.4
1961	-6.8	1	13.6	36.7	55.8	63.7	68.8	63.7	52.4	26.2	0.2	-19.5
1962	-5.2	9.1	20.1	38.4	52.2	63.3	70.2	65.6	48.5	34	9.6	-4
1963	3.7	7.7	22.7	39.8	57.7	62.5	68	68.8	54.2	33.1	-4.7	-0.6
1964	-12.4	7.7	15.5	37.9	46.6	66.6	66.2	62.7	55.2	33.4	4.7	-21.3
1965	-18.6	-6.8	35.6	41.6	53	63.2	67.5	63.6	57.1	23.9	2.6	-7.9
1966	-27.9	3.8	13.9	40.5	51.9	68.9	70.9	63.6	54	27.3	3.3	-11.7
1967	-12.4	1.2	21.7	41.8	54.7	71.1	68.9	67.9	55.8	30.8	12.6	-2.3
1968	-5	3.6	27.5	40.1	55.6	65.1	71.6	65.2	48.5	28.3	7.4	-14.4
1969	-26.8	-2.7	26.2	44.9	56.8	74.3	64.9	58.2	54.9	38.6	2.8	-1.3
1970	-16.8	11.9	33.2	40.6	56.8	63	67.1	62.8	45.5	22.7	12.8	-8.2
1971	-28	4.1	13.8	38.3	53.5	71.7	70.2	64.1	51.9	29.4	0.8	-8.8
1972	-19.2	-7.2	12.3	31.8	54.6	66.1	70.6	67.6	47.6	29.7	5	-5.6
1973	-18.1	-0.1	26.5	42.9	55.1	63.1	69.6	60.8	54.2	28.6	-4.8	-9.1
1974	-21	-7.5	18.9	43.6	57.1	63.7	68.1	64.5	56.1	26.7	5.6	-3.2
1975	-15.7	-3.5	24.7	39	56.5	65.4	70.6	64.3	53.4	28.1	-3.2	-16.8
1976	-9	-1.3	23.8	45.7	54.3	67.9	71.6	67.7	54.9	31.3	12.9	-5.5
1977	6.8	12.7	22.5	41.1	55.9	65.7	70.4	72.2	53.5	29.9	-2.6	-15.1
1978	-7.9	5	27.9	45.2	58.3	64.1	72.3	69.2	55.4	29.3	10.3	-1.2
1979	-11	-21.5	26.7	44	59.9	65.2	68.1	69.3	55.9	38.2	18.2	-12

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1980	-9.7	11.7	27.9	47.8	62.4	69.3	68.7	64.7	48.8	34.1	11.7	-30.1
1981	6.2	10.3	35.4	39.5	63.1	64	66.7	64.9	49.7	32.6	12	-7.1
1982	-25.7	-2	21.5	37.8	53.1	68.2	71.4	64.8	56	22.2	4.1	-3.6
1983	-15.2	4	24.7	46.5	58.7	66.3	68.9	62.2	45.8	29.3	7.4	-9.8
1984	-8.19	2.36	26.3	43.45	58.21	66.34	69.76	66.88	52.5	30.86	3.3	-3.3
1985	9.4	-1.7	27.6	33	58.23	59.5	67.2	60.7	48.3	29.7	-1.7	6.7
1986	0.9	4.2	17.4	31.5	52.8	66.9	69	61.8	56.5	32.5	2.4	3.3
1987	1.7	8.7	24.8	44.2	57.1	65.5	68.7	66.3	50.9	35.4	10.6	-2.2
1988	-9.1	4.6	27.5	44.2	56.9	66.7	68.4	62.7	52	24.4	3.9	-0.4
1989	-18.1	6.5	18	48.9	55.5	65.3	73.4	69.7	54.6	29.9	-1.4	4.8
1990	-10.2	-10.8	28.5	48.3	62.2	68.3	73.6	67.2	51.9	26	-5	-3
1991	-3.2	5.5	26.2	47.1	60.3	68.9	67.7	62.8	57.7	29.3	6.1	-1.2
1992	-1	0.9	28.2	38	51	68.4	70.3	64.8	38.1	25.7	10.5	-3.7
1993	0.7	8.8	29.7	49.1	62.3	69.3	72.6	65.2	54	35.7	11.1	-1
1994	-3.6	-2.9	25.1	48.3	58.7	68.1	72.9	71.8	51.4	28.4	4	-8.7
1995	-5.6	10.1	18.5	50.7	65.8	71.9	68.7	63.5	59.5	33.1	1.7	-6.1
1996	-21.6	7.3	25.8	45.2	56.7	65.7	69.8	60.2	49.4	18.6	-3.7	-15.2
1997	-14.9	11.3	16.3	44.4	57	66.7	70.3	66.2	59.1	23.2	10.6	1.2
1998	-9.7	8.4	29.1	48.8	60.8	68.9	71.4	64.7	54.1	29	6.3	-7.7
1999	-14.3	-6.9	24.4	41.7	53.1	69.3	70.3	66.7	52.6	28.5	3.2	-0.9
2000	-5.9	20	31.5	41.2	52	67.6	68.6	57.5	46.4	27.1	10.3	-2.3
2001	3.7	10.4	24.2	41.9	52.8	68.9	67.8	67.2	54.7	27.2	3.2	-9
2002	2.1	5.6	18.8	34.4	58.4	66.1	69.4	62.1	53.5	36.2	17.8	3.5
2003	-0.8	16.1	21.8	45.3	56.7	67	72.1	66.1	47.6	38.2	8.9	-7.2
2004	-15.4	12.9	18.1	44.6	61.7	75.1	71.5	70.7	46.1	31.3	9.5	-1.5
2005	-4.6	6	31.4	46.7	63.9	69.1	66.2	67.6	54.3	32.1	2.7	3.7

