RELATIONSHIPS BETWEEN VARVE THICKNESS AND CLIMATIC PARAMETERS AND PALEOCLIMATIC RECONSTRUCTION

by

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ABSTRACT

Varve thickness in Skilak Lake, Alaska is correlated with mean annual temperature (r^2=0.74) and inversely correlated mean annual cumulative snowfall (r^2=0.92) in the southern Alaska climatological division but not correlated with the mean annual precipitation (r^2=0.17) of this division. Varve thickness in Skilak Lake is sensitive to annual temperature and snowfall because Skilak Glacier, the dominant source of sediment for Skilak Lake, is sensitive to these climatic parameters. Varve thickness is also correlated with annual temperatures of the northern Alaska climatological division (r^2=0.75), State of California (r^2=0.41), State of Hawaii (r^2=0.46), western climatological division of Oregon (r^2=0.47), and the cities of Seattle (r^2=0.59) and North Head (r^2=0.68), Washington; and Eureka, California (r^2=0.41). The correlation between varve thickness and annual temperature in these locations probably results from annual variations in the mean position and intensity of the semipermanent pressure systems of the North Pacific.

Reconstructions of trends of annual snowfall in the southern Alaska climatological division and annual temperature in the southern and northern climatological divisions of Alaska and the cities of Seattle and North Head, Washington were made and for the years 1700-1906. These reconstructions are based on varve thickness in Skilak Lake and utilise the equations derived from the regression of varve thickness on the historic climatological data. These reconstructions suggest that annual snowfall in the southern Alaska climatological division during the 1700's and 1800's was much greater than that of the early and mid-1900's. Two periods, 1770-90 and 1890-1906, show a marked decrease in annual snowfall. Reconstructed trends of annual temperatures for the northern and southern climatological divisions of Alaska and the cities of Seattle and North Head suggest that annual temperatures during the 1700 and 1800's were cooler than those of the early and mid-1900's. Two periods of relatively warm annual temperatures coincide with the periods of low annual snowfall that occured during these years. Reconstructions of annual snowfall and annual temperature based on glacial fluctations or tree-ring data suggest that reconstructions of snowfall and temperature based on varve thickness are valid, at least for the State of Alaska.

INTRODUCTION

The annual nature of glacial varves is of interest as a tool for geochronology, and many studies have successfully used varve counts to date past geologic events (De Geer, 1912; Kuenen, 1951; Renberg, 1976; Tolonen, 1980). Because glaciolacustrine varves are a response to the melting cycle of glaciers and glacial lakes, climatic parameters influencing the melting cycles of glaciers and glacial lakes may be reflected in varve thickness. Thus, varve thickness may be a useful tool for paleoclimatic reconstruction.

Glaciolacustrine varve thickness is influenced primarily by the annual volume of sediment released into the lake and the proximity of the depositional site to the point of sediment influx. The decrease in the thickness of individual varves away from the point of sediment influx is well documented (Ashley, 1975; Agterberg and Banerjee, 1969; Sturm and Matter, 1980). Factors that influence the relationship between the annual volume of sediment released into the lake and the resulting varve thickness are not well documented, although annual stream discharge has been correlated to varve thickness (Gilbert, 1973; Granar, 1956).

Late spring snow-melt and glacial ablation are thought to be the dominant factors influencing annual stream discharge and resulting varve thickness (Gilbert, 1973). Because glacial ablation is sensitive to annual temperature and precipitation, varve thickness may be sensitive to these climatic parameters. We examine these possible relationships by comparing a series of varve thickness measurements to the complementary sequences of annual temperature, precipitation, and snowfall for the northern and southern Alaska climatological divisions. Correlations between varve thickness and recorded climatic data from Alaska suggest that temperature and snowfall are instrumental in the determination of varve thickness, consequentially these parameters may be determined from varve thickness measurements when recorded climatological data are lacking. These data are tested for regional significance with climatological data recorded from other Pacific Coast locations. Regression of varve thickness on these data yield fairly high coefficients of determination and these correlations are statistically siginificant. Utilising the relationships expressed by the regression equations, varve thicknesses are used to reconstruct trends of annual temperature and snowfall for select locations for the years 1700-1906.

SKILAK LAKE

Proglacial Skilak Lake is located on the Kenai Peninsula in south-central Alaska (fig. 1) in a moraine-dammed, glacially scoured basin (Karlstrom, 1964). The Skilak and Kenai Rivers flow into the lake at the east end and the Kenai River drains the lake on the west end (fig. 2). The lake is approximately 24 km long, as much as 7 km wide and encompasses an area of approximately 99 km^2. A submerged moraine rises over 120 m off the lake floor to separate the lake into two distinct basins (Rymer and Sims, 1976). The proximal basin, into which the deltas of Skilak and Kenai Rivers are built, has an area of approximately 67 km^2 and attains a depth of 183 m, whereas the distal basin, west of the submerged moraine, encompasses an area of approximately 32 km^2 and has a maximum depth of 92 m.

No quantitative data exist on the volume of sediment discharged into the lake by either the Skilak or Kenai Rivers. However, we believe most of the sediments discharged annually into Skilak Lake is transported by the Skilak

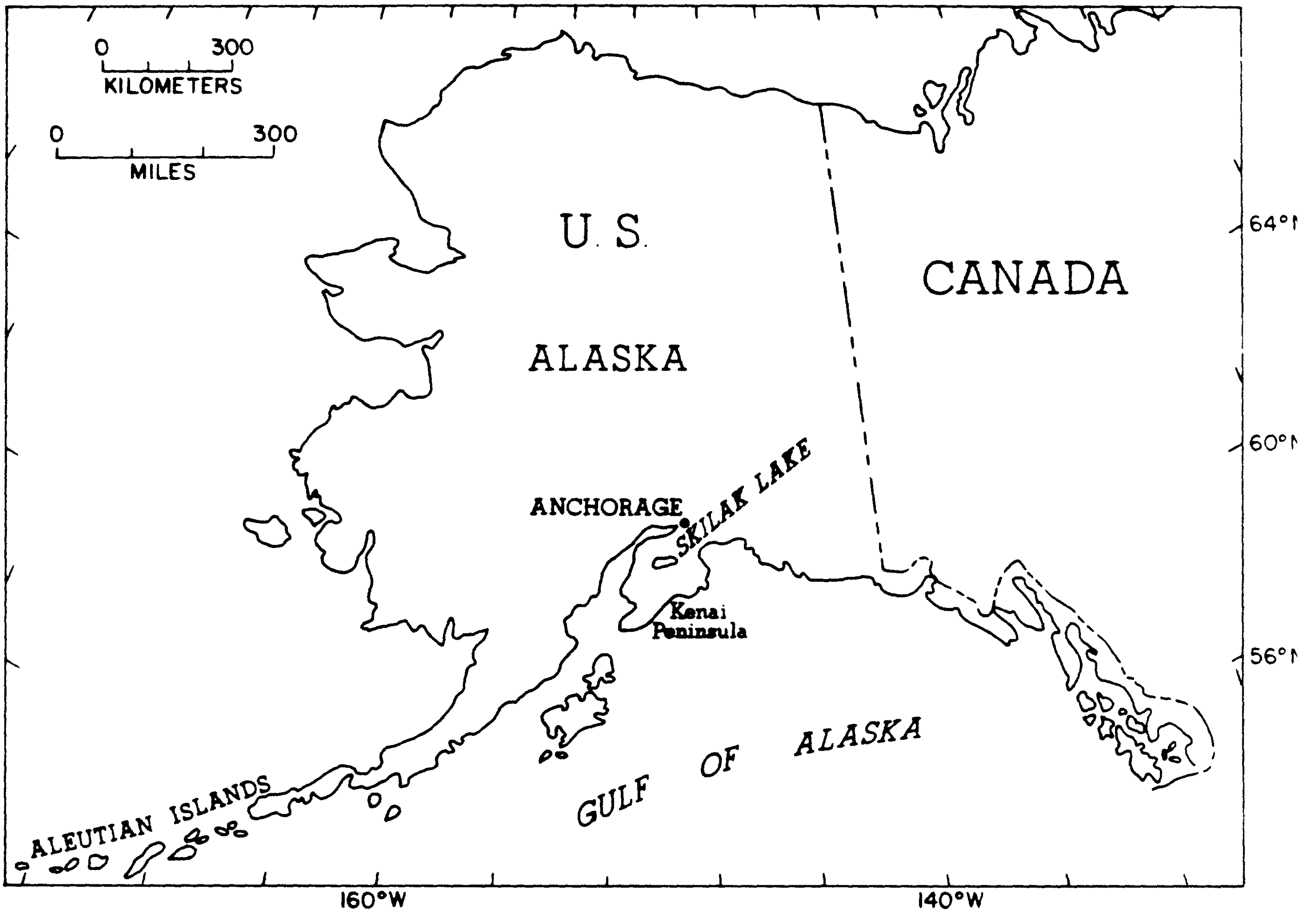

FIGURE 1. Map of Alaska showing the location of Skilak Lake and St. Augustine Volcano.

River. Skilak River flows along its valley train for 13 km from the terminus of Skilak Glacier to Skilak Lake with little addition of non-glacial sediment (fig. 2). Rivers that flow and deposit sediment along a valley train are extremely rich in glacial sediment and carry close to their maximum sediment capacity (Bloom, 1978; Flint, 1971). Black-and-white aerial photographs of the Skilak Lake area show the color tone of the Skilak River as white. This tone is due to the high albedo of the river produced by the high volume of suspended sediment. Aerial photographs show the tone of the Kenai River as dark grey, indicative of a river carrying a low volume of suspended sediment. The Kenai River, which drains Kenai Lake, is depleted in suspended sediment because Kenai Lake, and the smaller lakes in its drainage basin, trap most of the sediment that would have otherwise been transported to, and deposited in, Skilak Lake. Because no major streams enter the Kenai River between the two lakes, the Kenai River transports to Skilak Lake only the sediments which are entrained when the river is discharged from Kenai Lake. Thus, Skilak River is rich in glacially derived sediment whereas Kenai River is deficient in sediment.