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2006	-11.6	8.6	16.3	39.3	58.1	67.9	70.2	62.6	55.9	35.2	-7.1	-1.3
2007	-2	1.8	7.1	45.8	59	72	71.9	70.2	52.5	27.4	12.5	-7.8
2008	-7.9	-1	26.6	41.2	57.8	66	64.3	59.6	52.7	23.8	3.5	-9.8
2009	-10.7	4.3	15.9	42.1	59.4	66.5	74.9	62.4	53.8	33.7	3.7	-2.4
2010	-3.4	8.7	24.6	44.2	63.4	65	68.7	66.7	52.6	29.7	16.7	-9.8
2011	-7.7	3.2	17	40.9	59.8	64.8	68.7	66.2	58.9	31.7	-1.1	6.5
2012	-16.3	14.8	19.6	47.8	55.5	66.8	68.6	66.6	56.5	26.7	-3.8	-17.7
2013	0.4	8	20.7	29.9	54.1	74.3	71.2	69	49.7	39	8.8	-5.1
2014	8.2	-1.3	25.1	43.9	61.6	63.9	68.3					

Total Precipitation in inches

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1949	1.71	0.74	0.01	0.02	0.65	1.92	5.1	1.06	0.52	0.79	0.05	0.62
1950	0.98	0.04	0.11	0.03	0.99	0.58	4.83	0.39	0.54	0.23	0.31	0.44
1951	0.13	0.15	0.1	0.6	0.95	1.73	1.78	0.59	0.35	0.02	0.38	0.31
1952	0.74	0.2	0.17	0.06	0.44	3.72	2.45	1.54	0.86	0.74	0.49	0.29
1953	0.07	0.06	0.12	0.11	1.35	4	1.24	2.12	0.95	0.41	0.07	0.24
1954	0.16	0.15	0.18	0.14	1.52	1.71	1.21	0.6	0.9	0.21	0.19	0.51
1955	0.12	0.31	0.24	0.34	0.58	1.63	1.59	1.35	0.39	0.28	0.11	0.42
1956	0.21	0.47	0.05	0.15	0.39	1.58	2.4	0.59	0.7	1.2	0.82	0.2
1957	0.43	0.47	0.29	0.43	1.21	2.12	2.51	1.03	0.65	0.49	0.37	0.43
1958	0.2	0.18	0.16	0.43	0.76	0.51	1.47	2.94	1.07	1.05	0.32	0.23
1959	0.02	0.13	0.18	0.05	0.72	1.88	3.62	1.6	0.91	0.23	0.64	0.18
1960	0.14	0.78	0.08	0.01	0.52	1.7	3.62	2.61	1.04	1.02	0.52	0.34
1961	0.09	0.35	0.08	0.23	1.22	2.88	2.77	1.37	0.86	0.45	0.27	0.5