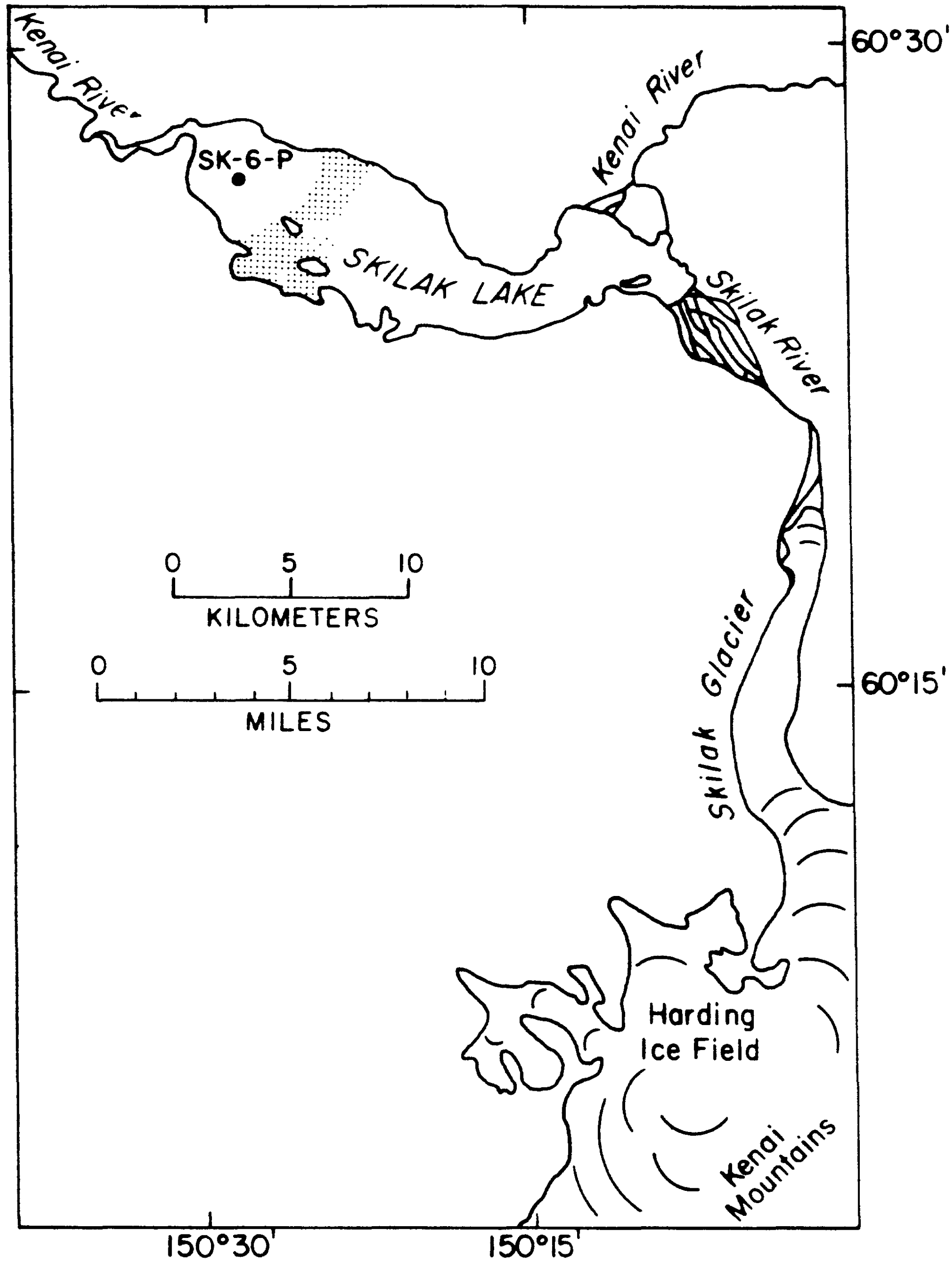

FIGURE 2. Map of the Skilak Lake area showing the locations of the coring cite of SK-6-P, the Skilak and Kenai Rivers, and the location of the Skilak Glacier. Stippled area represents the the submerged moraine which separates the two basins.

METHOD OF STUDY

In the summer of 1976, thirteen piston cores were retrieved from bottom sediments in Skilak Lake. Cores were obtained using a 2-m-long Kullenberg sampler with a removable rigid plastic core liner. After recovery the core liner with the contained core was removed and the end sealed to prevent dehydration.

The cores were extruded and cut to reveal varved lacustrine sediments which in some cores are interbedded with volcanic ash laminae. The hydrated condition of the cores prevented accurate detection and measurment of individual varves on the cut surfaces. However, desiccation of the cores was undesirable because of the differential shrinkage of individual varves. Thus x-ray radiographs were taken of a 1-cm-thick slice cut from the center of each core which yielded high resolution, dimensionally stable photographs of the undistorted varves.

X-ray radiographs of the center slice of the cores from the proximal basin of Skilak Lake show varves which are mainly composed of sequences of turbidites, many consisting of T_a through T_e Bouma sequences (Bouma, 1962). The thin T_e component in many of the turbidites resembles the winter component of a varve couplet, inhibiting individual varve recognition. Varves in this basin tend to be thick (about 1-2 cm), and the contacts of many of the varves are indistinct and locally show erosional contacts resulting from scars of superjacent turbidite units. The lack of accurate identification and measurments of the varves found in these cores prevented their use in this study.

X-ray radiographs of the center slice from the cores from the distal basin show thin (about 0.4 mm) varves that for the most part exhibit distinct contacts, because of a low sedimentation rate and lack of deposition from turbidity flows. Turbidity deposits do not occur because the submerged moraine separating the proximal and distal basins is a barrier that the turbidites, which originate at the deltas of the Skilak and Kenai Rivers, can not surmount. No streams of significant size enter the distal basin. Sediment deposited in this basin must be transported by lake currents from the deltas of the Skilak or Kenai River and passively settle out of the water column. This allows for the slow undisturbed accumulation of varve sediment in the distal basin. Identification and measurements of varves in the distal basin are reliable and we assume that the individual thicknesses are proportional to the annual volume of sediment released into the lake.

Core SK-6-P, recovered in the central region of the distal basin (fig. 2) exhibits good resolution on X-ray radiographs and is used as the basis for this study. The core is 1.92 m long and contains varved sediment interbedded with four recognizable volcanic ash laminae. The volcanic ash laminae occur at depths of 13.0, 90.5, 116.5, and 155.5 cm. Varves found in this core range in size from 1.4 to 9.6 mm and generally fall into groups I and IIa of the varve classification of Ashley (1975). In group I varves the winter clay thickness is greater than the summer silt thickness. In group IIa varves the winter clay couplet is approximately equal in thickness to the summer silt couplet. Radiographs of core SK-6-P show that the upper 10 cm and lower 27 cm of the core are disrupted. The disruption probably occurred as the coring device was being extracted from the lake bottom. Because the upper 10 cm of this core is disrupted, varve counts do not originate at the top of the core. Although the upper 10 cm of the core exhibits considerable disruption, 20 individual varves are recognized in this interval. However, the deformation renders these varves useless for varve thickness measurements. Varve counts indicate that the youngest ash found in the core was deposited prior to 1956. The most recent volcanic ash deposits (as of 1975) found in cores from Skilak Lake were deposited in 1935 and 1963 (Rymer and Sims, 1976) by the eruptions of St. Augustine Volcano (fig. 1). Saint Augustine Volcano erupted in January of 1976 (Hobbs and others, 1977) and deposited ash in the vicinity of Skilak Lake. This 1976 ash was not present in any of the cores obtained in either basin during the summer of 1976. The youngest ash found in this core occupies the same stratigraphic position and is similar in morphology to the 1935 ash found in other cores recovered from this basin during 1975 by Rymer and Sims (1976). For these reasons we correlate the uppermost ash deposit in this core to the 1935 ash resulting from the eruption of St. Augistine Volcano, and use it as a datum from which varve counts originate.

Below the 1935 ash a continuous sequence of 237 varves was identified and the thickness of each measured. Measurement of varve thicknesses ceased where varve contacts became indistinct and measurements could not be made precisely. The series of varves measured for thickness represents the years 1698 through 1934. Some varves show gradational or undulating contacts. The thickness of such varves is taken as the average of several measurements across the varve. The number of measurements made across such varves varied depending on the amount of undulation and nature of the gradation. Some varves show local disruption due to the forceful penetration of the sampler. The measurement of these varves was made at the point of least disruption. The six varves found between the 1935 ash and the lowest portion of the upper disruption were not measured. All measurments were made to the nearest 0.2 mm from radiographs using a calibrated magnifying eyepiece.

CLIMATOLOGICAL DATA

Climatological data used in this study were recorded for locations around the eastern and northern North Pacific Ocean (fig. 3) and consist of mean annual temperature, mean annual cumulative precipitation, and mean annual cumulative snowfall. Recorded values for precipitation include rainfall and the water equivalent of snowfall. The length of the climatological data record varies from a minimum of 28 years for the Alaska data to a maximum of 62 years for the city of San Francisco. Climatological data for states and divisions within states, consist of the mean of all reporting stations within the defined area. The number of recording stations in each division or state varies from year to year with an almost continuous increase in the number of recording stations with time.

The Weather Bureau divides the State of Alaska into a northern and southern climatological division. The southern division consists of the Pacific Coast, southwestern and southeastern districts and the northern division consist of the remainder of the state (fig. 3). The southern division tends to reflect maritime conditions because most of the recording stations in this division are located along the coastal region of the Gulf of Alaska. The northern division consists mainly of inland recording stations and tends to reflect continental climatic conditions.

The states of Washington and Oregon are also subdivided into an western and eastern divisions. The boundary between the western and eastern divisions of Washington lies along the crest of the Cascade Range. The boundary between the western and eastern divisions of Oregon lies along the 121° W. meridian. The 121° W. meridian lies near the crest of the Cascade Range throughout Oregon. The western divisions in both state tend to reflect coastal climatic conditions.

COMPARISON OF VARVE THICKNESSES TO CLIMATOLOGICAL DATA

Prior to the comparsons of varve thickness to climatological data, all data sets were smoothed to reduce random and intra-annual variations within each data set. Smoothing was done using a computerized curve smoothing technique (moving average) with a five-point filter (Davis, 1973). As a result of this smoothing technique the end two terms on each end of the series are lost. Raw and smoothed data for all series used in this study are tabulated in the appendix.

Varve thicknesses were compared to climatological data using visual-graphic and linear regression analysis. Comparison graphs used in this study have years plotted along the abscissa, varve thickness plotted along the right ordinate and the specific climatic parameter along the left ordinate.

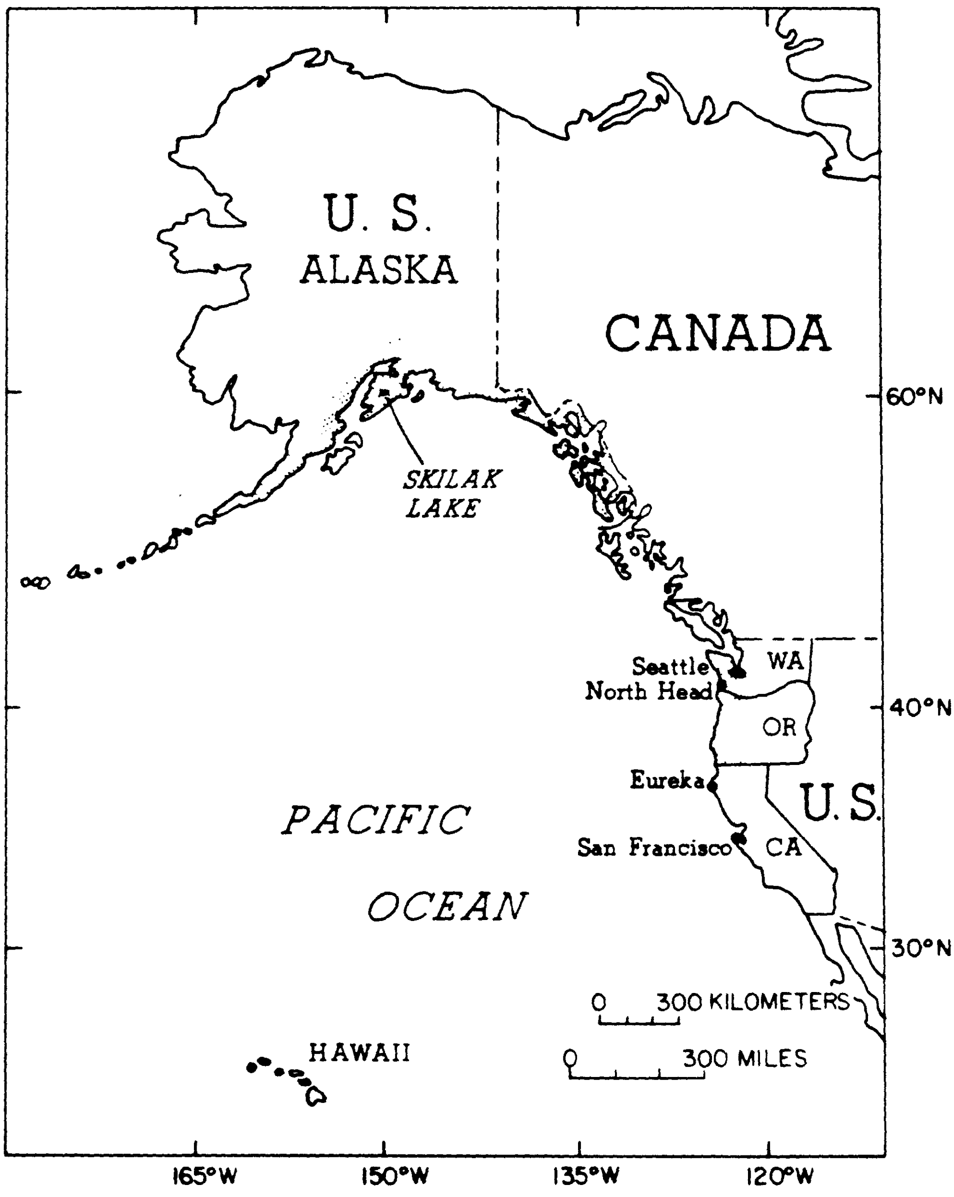

FIGURE 3. Map of the eastern and northern North Pacific showing the locations for which climatological data was compared to varve thickness. The stippled area in Alaska represents the southern Alaska climatological division, the northern climatological division consists of the remainder of the state. The stippled area in Oregon and Washington represents the western climatological divisions of these states.