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1962	0.45	0.37	0.17	0.29	1.64	3.07	2.51	2.74	0.61	0.1	0.44	0.28
1963	1.03	0.22	0.34	0.13	0.2	1.22	2.38	0.73	1.01	0.67	0.16	0.59
1964	0.25	0.13	0.24	0.35	0.1	3.28	4.34	1.68	0.99	0.07	0.13	0.45
1965	0.1	0.44	0.31	0.16	0.4	1.47	3.61	1.1	1.39	1	0.52	0.33
1966	0.22	0.58	0.19	0.02	0.58	1.31	0.29	0.89	1.74	0.48	0.63	0.09
1967	0.2	0.59	0.49	0.03	0.72	1.18	2.57	1.85	2.46	0.54	0.58	0.32
1968	0.53	0.35	0.06	0.07	2.25	2.83	1.83	2.72	1.61	0.36	0.24	0.07
1969	0.43	0.05	0.2	0.19	0.51	0.56	2.8	0.73	0.83	0.08	0.28	0.17
1970	0.1	0.22	0.03	0.35	0.5	1.28	3.01	2.01	1.29	0.64	0.23	0.3
1971	0.03	0.1	0.05	0.07	0.21	0.03	1.22	1.38	1.42	0.94	0.18	0.77
1972	0.22	0.49	0.24	0.09	0.3	1.75	1.88	0.53	0.28	0.69	0.12	0.15
1973	0.21	0.03	0.01	0.07	1.14	2.04	1.63	1.96	0.08	0.53	0.28	0.18
1974	0.09	0.35	0.12	0.02	0.65	2.13	3.53	1.73	0.13	0.48	0.22	0.24
1975	0.28	0.05	0.03	0.16	2.59	1.81	1.9	1.22	1.04	0.48	0.37	0.21
1976	0.3	0.07	0.18	0.01	0.7	0.43	2.3	1.8	0.27	0.09	0.34	0.36
1977	0.36	0.12	0.12	0.7	1.98	2.14	0.97	0.62	1.51	0.29	0.25	0.38
1978	0.34	0.1	0.07	0.1	1.33	0.7	2.71	0.32	1.13	0.88	0.24	0.28
1979	0.26	0.21	0.57	0.01	0.08	1.37	3.65	1.57	0.86	0.06	0.13	0.32
1980	0.3	0.23	0.11	0.39	0.05	1.41	3.22	1.5	1.41	0.21	0.18	0.09
1981	0.07	0.18	0.03	0.3	0.69	2.18	1.67	1.73	0.81	1.32	0.58	0.12
1982	0.16	0.71	0.42	0.27	0.35	1.03	1.06	0.74	0.61	0.77	0.51	0.2
1983	0.57	0.31	0.08	0.1	0.21	2.8	3.19	1.62	1.02	0.27	0.13	0.17
1984	0.3	0.24	0.2	0.24	0.67	1.51	2.35	1.24	0.95	0.49	0.34	0.35
1985	0.56	0.67	0.36	0.16	1.2	3.04	2.69	2.48	2.03	0.46	0.13	0.07
1986	0.52	0.08	0.09	0.11	1.01	1.33	1.9	0.42	0.02	0.31	0.3	0.18
1987	0.09	0.19	0.04	0.33	2.17	2.4	2.34	0.53	1.02	0.45	0.55	0.26