A least squares linear regression analysis was performed for each comparison to determine the relationship between varve thickness and the specific climatic parameter in question. The coefficient of determination (r^2) was used to quantify the correlation between the two parameters. The r^2 value may be thought of as the percent of the variation found in the dependent variable (varve thickness) that is reflected in variation of the independent variable (climatological data). The type of relationship, direct or inverse, is expressed by either a positive (direct) or negative (inverse) value of the regression coefficient. A significance test, t-test (t-test = regression coefficient / standard deviation) was performed for each regression using a 99 percent confidence level. The regression equation obtained for each regression expresses the mathematical relationship between the two parameters.

Southern Alaska

Comparisons of varve thickness in Skilak Lake to mean annual temperature, cumulative snowfall, and cumulative precipitation in the southern Akaska climatological division indicates varve thickness is significantly correlated with temperature and snowfall and not correlated with precipitation. Visual-graphic comparisons of varve thickness to mean annual temperature, cumulative snowfall, and cumulative precipitation are shown in figure 4. Regression of varve thickness on mean annual temperature yield an r^2 value of 0.728 and this correlation is statistically significant at $t_\alpha = 0.01$. Regression of varve thickness on mean annual cumulative snowfall yields an r^2 value of 0.912 and this correlation is obviously significant. Regression of varve thickness on mean annual cumulative precipitation yield an r^2 value of 0.005 and this correlation is not significant at $t_\alpha = 0.01$. Statistical data pertaining to these comparisons are tabulated in table 1.

Northern Alaska

Comparisions of varve thickness to mean annual temperature and mean annual cumulative snowfall in the northern Alaska climatological division indicates varve thickness is significantly correlated with temperature and not correlated with snowfall in this division. Varve thickness was not compared to mean annual cumulative precipitation in this division because varve thickness is not significatly correlated with the mean annual cumulative precipitation of the southern Alaska climatological division. Visual-graphic comparisons of varve thickness to mean annual temperature and cumulative snowfall in this division are shown in figure 4. Regression of varve thickness on mean annual temperature yield an r^2 value of 0.749 and this correlation is significant at $t_\alpha = 0.01$. Regression of varve thickness on mean annual cumulative snowfall yields an r^2 value of 0.005 and this correlation is not significant at $t_\alpha = 0.01$. Statistical data pretaining to these correlations are tabulated in table 1.

Discussion of Southern and Northern Alaska Data

The high correlation of varve thickness with mean annual temperature in the southern Alaska climatological division shows that there is a direct relationship between mean annual temperature in the southern division and varve thickness in the Skilak Lake. Because annual stream discharge is correlated with varve thickness (Gilbert, 1973), the annual volume of sediment released into the lake is a major factor that influences varve thickness. At a fixed location within the lake, such as at core site of SK-6-P, annual

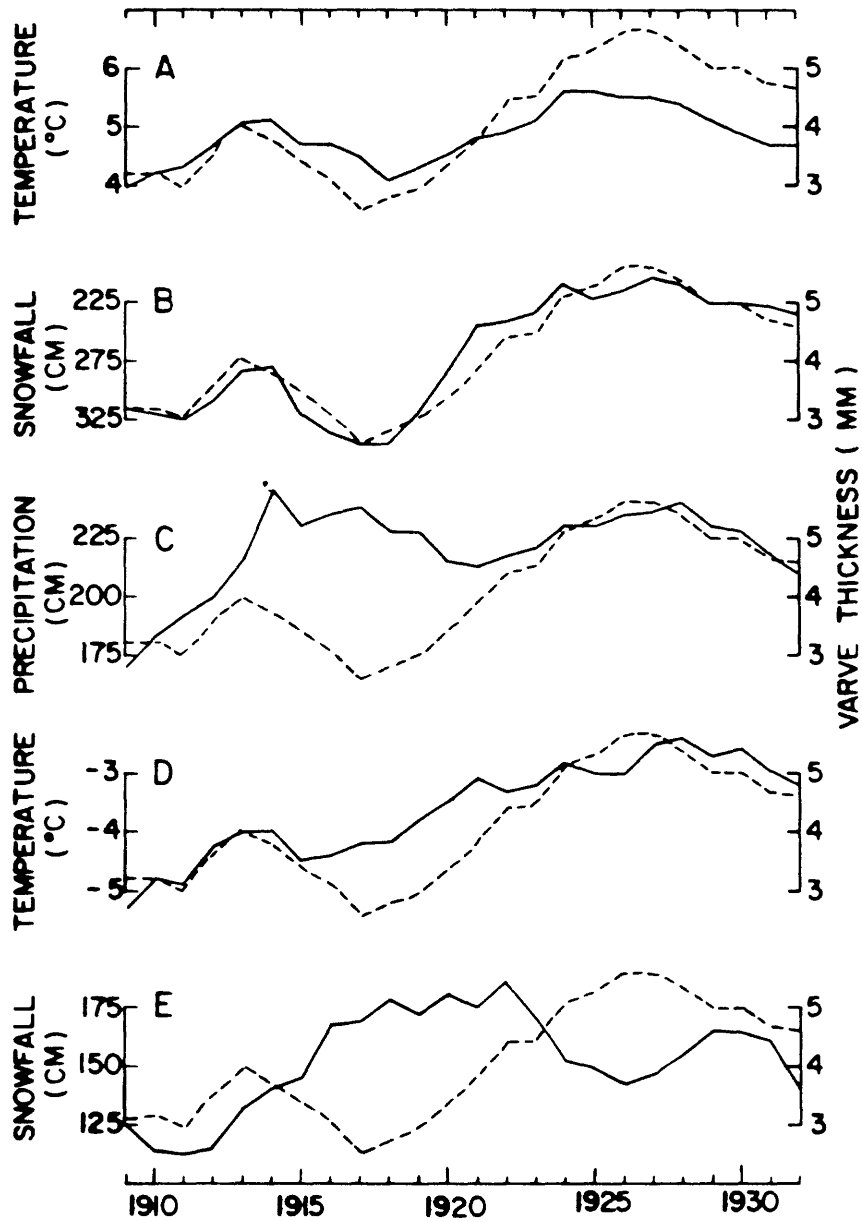

FIGURE 4. Plots of varve thickness (dashed line) relative to climatological data (solid line) for the southern and northern Alaska cliamtological divisions; (A) mean annual temperature, southern division; (B) mean annual cumulative snowfall, southern division; (C) mean annual cumulative precipitation, southern division; (D) mean annual temperature, northern division; (E) mean annual cumulative snowfall, northern division.

volume of sediment influx is the determinative factor influencing varve thickness. Because Skilak River carries the bulk of sediment transported annually to the lake, annual variation in this stream discharge should be reflected in varve thickness. The variations in the annual volume of sediment transported by the Skilak River are dominantly produced by variations in the annual ablation of Skilak Glacier.

TABLE 1. Statistical data pertaining to the comparisons of varve thickness to climatological data.

	COEFFICIENT OF DETERMINATION (r^2)	t VALUE	REGRESSION EQUATION	DEGREES OF FREEDOM
SOUTHERN ALASKA				
MEAN ANNUAL TEMPERATURE	0.728	7.68	$y = -4.15 + 1.71x$	22
MEAN ANNUAL CUMULATIVE PRECIPITATION	0.173	2.14	$y = -0.681 + 0.0218x$	22
MEAN ANNUAL CUMULATIVE SNOWFALL	0.912	-15.11	$y = 8.99 - 0.0181x$	22
NORTHERN ALASKA				
MEAN ANNUAL TEMPERATURE	0.749	8.11	$y = 7.68 + 0.990x$	22
MEAN ANNUAL CUMULATIVE SNOWFALL	0.005	0.34	$y = 3.61 + 0.0032x$	22
MEAN ANNUAL TEMPERATURES OF WASHINGTON STATE	0.085	1.91	$y = -6.07 + 1.12x$	39
MEAN ANNUAL TEMPERATURES OF WESTERN WASH.	0.023	0.95	$y = 0.0234 + 0.0463x$	39
MEAN ANNUAL TEMPERATURES OF SEATTLE, WASH.	0.594	7.36	$y = -20.4 + 2.30x$	37
MEAN ANNUAL TEMPERATURES OF NORTH HEAD, WASH.	0.670	9.12	$y = -15.3 + 1.96x$	41
MEAN ANNUAL TEMPERATURES OF OREGON	0.194	3.07	$y = 9.05 + 1.49x$	39
MEAN ANNUAL TEMPERATURES OF WESTERN OREGON	0.474	5.93	$y = 23.2 + 2.55x$	39
MEAN ANNUAL TEMPERATURES OF CALIFORNIA	0.413	4.74	$y = 22.6 + 1.81x$	32
MEAN ANNUAL TEMPERATURES OF EUREKA, CALIF.	0.390	5.18	$y = -18.1 + 2.07x$	42
MEAN ANNUAL TEMPERATURES OF SAN FRANCISCO	0.000	0.01	$y = 4.45 + 0.0017x$	57
MEAN ANNUAL TEMPERATURES OF HAWAII	0.461	4.53	$y = -47.1 + 2.32x$	24

Glacial ablation is sensitive to variations in temperature (Heusser, 1957; Hubley, 1956; LaChapelle, 1965; Mathews, 1951; Tangborn, 1980). Ambient temperatures at Skilak Glacier actually determine the annual ablation of Skilak Glacier. However, ambient temperatures are not recorded for Skilak Glacier and thus regional temperatures are used to represent the thermal effects on the glacier.

Annual temperature may affect the ablation of Skilak Glacier by influencing both the duration and rate of ablation. During a warm year ablation will begin earlier and terminate later than during an average year. A warm year will also produce an increase in the rate of ablation. This increases the annual volume of sediment released by the Skilak Glacier and increases the volume of water discharged from the glacier which increases the competence of Skilak River. Both of these factors increase the volume of sediment transported to, and deposited in, Skilak Lake, to produce a relatively thick varve. The converse would happen during a cool year as compared to the average year.