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1988	0.12	0.22	0.11	0.55	2.21	2.45	3.76	1.01	0.18	0.87	0.2	0.33
1989	0.22	0.01	0.2	0.16	2.06	2.28	0.57	1.47	0.32	0.5	0.37	0.48
1990	0.17	0.48	0.08	0.12	0.39	1.13	0.44	1.51	2.34	0.59	0.34	0.39
1991	0.19	0.21	0.23	0.01	0.92	1.92	2.7	0.69	0.96	0.36	0.87	0.29
1992	0.32	0.08	0.01	0.14	1.06	1.22	4.53	1.34	1.06	0.17	0.26	0.18
1993	0.28	0.25	0.16	0.35	0.77	2.58	0.9	1.76	0.48	0.17	1.05	0.17
1994	0.19	0.08	0.38	0.03	1.37	1.35	4.5	0.93	0.97	0.63	0.34	0.09
1995	0.11	0.44	0.21	0.24	1.39	1.71	4.18	1.81	0.77	0.24	0.21	0.06
1996	0.09	0.33	0.95	0.11	1.67	1.78	0.68	1.27	0.2	0.94	0.27	0.28
1997	0.39	0.01	0.13	0.46	0.6	1.21	3.24	2.51	0.1	0.37	0.03	0.23
1998	0.12	0.21	0.59	0.01	0.18	1.11	1.5	0.49	0.66	0.49	0.07	0.22
1999	0.26	0.01	0.13	0.17	1.17	2.91	2.19	2.26	0.93	0.58	0.28	0.46
2000	0.22	0.01	0.07	0.25	1.08	4.42	1.95	2.96	3.52	0.51	0.1	0.11
2001	0.22	0.35	0.02	0.71	1.65	1.17	4.97	1.05	2.23	0.66	0.36	0.2
2002	0.59	0.03	0.24	0.21	0.8	3.28	4.94	2.3	1.17	1.22	0.57	0.23
2003	0.02	0.01	0.01	0.01	1.27	0.41	0.58	0.34	1.43	0.13	0.6	0.37
2004	0.17	0.28	0.09	0.01	1.48	2.67	1.39	1.7	1.3	0.63	0.03	0.49
2005	0.18	0.01	0.01	0.01	0.74	2.54	6.49	0.76	0.52	0.2	0.59	0.1
2006	0.17	0.11	0.06	0.65	0.65	1.06	2.84	1.63	1.15	0.34	0.29	0.4
2007	0.13	0.08	0.22	0.66	1.18	0.9	2.86	1.81	1.91	0.25	0.38	0.31
2008	0.16	0.07	0.07	0.32	0.75	1.69	4.7	1.19	1.01	0.46	0.35	0.37
2009	0.27	0.16	0.23	0.02	0.39	4.56	0.93	1.62	0.63	0.69	0.39	0.07
2010	0.12	0.05	0.02	0.14	0.41	5.68	6.18	2.04	2.32	0.68	0.82	0.23
2011	0.32	0.82	0.01	0.12	0.41	2.23	4.09	3.5	0.4	0.42	0.61	0.56
2012	0.14	0.2	0.24	1.33	1.31	4.03	2.78	0.56	0.35	0.84	0.58	0.01
2013	0.21	0	0	0	0.87	1.36	1.04	1.56	1.36	0.08	0.36	0

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2014	0	0	0	0	0.38	2.22	2.03					

Mean Snow Depth in inches

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1949	39.3	46	16.2	6.5	0.5	0	0	0	0	4.6	7	11.4
1950	20.2	21.6	17.8	9	0.1	0	0	0	0	0.4	3.9	8.5
1951	10	11.1	11.2	1.9	0.1	0	0	0	0	0	3.8	11.3
1952	22.5	31.2	28.2	13.3	0	0	0	0	0	1.2	5.8	11.4
1953	11.7	10.1	11.1	4.6	0	0	0	0	0	1.6	7.7	8.5
1954	10.1	10.4	11.2	4.6	0	0	0	0	0	1	1.9	10.9
1955	14.8	16.7	19.1	10.6	0.2	0	0	0	0	2.1	8.7	16.7
1956	25.3	33.7	40.6	18.8	0	0	0	0	0.8	12.4	22	27.3
1957	29.3	35.2	33.5	20.5	1.2	0	0	0	0.12	2.08	2	7.7
1958	12.1	13.8	17.1	7.9	0	0	0	0	0	2.8	8.4	11.1
1959	11.5	13.4	14.8	4.3	0	0	0	0	0	0.6	5.2	11.8
1960	14	17.3	23.7	9.4	0	0	0	0	0	2.6	9.2	13.8
1961	17.5	19.4	19.2	4.7	0	0	0	0	0	1.5	3.5	8.8
1962	13.3	16.59	18.7	7.5	0.1	0	0	0	0	0.7	3.6	5.3
1963	11.1	17.1	15.5	6.8	0	0	0	0	0	1.2	6.9	8.9
1964	13.4	12.3	11.9	4.5	0	0	0	0	0	0	0.8	4.1
1965	7	10	7.8	1	0	0	0	0	0	2.08	6.73	14.8
1966	17	17	16.1	6.7	0	0	0	0	0	1.8	9.8	12.9
1967	14.5	19.2	27.6	10.7	0.4	0	0	0	0	1.1	5.1	6.3
1968	12.5	16.1	12.9	5.7	0	0	0	0	0	1.6	4.4	6
1969	9.4	11.9	10.7	4.1	0	0	0	0	0	0	3.7	5.9