Varve thickness is also highly correlated with annual temperature in the northern Alaska climatological division. Because trends in the annual temperatures in the northern and southern climatological divisions are similar (fig. 4A and 4D) and correlated with each other, varve thickness is expected to be similar. Annual temperatures in both divisions are about equally correlated with varve thickness in Skilak Lake suggesting, varve thickness is sensitive to the parameters which control temperature fluctations over this large geographic area.

Varve thickness is highly correlated with mean annual cumulative snowfall in the southern Alaska climatological division, with varve thickness decreasing with increased snowfall. Although no recorded snowfall data exist for the Skilak Lake area the snowfall in this area is probably consistent with the snowfall of the southern division. A possible explanation for this correlation is that fresh snow increases the albedo of the glacier surface thereby insulating the sediment-rich glacial ice from incident solar radiation. Incident solar radiation seems to be extremely influential in determining glacial ablation (Dorrer and Wendler, 1976; Tangborn, 1980; Wendler and Weller, 1974). The albedo of fresh snow, prior to the ablation season, can be as high as 80 percent (Wendler and Weller, 1974), whereas the albedo of glacial ice is about 30 percent (Wendler and Ishikawa, 1973). The blanket of clean snow deposited in winter and early spring increases the albedo of the glacier surface and inhibits melting of the sediment-rich glacial ice during the spring. Abundant snowfall during winter and early spring may delay the melting of the sediment-rich glacial ice significantly, thereby decreasing the annual volume of sediment transported to, and deposited in, Skilak Lake, to produce a decrease in varve thickness. Increase in the albedo of the glacial surface also produces a decrease in the volume of water discharged from the glacier during early spring which in turn would decrease the competence of the Skilak River, contributing to the decrease in sediment influx to Skilak Lake. The converse would result from decreased snowfall during winter and early spring. Possible contributing factors for the strong correlation between varve thickness and annual snowfall are that abundant snowfall during winter and early spring is indicative of a decrease in the annual ablation of Skilak Glacier, probably caused by cool mean annual temperature, cool winds, and an increase in cloud cover. Insufficent data exist at present to determine the details of the relationship between varve thickness in Skilak Lake and the mean annual cummulative snowfall in the southern climatological division.

Varve thickness at Skilak Lake is not sensitive to snowfall in the northern Alaska climatological division. Annual snowfall in the two climatological divisions is quite different for the period 1907-1934 (fig. 4B and 4E) so varve thickness can not be highly correlated with snowfall in both divisions. A possible reason of the lack of correlation between varve thickness and annual snowfall in the northern division is that a dense cold air mass is usually situated over inland Alaska during the winter. This cold air mass tapers toward the north and acts like a shield causing storm systems, approaching from the south and southwest, to rise above the dense cold air mass. During the ascent of these moisture-laden storm systems, a critical altitude is reached and precipitation occurs in the form of snowfall. The altitude at which snowfall occurs varies depending upon characteristics of the incoming storm system. The distance inland at which snowfall occurs is then a function of the altitude at which snowfall occurs, the higher the altitude the further inland snowfall will originate. Thus, snowfall during winter in the northern division is localized, variable, and not consistent with that in the southern division. This may explain why varve thickness is correlative only with the annual snowfall of the southern division, a relatively small geographic area encompassing only about 0.25 x 10^6 km^2 with a strong maritime climatic influence.

Varve thickness in Skilak Lake has no significant correlation with the mean annual cumulative precipitation in the southern Alaska climatological division. In part this may be attributed to the fact that precipitation seems to play a subordinate role in the ablation of most glaciers (Flint, 1971) and hence may not be reflected in varve thickness. However, precipitation is known to be the primary climatic parameter responsible for the ablation of some glaciers (Lamb and others, 1965). The lack of correlation between varve thickness and precipitation may result from the ambient precipitation of Skilak Lake not being representative of the southern region. The fact that annual snowfall is highly correlative with varve thickness makes it unlikely that the precipitation in the Skilak Lake area is not representative of the southern region. The lack of correlation between varve thickness and precipitation probably occurs because precipitation has a minor affect on the ablation of Skilak Glacier. This hypothesis can not be confirmed at present because precipitation in the Skilak Lake area can not be compared to the regional data, owing to the absence of precipitation data for the Skilak Lake area.

Geographic Extent to Which Varve Thickness is Correlated with Annual Temperature

To determine if varve thickness in Skilak Lake correlates with annual temperature in locations outside of Alaska, varve thickness is compared to the mean annual temperatures in the states of California, Hawaii, Oregon, and Washington. Varve thickness is also compared to the mean annual temperatures in the western climatological divisions of the states of Oregon and Washington and the cities of Seattle and North Head, Washington and Eureka and San Francisco, California.

Visual-graphic (fig. 5) and regression analysis (table 1) indicate that varve thickness in Skilak Lake has a significant correlation to the mean annual temperatures of Hawaii (r^2=0.39), California (r^2=0.41), Oregon (r^2=0.19), the western division of Oregon (r^2=0.47), Seattle (r^2=0.59), North Head (r^2=0.67), and Eureka (r^2=0.39). Varve thickness is not significantly correlated with mean annual temperatures of the the State of

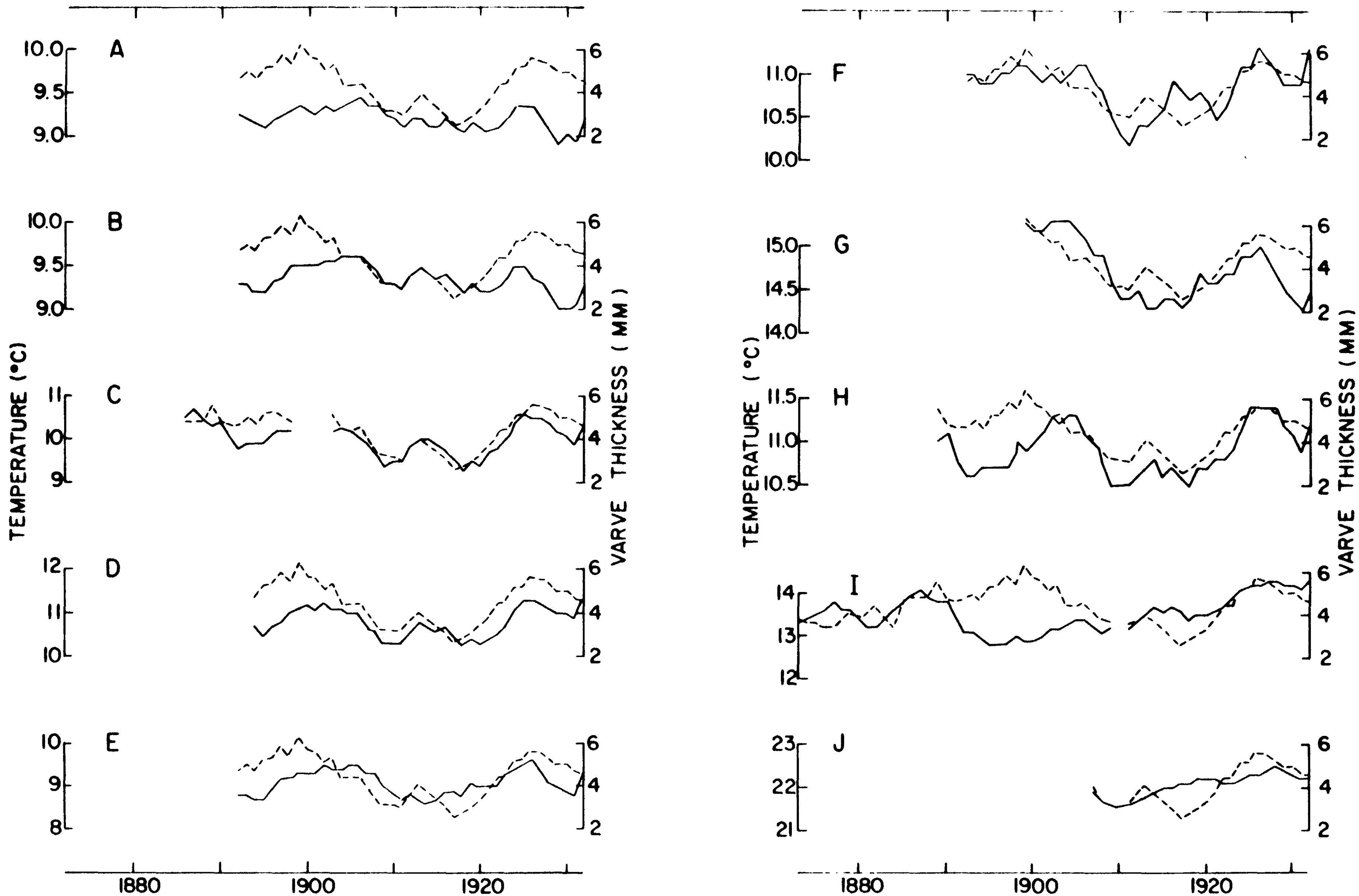

FIGURE 5. Plots of varve thickness (dashed lines) relative to the annual temperatures (solid lines) of, the State of Washington (A), the western division of Washington (B), North Head (C), Seattle (D), the State of Oregon (E), the western division of Oregon (F), the State of California (G), Eureka (H) San Francisco (I), and the State of Hawaii (J).

Washington (r^2=0.085), the western climatological division of Washington (r^2=0.023), and the city of San Francisco (r^2=0.00).

Varve thickness in Skilak Lake is correlated with mean annual temperature throughout much of the eastern and northern North Pacific region. Varve thickness tends to exhibit a significantly stronger correlation with the annual temperatures of the western climatological division of Oregon than to the state as a whole. This suggests that varve thickness in this region is more sensitive to the annual temperatures of coastal locations as compared to those more inland. To test this hypothesis varve thickness is compared to the annual temperatures of locations along the coast of Washington and California. No continuous temperature records are available for coastal Oregon. Varve thicknes is compared to the annual temperatures recorded in the cities of Seattle and North Head, Washington and Eureka and San Francisco, California. Visual-graphic (fig. 6.) and regression analysis (table 1) indicate varve thickness is significantly correlated with the annual temperatures of the cities of Seattle (r^2=0.594), North Head (r^2=0.670), and Eureka (r^2=0.390) and not significantly correlated with the annual temperatures of San Francisco (r^2=0.000). Because the annual temperatures of most of these coastal cities exhibit as strong, or stronger correlation with varve thickness as their more regional inland counterparts (the states of California and Oregon), which reflect a more conteninta1 climate. This tends to support the hypothesis that varve thickness exhibits a stronger correlation with the Pacific Coast region than with the more inland regions exhibiting a more comtinental climate, at least between San Francisco and Seattle.

Variations in the annual temperatures of the state of Alaska, California, Hawaii, and Oregon seem to be synchronous, because they are all are linearly correlated with varve thickness. The synchronous variations of annual temperature of these locations suggest that the mechanism responsible for such variations is active over an extremely large geographic area (an area greater than 15 x 10^6 km^2). Whatever mechanism is responsible for the correlation between varve thickness and annual temperatures the effect of it on annual temperature decreases with increasing distance from Alaska, as suggested by the decrease in the value of r^2 with increasing distance from Alaska, and a decrease with increasing distance inland for the states of Oregon and Washington.

Variations in the annual temperatures of the northern and southern climatological divisions of Alaska, California, Hawaii, the western climatological division of Oregon, and the cities of Seattle and North Head probably result from variations in the general atmospheric circulaton pattern over the North Pacific. Surficial expression of the general circulation pattern over the North Pacific is reflected in the position and intensity of two large pressure systems over the North Pacific Ocean, the Aleutian low and the eastern Pacific high. Winter is generally characterized by the presence of the Aleutian low over the northern North Pacific (mean location about lat. 50°N, long. 180°W) and the eastern Pacific high located off the coast of Baja California (mean location about lot. 30°N, long. 135°W). Summer is generally characterized by the absence of the Aleutian low over the North Pacific and the northward migration and intensification of the eastern Pacific high. The northward migration of the eastern Pacific high culminates with it centered at about 40°N latitude, 135° W longitude. Mean pressure patterns during January and July typify pressure patterns during winter and summer, respectively (fig. 6). Unstable conditions characterize the transition between winter and summer conditions and give rise to all sorts of

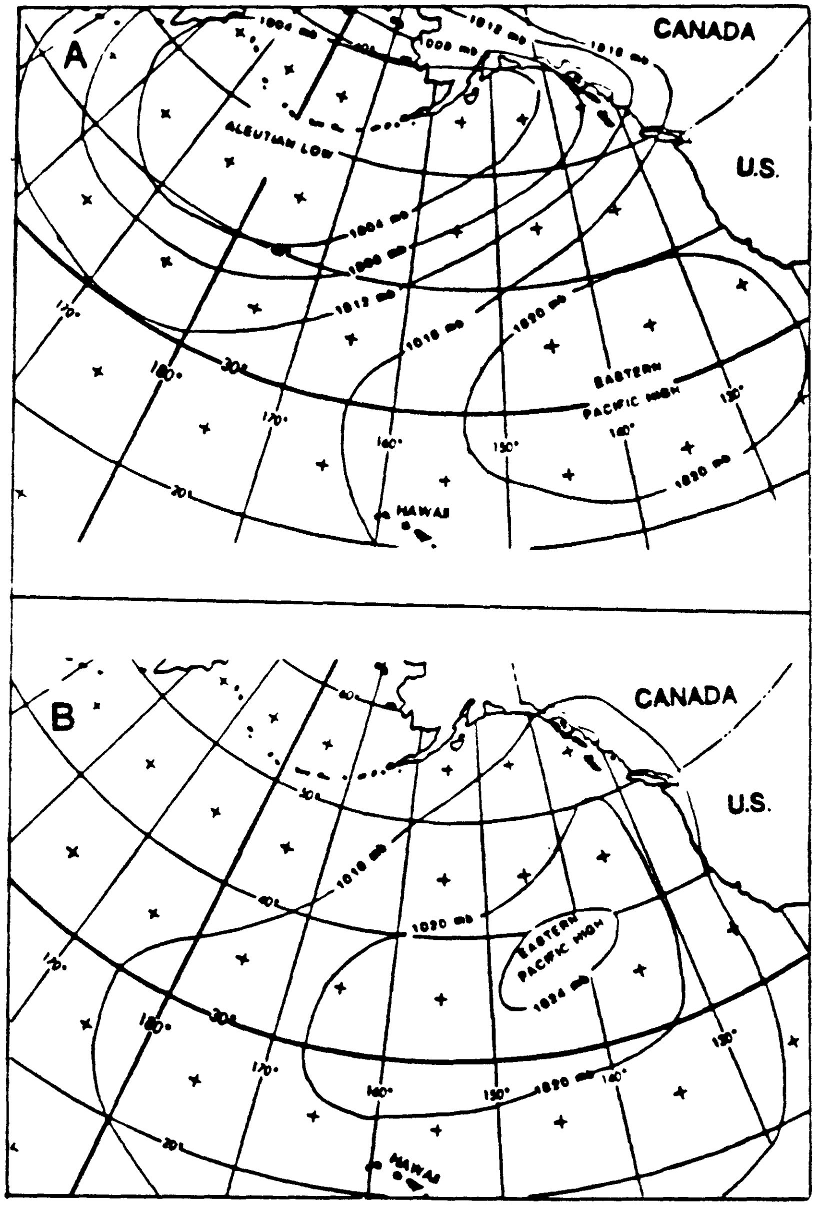

FIGURE 6. Map showing the mean position of the Aleutian low and eastern Pacific high during January (A) and July (B) which typify pressure patterns during winter and summer, respectively (modified from Miller and Thompson, 1979).

singularities in the atmospheric circulation. These high and low pressure systems are not discrete entities because atmospheric pressure varies continuously and these pressure systems build, move, and decay.

In general, a cooler than average year is characterized by an intensification and eastward expansion of the Aleutian low and a more southerly location and weakening of the mean position of the eastern Pacific high during winter. The Aleutian low persists in the North Pacific for a longer period of time during the spring and reforms earlier in the fall.

Summer is characterized by a decrease in the intensity and northward migration of the eastern Pacific high. Conversely, the winter of a warmer than average year is generally characterized by a decrease in the intensity of the Aleutian low and an increase in the intensity of the Pacific high, located further north than during the average winter. The Aleutian low dissipates from the North Pacific earlier and reforms later than in an average year. The Pacific high migrates further north during the summer of a warmer than average year. Thus, variations in the general atmospheric circulation pattern over the North Pacific, as reflected in the positions and intensities of the Aleutian low and eastern Pacific high pressure systems, is probably responsibile for the synchronous variations of the annual temperatures of locations that correlate well with varve thickness.

A strong Aleutian low and corrosponding weak eastern Pacific high favors glacier growth in the Kenai Mountains (Fahl, 1975). Conversely a weak Aleutian low, implying a strong eastern Pacific high, favors glacier decay. Annual temperatures generally decrease during periods of glacier growth and increase during periods of glacier decay. However, the precise relationships between barometric pressue, annual temperature, and glacial variations are inadequately known.

If variations in the relative positions and intensities of the Aleutian low and eastern Pacific high are responsible for the synchronous variations in the annual temperatures of the locations correlative with varve thickness, then the annual temperatures of locations strongly influenced by these pressure systems are probably correlative with varve thickness also. However, further comparisons of varve thickness in core SK-6-P to the annual temperatures of locations around the eastern and northern north Pacific can not be done, owing to the lack of climatological data for the late 1800's and early 1900's.

RECONSTRUCTION OF MEAN ANNUAL TEMPERATURE AND CUMULATIVE SNOWFALL BASED ON VARVE THICKNESS

Varve thickness in Skilak Lake correlates well with annual snowfall in the southern Alaska climatological division and with annual temperature in both the northern and southern climatological divisions of Alaska, California, Hawaii, Oregon, the western climatological division of Oregon, along with the cities of Seattle, North Head, and Eureka. Correlation between varve thickness and annual temperature and snowfall which yield r^2 values greater than 0.5 are sufficiently strong for varve thickness to be used to reconstruct trends of annual temperature and snowfall. Reconstructions based on correlations which exhibit r^2 values of less than 0.5 are not warranted. Regression analysis yields a mathematical expression for each of the comparisons (table 1) and quantitatively determines to what extent the parameters are correlative. The regression equations for each location utilize all the available climatological data for that specific location. Thus, regression equations that utilize the longer spans of time are inherently more precise and probably more accurate in reflecting the relationships between varve thickness and these climatic parameters. By solving the regression equation for snowfall or temperature (x), a known varve thickness value (y) may be used to reconstruct the snowfall or temperature for a given year. The modified regression equations are shown in table 2. Varves formed between 1698 and 1908 in core SK-6-P (as determined by varve counts) are used for the reconstructions. The resulting smoothed series spans the

TABLE 2. Modified regression equations used in the reconstruction of annual temperature and snowfall.

LOCATION	EQUATION
	SNOWFALL
SOUTHERN ALASKA	x = (8.99 - y) / 0.0181
	TEMPERATURE
SOUTHERN ALASKA	x = (y + 4.15) / 1.71
NORTHERN ALASKA	x = (y - 7.68) / 0.990
SEATTLE, WASSINGTON	x = (y + 6.07) / 1.12
NORTH HEAD, WASHINGTON	x = (y + 15.3) / 1.96

period 1700 through 1906, using the aforementioned curve smoothing techinque with a five point filter. The values of the reconstructed climatic parameters are given in the appendix.

Reconstruction trends of mean annual cumulative snowfall in the southern Alaska climatological division shows two periods of decreased annual snowfall which occured during the years 1770-90 and 1880-1906 (fig. 7). The latter period is longer in duration and more intense. Periods of extremely abundant snowfall are absent, and most of the annual snowfall values range between 300 and 400 cm. The reconstruction suggests that for the most part the 1700's and 1800's had significantly greater snowfall than that of the early and mid-1900's.

Reconstruction of the mean annual temperature trends in the southern and northern Alaska climatological divisions and the cities of Seattle and North Head, Washington are shown in figure 8. The trends of annual temperature for these locations are plotted on a single graph because the reconstructed annual temperatures in these locations are linearly related to varve thickness. Two periods of relatively high annual temperature occurred during the years 1770-90 and 1890-1906 (fig. 8). These two periods are consistent with periods of low annual snowfall (fig. 7). The inverse relationship between the reconstructed snowfall and temperature values is expected owing to the fact that both are linearly related to varve thickness but snowfall has a negative correlation to varve thickness whereas temperature has a positive correlation. For the most part temperatures during the 1700's and 1800's were cooler than those of the early and mid-1900's. The reconstructed values are valid only for the specific location. However, because the reconstructed trends of annual temperature at each location are approximately synchronous, trends representative of intermediate locations are expected to be similar.

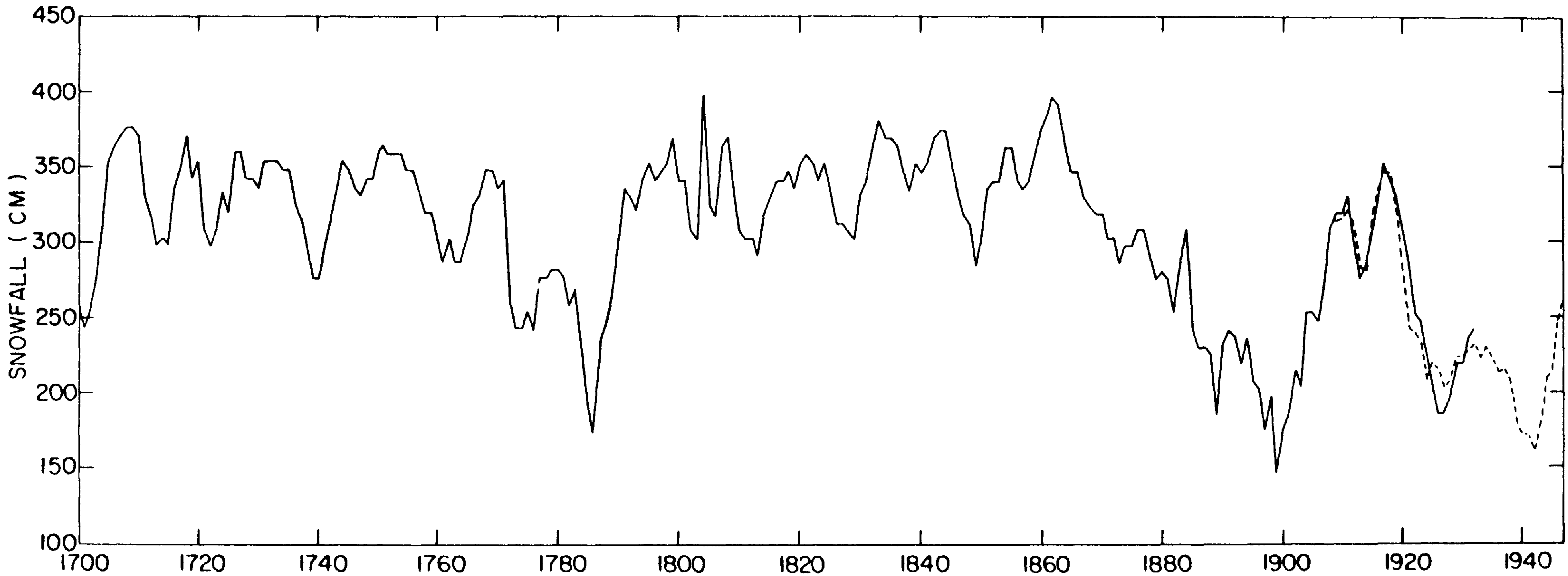

FIGURE 7. Reconstruction of trends of annual cumulative snowfall of the southern Alaska climatological division based on varve thickness. Solid line represents trends of annual snowfall as determined from varve thickness and the dashed line represents recorded trends of annual snowfall of the southern Alaska climatological division.