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1970	7.4	11.5	10	4.6	0	0	0	0	0.1	4.5	5.4	11.5
1971	14.2	14	14.5	5.1	0.2	0	0	0	0	2.3	14.4	28.2
1972	43.5	27.6	22.1	12.6	1.5	0	0	0	0	2.7	7.1	11.3
1973	15.3	16.2	13.3	3.1	0.1	0	0	0	0	4.4	9.9	17.1
1974	18	18.6	16.3	5.7	0	0	0	0	0	3.1	6.6	9.8
1975	13.2	15	14.7	5.2	0	0	0	0	0.1	1.4	6	7.2
1976	12.2	10.5	10.9	4.2	0	0	0	0	0	0.2	3.4	11.1
1977	13.5	16.1	14.5	8	0	0	0	0	0	1.6	5.4	9.4
1978	14.7	18.3	10.5	1.6	0	0	0	0	0	3.4	4.8	9.4
1979	15.8	25.6	23.2	7.7	0	0	0	0	0	0.1	1.7	6.2
1980	6.9	7.3	9.1	7.27	0	0	0	0	0.2	0	2.5	4.6
1981	4.8	6.4	6.5	1.9	0	0	0	0	0	1.8	4	12.8
1982	15.8	20.6	24.4	16.8	1.5	0	0	0	0	3	13.3	17.5
1983	22.1	24.6	21.7	8.4	0	0	0	0	0.2	0.9	1.6	11.25
1984	14.76	16.59	15.85	7.27	0.2	0	0	0	0.12	2.08	5	8.8
1985	14.7	18.8	21.3	14.2	0.2	0	0	0	0	2.08	6.8	11.25
1986	9.9	13.8	13.5	10.5	0	0	0	0	0	0.1	3.5	6.7
1987	14.76	11.3	11.7	2.1	0	0	0	0	0	0.5	10.2	15.8
1988	14.2	17.1	15.9	6.8	0	0	0	0	0	9.2	16.5	17.3
1989	17.1	17.5	16	5.4	0.1	0	0	0	0	4.9	13.8	19.1
1990	22.2	21.8	22.7	6.6	0	0	0	0	0.12	4.7	9.4	13.7
1991	17.3	17.5	14.7	2.9	0	0	0	0	0	2	7.5	18.4
1992	13.8	17.7	14.4	7.2	0	0	0	0	3.5	2.08	11.4	13.7
1993	14.9	16.59	16.1	7	0	0	0	0	0.1	0.4	7.8	14.9
1994	15.5	13.4	14.4	2.6	0	0	0	0	0	3.5	6.73	18.7
1995	16.4	20.3	22.3	3.9	0	0	0	0	0	0.6	3.8	6.7