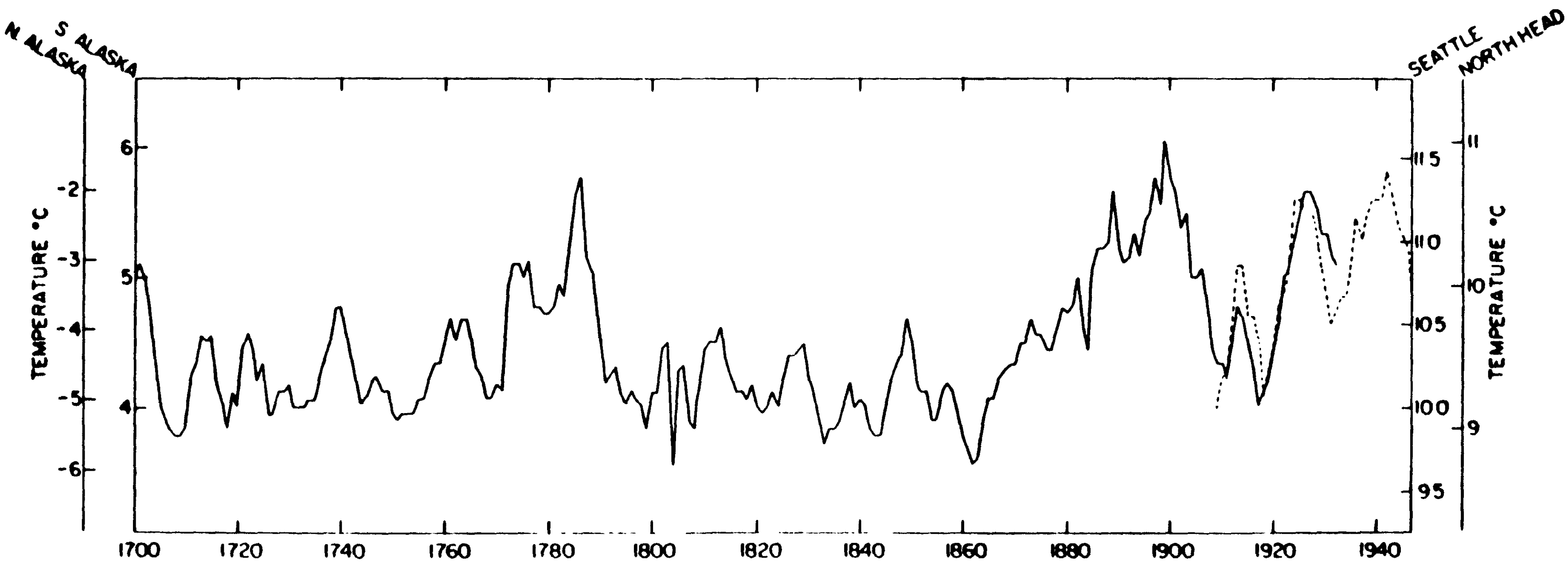

FIGURE 8. Reconstructions of trends of annual temperature in the northern and southern Alaska climatological divisions and the cities of Seattle and North Head, Washington. Solid line represents the reconstructed temperature trends and the dashed line represents the recorded temperature trends of the southern Alaska climatological division.

The reconstructed trends of annual temperature are also valid to a lesser degree for California, Hawaii, and the western climatological division of Oregon because the annual temperature in these locations are also correlated with varve thickness (r^2 values 0.39-0.47).

An independent check on the accuracy of the reconstructions is desiable. Fluctuations of glaciers may be used as an indirect means for estimating annual snowfall and temperature. Glaciers generally respond to climatic fluctuations with advance occurring during periods of abundant annual snowfall and cool annual temperatures, and retreat occurring during periods of decreased annual snowfall and warm annual temperatures. The size of a glacier is a major factor in determining its response time to annual snowfall and temperature. Small glaciers are generally more sensitive to variations in short term fluctuations of annual snowfall and temperature while large glaciers are generally more sensitive to long term fluctuations.

Alaska is the only location included in the study for which fluctuations of glaciers have been determined and can be used as a check on the reconstructed snowfall and temperature. The Lemon Creek Glacier, located in the Coastal mountains of southeastern Alaska, has gone through five major fluctations during the years 1700-1906: 1) The Lemon Creek Glacier attained a maximum during the 1750's and presumably was advancing during the early 1700's.; 2) After about 1759 continuous recession occured until about 1820.; 3) The period 1819-91 is marked by chaotic moraines, suggesting periodic decreases in the recession rate.; 4) During the period 1891-1902 the recession rate increased nearly 20 fold.; 5) After 1902 the recession rate decreased to roughly to that of the pre-1890's (Heusser and Marcus, 1964).

Glaciers eminating from the Juneau Ice Field show a similarity to the well studied Lemon Creek Glacier. These glaciers reached a maximum in the early to mid-1700's, and were actively retreating by 1765 (Lawrence, 1950). Recessional moraines at two of the most studied glaciers, Herbert and Mendenhall Glaciers, indicate readvances sometime during the period 1835-61 and 1832-65 respectively. Herbert Glacier experienced a period of rapid recession between 1871 and 1910 (Heusser and Marcus, 1964). Two moraines dated at 1883-85 and 1901-03 are present for the Mendenhall Glacier and bracket this period of rapid recession.

The glaciers of Glacier Bay began retreating sometime between 1735 and 1785 (Cooper, 1935) . These glaciers are thought to have been advancing for at least several centuries prior to their maxima during the mid-1700's. In this region very rapid rates of recession also occured about 1900. For two of the larger glaciers, Muir and Grand Pacific Glaciers, this recession is well documented and dated at 1903-07 and 1899-1912 respectively.

General trends in the advance and retreat of the Lemon Creek Glacier and the glaciers of Glacier Bay and the Juneau Ice Field are approximately synchronous. Glaciers in all three locations were advancing during the early 1700's and had reached a maximum soon after the mid-1700's. Recession continued until about 1830, at which time some glaciers began to readvance whereas others decreased their rate of recession. This period of readvance or reduced recession lasted until about 1865 at which time recession was renewed or increased. Rapid recession took place from 1890 to about 1910. Post-1910 is characterized by modest recession rates, approximately that of the pre-1890's. During the early and mid-1900's most glaciers in Alaska were receding although some were advancing (Lawrence, 1950).

Assuming that glacial advance is indicative of abundant snowfall and cool annual temperatures and glacial retreat indicative of decreased annual snowfall and warm annual temperatures, five separate periods of climatic fluctuation may be inferred from the fluctuations of glaciers in Alaska. During the early and mid-1700's abundant annual snowfall and cool annual temperatures prevailed and probably produced glacier advances. Snowfall decreased and temperature increased to produce the glacial recessions that began about 1760. Recession continued until about 1830 when snowfall again increased and temperatures decreased to produce the readvance of some glaciers and the decrease in the recession rate of others. This period lasted until about 1865. The latter 1800's and earliest 1900's are characterized by a phenomenal increase in the recession rate indicating a drastic reduction in snowfall and increase in temperature. After this period snowfall again increased and temperatures decreased.

Trends of reconstructed snowfall and temperature (fig. 7 and 8) are in general agreement with the climatic history of Alaska based on fluctuations of glaciers. Abundant snowfall and cool temperatures of the early 1700's are consistent with glacial advance during this time. The period 1770 to 1790 when snowfall decreased and temperature increased is within ten about years of the of the average time in which glacial maximum and recession occured. Between 1790 and 1830, the abundant snowfall and cool temperature, indicated by figure 7 and 8, are opposite that suggested by glacial fluctuations. Between 1830 and 1860 snowfall increased and temperatures decreased, which is again consistent with glacial fluctuations (fig. 7 and 8). The period 1890-1902 was characterized by a drastic decrease in snowfall and very warm temperatures and is in good agreement with that suggested by glacial flucuations.

Trends of annual temperature in the State of Alaska during the 1800's have been determined based on tree-ring width (Blasing and Fritts, 1975). General trends of temperature are based on their reconstruction of air pressure anomalies for this region which suggest that cool annual temperatures persisted generally during the years 1804 through 1844. Between about 1845 and 1860 average to warm temperatures existed. Annual temperatures after 1860 were characterized by average to slightly above average temperatures. Average in this context refers to the period 1899-1966, which was used as a standard to which comparisons were made. The periods of cool temperatures (1804-1844) and average to slightly above average temperatures (1860-1906) are consistent with temperatures reconstructed by this study. The warm period between 1845 and 1860 is not reflected in the reconstruction of annual temperature based on varve thickness. During this period glacial advances were occuring at Mendenhall and Herbert Glaciers and the chaotic moraines found at the Lemon Creek Glacier. We interpret these data to suggest a cooler than average period.

In general the annual snowfall and temperature reconstructions of Alaska based on varve thickness are in agreement with reconstructions based on other sources. Verification of the annual temperature reconstructions for locations outside of Alaska can not be done, owing to the lack of climatological or inferred climatological data for these locations. Because the reconstructed values of annual snowfall and temperature of Alaska are in agreement with the data from other sources, we assume the reconstructed annual temperatures of the locations outside of Alaska are valid also. The correlations between annual temperature and varve thickness in Skilak Lake tends to decreasse with increasing distance from Alaska indicating accuracy and precision of the reconstructed values also decreases with increasing distance.

POSSIBLE SOURCES OF ERROR

Both random and systematic errors are present in correlating varve thickness to the three climatic parameters. The main random errors are: 1) A "varve" year varies slightly in length depending on seasonal climatic variations and is not coincident with a calendar year for which the climatological data are recorded. A "varve" year begins in spring when the lake thaws allowing a large influx of sediment to the lake and terminates when the lake thaws again in the following spring. 2) Significantly different varve thicknesses may be produced in years which have identical mean annual climatic data. Intra-annual perturbations of monthly climatic trends affect varve thickness differently, depending upon the part of the year in which they occur. For example a 4°C year consisting of a warmer than average winter and a cooler than average summer would produce a thinner varve than a 4°C year consisting of a cooler then average winter and a warmer than average winter. 3) Errors in varve identification and measurement probably have occured owing to the difficulity in distinguishing complex varves and the measurements of varves showing gradational contacts. 4) Smoothing of the data by the use of a moving average prior to the comparisons has introduced error. No attempt was made to compensate for this error in either the comparisons or the reconstructions. Visual-graphic comparison of the raw and smoothed varve thickness data is shown in figure 9. Quantative determination of this error can not be made owing to the lack of a datum to which varve counts can be compared. Systematic errors include 1) Undetected disruption of sediment during sampling or laboratory analysis. 2) Decreased reliability of the recorded climatic data with age owing to the lower number of recording stations. 3) Effects of compaction on the older varves that serves to reduce varve thickness. However, the compaction effects are probably negligible for core SK-6-P is less than 2 m long. To what extent these possible errors have influenced this study can not be ascertained.

SUMMARY

Varve thickness in Skilak Lake, Alaska is shown to correlate with mean annual temperature (r^2=0.73) and cumulative snowfall (r^2=0.92) and not correlate with the mean annual cumulative precipitation (r^2=0.17) in the southern Alaska climatological division. Annual temperature and snowfall in this division are reflected in varve thickness because the annual ablation of Skilak Glacier is sensitive to these climatic parameters. A relatively warm year produces an increase in the duration and rate of ablation of Skilak Glacier to produce an increase in the annual volume of sediment deposited in Skilak Lake, thereby producing a relatively thick varve. The converse happens during a relatively cool year. Varve thickness exhibits an inverse relationship to annual snowfall. This may be caused by snowfall increasing the albedo of the glacier surface therby inhibiting the melting of the sediment-rich glacial ice and also decreasing the volume of water discharged from Skilak Glacier which decreases the compentence of Skilak River. Both of these factors decrease the volume of sediment transported to, and discharged in, Skilak Lake, to produce a decrease in varve thickness. The converse would happen during years of decreased snowfall. Abundant snowfall may occur during years of cool annual temperature, cool winds, and increased cloud cover all of which contribute to a decrease in the annual ablation of Skilak Glacier and resulting varve thickness.

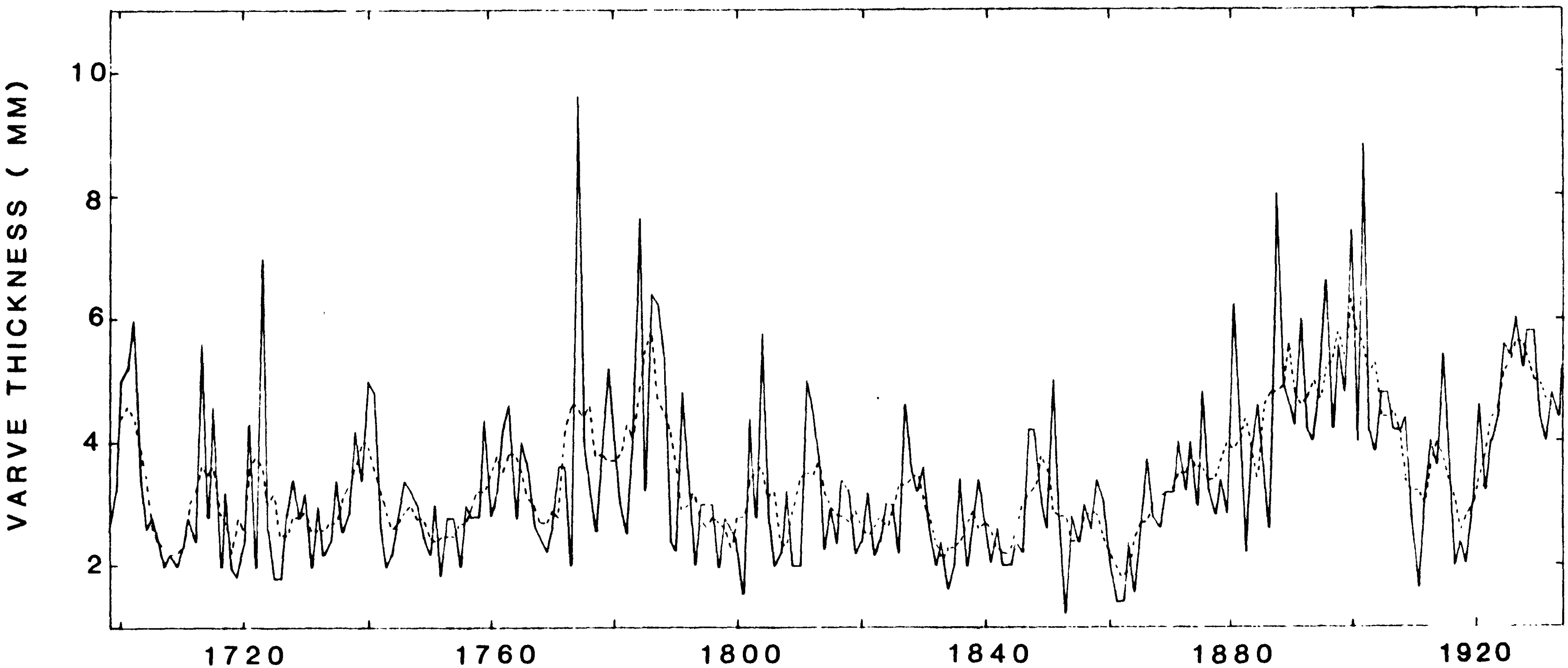

FIGURE 9. Plots of raw (solid line) varve thickness and smoothed (dashed line) varve thickness data.

Varve thickness in Skilak Lake is correlated with mean annual temperature (r^2=0.75) of the northern Alaska climatological division and not correlated with mean annual cumulative snowfall (r^2=0.005) in this division. Thus, varve thickness in Skilak Lake is sensitive to annual snowfall over a relatively small geographic area (the southern climatological division), but sensitive to annual temperature over a large geographic extent.

Futher comparisions of varve thickness to annual temperature indicate varve thickness is significantly correlated with the annual temperatures of California, Hawaii, the western climatological division of Oregon, and to the coastal cities of; Seattle and North Head, Washington; and Eureka, California, with r^2 values ranging from 0.39 to 0.68. The synchronous variations in annual temperature of these locations is probably the result of variations in the atomspheric circulation pattern over the North Pacific which is reflected by the the locations and intensities of the Aleutian low and eastern Pacific high.

The high correlations between varve thickness and mean annual cumulative snowfall (r^2=0.92) and mean annual temperature (r^2 values 0.59-0.75) enables varve thickness to be used to reconstruct of trends of annual snowfall and temperature. Varve thickness may be used to estimate the snowfall or temperature for the year in which it was formed as defined by the relationships expressed by the regression equations. Annual snowfall trends for the southern Alaska climatological division are reconstructed for the period 1700-1906. The reconstruction suggest that annual snowfall in this division during the 1700's and 1800's was significantly greater (300-400 cm) than during the early and mid-1900's (200-300 cm). Two periods, 1770-90 and 1890-1906, show a marked decrease in the annual snowfall in this division. Trends of the annual temperatures of the southern and northern climatological divisions of Alaska and the cities of Seattle and North Head, Washington are similar because varve thickness is linearly related to the annual temperatures of these locations. The reconstructions shows annual temperature of these locations during the 1700's and 1800's was generally cooler than that of the early and mid-1900's. Two periods, 1770-90 and 1890-1906, show a marked increase in annual temperatrue, corresponding to the periods of decreased annual snowfall in the southern Alaska climatological division. Because trends of annual temperature in these locations is probably the result of variations in the atmospheric circulation pattern over the North Pacific, these trends of annual temperature may be valid throughout the North Pacific. The reconstructed trends in annual temperature are probably valid for California, Hawaii, and the northern climatological division of Oregon because the annual temperature of these locations are correlated with varve thickness. The low r^2 values (<0.5) determined for these locations are not high enough to warrant reconstructions based on these regression equations.

Glacier fluctations and temperature reconstructions based on tree-ring data for Alaska suggest the reconstructions from the varve thickness data are valid. Futher comparisons of varve thickness to climatological data are necessary to determine details of these relationships.

Comparisons began with varves formed in 1934 because the upper portion of core SK-6-P is disturbed and the varves are distorted. This study suffers from the lack of comparisons of varve thickness to the climatological data from 1935 to present. Increasing the data base used in determining the standards from which the reconstructions are made will increase the accuracy and precision of these reconstructions. Additional cores from the distal basin of Skilak Lake, which lack disruption of varves should yield varve thickness measurements to which the climatological data from many locations can be compared. In addition, longer cores may greatly extend the reconstructions of annual temperature and snowfall.

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APPENDIX

Varve Thickness Measured in mm

YEAR	RAW	SMOOTHED	YEAR	RAW	SMOOTHED	YEAR	RAW	SMOOTHED	YEAR	RAW	SMOOTHED	YEAR	RAW	SMOOTHED	YEAR	RAW	SMOOTHED
1934	5.2																
	4.4																
	4.8	4.6															
	4.0	4.7															
1930	4.4	5.0	1890	4.2	4.8	1850	2.6	3.5	1810	2.0	3.4	1770	2.6	2.9	1730	3.2	2.9
	5.8	5.0		4.6	5.6		3.2	3.8		2.0	2.9		2.2	2.7		2.8	2.8
	5.8	5.4		5.0	4.9		4.2	3.3		3.2	2.3		2.4	2.7		3.4	2.8
	5.2	5.6		8.0	4.8		4.2	3.2		2.2	2.4		2.6	3.0		2.8	2.5
	6.0	5.6		2.6	4.8		2.2	3.0		2.0	3.2		3.6	3.1		1.8	2.5
1925	5.4	5.3	1885	3.6	4.6	1845	2.4	2.6	1805	2.8	3.1	1765	4.0	3.5	1725	1.8	3.2
	5.6	5.1		4.6	3.4		2.0	2.2		5.8	3.6		2.8	3.8		2.6	3.0
	4.4	4.5		4.0	3.8		2.0	2.2		2.8	3.5		4.6	3.8		7.0	3.6
	4.0	4.4		2.2	4.4		2.6	2.3		4.4	3.4		4.2	3.5		2.0	3.8
	3.2	3.8		4.8	4.0		2.0	2.6		1.6	2.8		3.2	3.8		4.8	3.6
1920	4.6	3.4	1880	6.2	3.9	1840	2.8	2.7	1800	2.4	2.8	1760	2.8	3.5	1720	2.4	2.6
	3.0	3.0		2.8	4.0		3.4	2.6		2.6	2.3		4.4	3.2		1.8	2.8
	2.0	2.8		3.4	3.7		2.8	2.9		2.8	2.6		2.8	3.2		2.0	2.3
	2.4	2.6		2.8	3.4		2.0	2.7		2.0	2.7		2.8	3.0		3.2	2.7
	2.0	3.1		3.2	3.4		3.4	2.4		3.0	2.8		3.0	2.7		2.0	2.9
1915	3.8	3.4	1875	4.8	3.6	1835	2.0	2.3	1795	3.0	2.6	1755	2.0	2.7	1715	4.6	3.6
	5.4	3.8		3.0	3.6		1.6	2.3		3.0	2.8		2.8	2.5		2.8	3.5
	3.6	4.0		4.0	3.8		2.4	2.1		2.0	3.2		2.8	2.5		5.6	3.6
	4.0	3.6		3.2	3.5		2.0	2.4		3.2	3.0		1.8	2.5		2.4	3.2
	3.2	3.0		4.0	3.5		2.6	2.8		4.8	2.9		3.0	2.4		2.8	3.0
1910	1.6	3.2	1870	3.2	3.2	1830	3.6	3.0	1790	2.2	3.6	1750	2.2	2.5	1710	2.2	2.3
	2.8	3.2		3.2	3.2		3.2	3.5		2.4	4.2		2.4	2.8		2.0	2.2
	4.4	3.4		2.6	3.1		3.6	3.4		5.4	4.5		3.0	2.8		2.2	2.2
	4.2	4.1		2.8	3.0		4.6	3.3		6.2	4.7		3.2	3.0		2.0	2.3
	4.2	4.5		3.8	2.7		2.2	3.3		6.4	5.8		3.4	2.9		2.4	2.4
1905	4.8	4.4	1865	2.8	2.7	1825	3.0	3.0	1785	3.2	5.5	1745	2.8	2.7	1705	2.8	2.6
	4.8	4.4		1.6	2.4		3.0	2.6		7.6	4.8		2.2	2.6		2.6	3.4
	3.8	5.3		2.4	1.9		2.4	2.8		4.2	4.1		2.0	2.9		3.4	4.0
	4.2	5.1		1.4	1.8		2.2	2.6		2.6	4.3		2.6	3.3		6.0	4.4
	8.8	5.6		1.4	2.0		3.2	2.5		3.0	3.8		4.8	3.6		5.2	4.6
1900	4.0	5.8	1860	2.0	2.2	1820	2.4	2.6	1780	4.0	3.7	1740	5.0	4.0	1700	5.0	4.4
	7.4	6.3		3.0	2.5		2.2	2.9		5.2	3.7		3.4	4.0		3.2	
	4.8	5.4		3.4	2.8		3.2	2.7		3.6	3.8		4.2	3.6		2.6	
	6.6	5.8		2.6	2.9		3.4	2.8		2.6	3.8		2.8	3.3			
	4.2	5.3		3.0	2.8		2.4	2.8		3.4	4.6		2.6	3.1			
1895	6.0	5.2	1855	2.4	2.4	1815	3.0	3.0	1775	4.0	4.4	1735	3.4	2.7			
	5.0	4.7		2.8	2.4		2.2	3.2		9.6	4.6		2.4	2.7			
	4.0	5.0		1.2	2.8		3.8	3.7		2.2	4.6		2.2	2.6			
	4.2	4.7		2.6	2.8		4.6	3.5		3.6	4.3		3.0	2.6			
	6.0	4.6		5.0	2.9		5.0	3.5		3.6	2.8		2.0	2.6			