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1996	8.6	11.5	16.1	7.4	0	0	0	0	0	2.6	10.4	13.1
1997	15.7	17.5	17.5	10.4	0	0	0	0	0	3.5	8.1	11.1
1998	13.3	16.9	15.7	6.8	0	0	0	0	0	0.3	1.9	6.6
1999	10	10	9.6	4.9	1	0	0	0	0	1.8	7	8.7
2000	9.8	8.8	7.5	7.27	0.2	0	0	0	0.6	3.8	7.3	7.2
2001	10.4	14.5	12.8	5.3	0.2	0	0	0	0.12	2.08	6.73	11.25
2002	10.8	16.59	14	9.8	0.2	0	0	0	0.12	2.08	4.9	11.25
2003	10.5	9.2	7.1	9.7	0.2	0	0	0	0.8	0.5	4.9	7.4
2004	11	12.6	11.9	7.27	0.2	0	0	0	0.12	1.4	2	4.7
2005	12.7	13.5	10.5	7.27	0.2	0	0	0	0.12	2.08	7.3	10.2
2006	14.76	16.59	15.85	7.27	0.2	0	0	0	0.12	2.08	6.73	11.25
2007	14.76	16.59	15.85	7.27	0.2	0	0	0	0	1.3	6.4	9.7
2008	9.4	9.1	10.1	7.27	0.2	0	0	0	0	2.08	7.9	9.6
2009	10.6	11.3	10.8	6.3	0.2	0	0	0	0	0.5	5.7	7.3
2010	14.76	9.4	9	4.8	0	0	0	0	0.3	3.4	7	11.8
2011	14.76	18.3	18.7	12.6	0.1	0	0	0	0	1.6	6.73	11
2012	13.9	15.9	20	7	0	0	0	0	0	1.6	11.5	12.6
2013	14.76	16.6	14.4	12.5	3.9	0	0	0	0.1	0	6.73	11.25

Snowfall in inches

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1949	29.9	7.4	0.1	0.2	0.1	0.1	0	0	0.1	10.5	0.9	8.6
1950	13.9	1.3	1.2	0.1	1.8	0	0	0	0	5.1	5.7	9.6
1951	1.7	2.2	1.8	7	1.8	0	0.1	0	1.3	0.2	6.2	7.7
1952	15.9	4.3	3.7	0.4	0.1	0.1	0	0	0.1	5.2	7.1	5.1

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1953	1.4	1.7	3.5	2.3	0.1	0	0	0.1	1.1	12.8	3.8	5.7
1954	4.4	2.5	2.5	3.4	0.1	0.1	0	0	0.1	2.7	4.3	11.5
1955	1.9	7.7	4.4	8.8	0.1	0.1	0	0.1	0.1	8.9	4.9	21.7
1956	12.9	13.6	2	3.2	0	0	0	0	4.3	17.3	14.1	1.9
1957	8.4	6.3	8.2	4.6	0.5	0	0	0.03	0.89	7.84	3.6	6.3
1958	2.9	2.2	3.1	8	0.1	0	0	0	0.6	9.4	5	2.4
1959	0.2	2.9	2.4	0.1	0	0	0	0	0.1	1.3	10.9	2.6
1960	1.8	9.4	0.7	0.1	0.1	0	0	0.1	0.1	11.6	6.5	3.8
1961	1.6	4	1.1	2.3	1.5	0	0	0	0.1	3.8	2.8	7.7
1962	7.5	4	2.3	4.7	0.5	0	0	0.2	0.2	0.5	4.4	2.8
1963	11.3	1.8	2.8	1.8	0.1	0	0	0	0.1	7	1.8	6
1964	3.3	1.6	2.5	3.9	0.6	0	0	0	0.3	0.8	1.7	4.9
1965	0.9	5.4	0.4	2.2	0.9	0	0	0	0.2	5.28	2.4	5.9
1966	3.6	9.9	3.6	0.1	0.1	0	0	0	0	5.3	7.3	0.8
1967	4.9	8.1	13.4	0.3	4	0	0	0	0.1	4.4	3.3	2.5
1968	9.4	5	1.4	0.7	0.1	0	0	0	0.1	5.2	2.4	0.6
1969	5.1	0.5	3.2	2.5	0.1	0	0	1	0	0.1	3.9	3.8
1970	3	5.1	0.4	3.6	0.1	0.1	0	0	2.6	6.2	3.1	8.2
1971	0.3	0.4	0.5	0.6	1.2	0	0	0.5	0.1	9.8	5.7	26.8
1972	12.1	7.1	2.7	1.8	0.1	0	0	0	1	10	3.4	3.6
1973	3.2	1.7	0.6	1.9	4.4	0	0	0	0.1	5.4	6.4	4
1974	0.9	4.7	1.6	0.2	0.1	0.1	0	4	0.1	7.4	2.7	5.5
1975	4.4	0.4	0.7	1.6	0.1	0	0	0	0.5	7.3	6.9	2.8
1976	6.2	0.9	2.3	0.6	0.1	0	0	0	0	1.6	3.6	5.7
1977	4.9	1.8	2.8	7.2	0.1	0	0	0	4	5.8	3.2	4.8
1978	9.1	2	1.4	0.1	0.1	0	0	0	1	11.3	4.6	6.2

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1979	6.3	8.2	4.7	0.4	0	0	0	0	0.1	1.1	2.1	5.4
1980	4.5	4.4	2	4.9	0	0	0	0	4.1	1.7	2.6	1.8
1981	1.3	3.1	0.7	0.1	0.1	0	0	0	3.1	5.3	10.5	3.8
1982	3.3	7.4	7.6	6	1.1	0	0	0	0.1	15.3	7.2	5.5
1983	10.1	8.3	2.1	0.7	0.1	0	0	0	1.7	4.5	2.2	1.5
1984	5.71	4.51	2.95	2.5	0.2	0	0	0	1.76	5.83	7.5	6.5
1985	9.7	10	8.8	1.8	0.1	0	0	0	0.2	7.81	8.4	5.82
1986	16.3	1.6	6.1	2.9	0.5	0	0	0	0.1	1.7	9	4.6
1987	2.7	6.3	0.7	8.4	0	0	0	0	4.6	4.7	17.1	6.5
1988	4	4.5	4.9	2.3	0.1	0	0	0	0.3	22.7	13.8	5.8
1989	4.9	0.2	4.4	0.1	6.1	0.1	0	0	0.1	11.8	9.5	8.5
1990	2.4	7.8	2.1	0.1	0.1	0.1	0.1	0	0.1	12.9	6.7	7.7
1991	4	8.6	6.7	0.1	0.1	0.1	0	0.1	0	4.9	17.3	6.4
1992	7.1	2	0.1	3.2	1.1	0	0	0	19.2	3.9	7.2	8.1
1993	6.4	5.4	2.5	1.6	0	0.1	0	0	2	2.1	20.7	3.8
1994	5.5	1.8	5.9	0.1	0.1	0.1	0.1	0	0.1	10.5	9.8	4.6
1995	1.8	8.6	7	1	5	0.1	0	0.1	0	2.9	3.9	2.2
1996	3.2	9.7	11.2	0.1	0.1	0.1	0	0	0.5	12.6	7.2	5
1997	7.3	3.8	3.6	1.3	0.1	0	0	0	0	12.4	2.6	5.8
1998	3.2	6.3	8.1	0.1	1	0	0	0	0.8	1.6	4.7	7.4
1999	6.6	0.9	2.4	0.3	8.4	0	0	0	1.7	8.6	10.1	8.8
2000	3.9	0.2	4.69	1.54	1.62	0	0	0	4.3	7.9	2	6.09
2001	5	8.8	0.5	6	1.83	0	0	0	2.41	8.54	9.47	6.16
2002	4.66	4.9	3.26	2.18	3.21	0	0	0	2.14	6.72	7.03	6.16
2003	5.88	4.92	3.26	2.18	2.65	0	0	0	7.3	2.9	7.03	6.16
2004	5.88	6.9	3.26	2.18	1.93	0	0	0	4.7	6.72	7.03	6.16

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2005	5.88	4.92	3.26	2.18	3.78	0	0	0	2.14	6.72	7.03	6.16
2006	5.88	4.92	3.26	2.18	2.67	0	0	0	2.14	6.72	7.03	6.16
2007	5.88	4.92	3.26	2.18	3.94	0	0	0	0	3.2	10.6	9.4
2008	5.5	4	2.1	2.18	3.96	0	0	0	0	6.72	11.6	6.16
2009	6.4	3.8	5.7	0.5	3.28	0	0	0	0.4	12.5	17.3	2.8
2010	5.88	3.7	2.1	0.5	0	0	0	0	2.4	8.1	11.6	8.1
2011	6.2	22	0.1	2	3.2	0	0	0	0.1	3.1	15.4	7.6
2012	4.2	4.9	5.2	0.4	1.6	0	0.1	0	0.1	9.1	14.3	6.6
2013	5.88	2.3	3	5.3	11.6	0	0	0	4.1	3.3	7.03	11.9