Annual Temperature, Precipitation, and Snowfall of the Southern Alaska Climatological Division

YEAR	ANNUAL TEMPERATURE MEAN	ANNUAL TEMPERATURE SMOOTHED MEAN	ANNUAL CUMULATIVE PRECIPITATION MEAN	ANNUAL CUMULATIVE PRECIPITATION SMOOTHED MEAN	ANNUAL CUMULATIVE SNOWFALL MEAN	ANNUAL CUMULATIVE SNOWFALL SMOOTHED MEAN
1934	5.7		207.7		204	
	3.8		185.4		239	
	4.1	4.7	202.0	209.8	263	233
	5.5	4.7	218.0	215.8	209	228
1930	4.6	4.9	236.0	228.5	251	225
	5.3	5.1	327.6	230.6	177	225
	5.2	5.4	249.1	240.0	227	209
	4.7	5.5	212.1	236.3	263	204
	7.1	5.5	265.3	235.2	125	216
1925	5.2	5.6	217.5	231.8	226	221
	5.2	5.6	232.0	231.1	238	209
	5.8	5.1	231.9	220.3	254	233
	4.7	4.9	208.9	218.3	204	241
	4.7	4.8	211.4	213.0	244	244
1920	4.3	4.5	207.5	215.8	265	280
	4.5	4.3	205.2	227.4	253	322
	4.5	4.1	245.8	228.2	436	347
	3.5	4.5	267.2	238.0	415	348
	3.9	4.7	215.2	236.8	367	336
1915	6.3	4.7	256.4	230.6	267	318
	5.2	5.1	119.5	244.8	194	281
	4.6	5.1	214.8	216.1	345	284
	5.3	4.7	237.9	199.3	231	311
	4.3	4.3	172.0	191.9	384	324
1910	4.1	4.2	172.4	183.4	399	317
	3.2	4.0	162.2	169.1	263	315
	4.3		172.7		308	
	4.0		166.1		220	

Annual Temperature and Snowfall of the Northern Alaska Climatological Division

YEAR	ANNUAL TEMPERATURE MEAN	ANNUAL TEMPERATURE SMOOTHED MEAN	ANNUAL CUMULATIVE SNOWFALL MEAN	ANNUAL CUMULATIVE SNOWFALL SMOOTHED MEAN
1934	-2.2		160	
	-4.2		146	
	-3.7	-3.2	147	142
	-2.6	-3.0	141	161
1930	-3.2	-2.6	169	165
	-1.4	-2.7	202	165
	-2.3	-2.4	167	154
	-4.1	-2.5	147	147
	-1.1	-3.0	86	143
1925	-3.4	-3.0	135	150
	-3.9	-2.8	181	153
	-2.3	-3.2	202	171
	-3.3	-3.3	161	185
	-3.2	-3.1	178	175
1920	-3.9	-3.5	201	181
	-2.7	-3.8	135	173
	-4.2	-4.2	232	178
	-5.1	-4.2	119	169
	-4.9	-4.4	204	167
1915	-4.2	-4.5	156	144
	-3.7	-4.0	126	141
	-4.8	-4.0	114	130
	-2.4	-4.3	105	116
	-4.8	-4.9	151	112
1910	-6.0	-4.8	84	116
	-6.6	-5.3	105	126
	-4.3		136	
	-4.7		155	

Annual Temperatures of the State of Oregon and the Western Climatological Disision of Oregon

YEAR	OREGON STATE ANNUAL TEMPERATURE MEAN	OREGON STATE ANNUAL TEMPERATURE SMOOTHED MEAN	WESTERN OREGON ANNUAL TEMPERATURE MEAN	WESTERN OREGON ANNUAL TEMPERATURE SMOOTHED MEAN
1934	11.1		12.7	
	9.0		10.6	
	8.7	9.4	10.9	11.3
	9.4	8.8	11.6	10.9
1930	8.7	8.9	10.8	10.9
	8.4	9.0	10.4	10.9
	9.4	9.1	10.9	11.0
	9.1	9.4	10.7	11.2
	10.1	9.6	12.3	11.3
1925	10.2	9.5	11.7	11.1
	9.1	9.4	10.9	11.1
	9.2	9.3	10.1	10.8
	8.5	9.0	10.3	10.6
	9.4	9.0	11.0	10.5
1920	8.9	9.0	10.5	10.7
	8.8	9.1	10.4	10.8
	9.6	8.8	11.4	10.7
	8.8	8.9	10.8	10.8
	7.8	8.9	10.2	10.9
1915	9.3	8.7	11.1	10.6
	9.6	8.6	10.8	10.5
	8.3	8.7	10.2	10.4
	8.7	8.8	10.3	10.4
	8.3	8.7	9.8	10.2
1910	9.4	8.9	10.7	10.3
	8.8	9.0	10.2	10.5
	9.2	9.3	10.6	10.8
	9.4	9.3	11.2	10.9
	9.6	9.5	11.4	11.1
1905	9.3	9.5	11.0	11.1
	9.9	9.4	11.3	11.0
	9.1	9.4	10.8	10.9
	9.2	9.5	10.7	11.0
	9.6	9.3	10.9	10.9
1900	9.8	9.3	11.5	11.0
	8.7	9.3	10.8	11.1
	9.1	9.2	11.1	11.1
	9.2	9.2	11.2	11.0
	9.1	8.9	11.1	11.0
1895	8.7	8.7	10.7	10.9
	8.5	8.7	10.9	10.9
	8.2	8.8	10.6	11.0
	9.1	8.8	11.2	11.0
	9.3		11.4	
1890	8.8		10.7	

Annual Temperatures for the State of Washington, Western Climatological Division and the Cities of North Head and Seattle.

YEAR	WASHINGTON STATE ANNUAL TEMPERATURE		WESTERN DIVISION ANNUAL TEMPERATURE		NORTH HEAD ANNUAL TEMPERATURE		SEATTLE ANNUAL TEMPERATURE	
	MEAN	SMOOTHED MEAN	MEAN	SMOOTHED MEAN	MEAN	SMOOTHED MEAN	MEAN	SMOOTHED MEAN
1934	11.0		11.1		11.6		12.9	
	.9		8.9		9.5		10.9	
	9.1	9.4	9.1	9.5	9.7	10.3	10.9	11.4
	9.4	8.9	9.6	9.1	10.7	9.9	11.6	10.9
1930	8.7	9.0	8.9	9.0	10.0	10.1	10.7	11.0
	8.3	8.9	8.8	9.0	9.8	10.2	10.5	11.0
	9.4	9.1	8.7	9.3	10.5	10.4	11.2	11.1
	8.7	9.4	9.1	9.6	10.0	10.5	10.8	11.2
	10.4	9.7	10.9	9.7	11.6	10.5	12.2	11.3
1925	10.4	9.7	10.4	10.0	10.6	10.6	11.4	11.3
	9.4	9.7	9.6	10.0	9.9	10.4	10.8	11.1
	9.7	9.4	9.9	9.7	10.7	10.0	11.1	10.7
	8.5	9.2	9.0	9.5	9.3	9.8	9.9	10.5
	9.2	9.1	9.4	9.4	9.7	9.7	10.3	10.4
1920	9.2	9.2	9.4	9.4	9.4	9.4	10.3	10.3
	8.9	9.3	9.3	9.6	9.3	9.5	10.2	10.4
	10.0	9.1	10.1	9.4	9.4	9.3	10.9	10.3
	9.3	9.2	9.6	9.6	9.5	9.6	10.4	10.5
	7.9	9.4	8.6	9.8	9.1	9.8	9.6	10.7
1915	10.1	9.2	10.6	9.7	10.7	9.9	11.6	10.6
	9.8	9.2	10.3	9.8	10.2	10.0	11.2	10.7
	8.9	9.4	9.6	10.0	9.9	10.0	10.3	10.8
	9.3	9.4	10.1	9.8	10.3	9.8	10.8	10.6
	9.0	9.2	9.2	9.5	9.1	9.5	10.1	10.3
1910	9.8	9.4	9.7	9.6	9.4	9.5	10.5	10.3
	8.9	9.5	9.1	9.6	9.0	9.4	9.8	10.3
	9.9	9.7	9.8	9.9	9.6	9.7	10.5	10.6
	9.7	9.7	10.1	10.0	10.1	9.9	10.6	10.7
	10.3	9.9	10.6	10.2	10.4	10.1	11.4	11.0
1905	9.7	9.8	10.2	10.2	10.3	10.2	11.1	11.0
	10.0	9.7	10.4	10.2	10.1	10.3	11.3	11.1
	9.2	9.6	9.8	10.1	10.1	10.2	10.7	11.1
	9.4	9.7	10.1	10.1	****	****	11.2	11.2
	9.6	9.5	9.8	10.0	****	****	11.1	11.1
1900	10.2	9.6	10.5	10.0	****	****	11.6	11.2
	9.3	9.7	9.7	10.0	****	****	10.7	11.1
	9.7	9.6	10.1	10.0	10.4	10.2	11.2	11.0
	9.6	9.5	10.1	9.7	10.2	10.2	10.8	10.8
	9.4	9.4	9.5	9.6	10.1	10.1	10.6	10.7
1895	9.3	9.2	9.3	9.4	10.3	9.9	10.7	10.5
	9.1	9.3	9.2	9.4	9.6	9.9	10.2	10.7
	8.6	9.4	8.9	9.6	9.3	9.9	10.1	
	10.1	9.5	10.2	9.6	10.3	9.8	12.1	
	10.1		10.2		10.1	10.1		
1890	9.8		9.7		9.9	10.4		
					11.1	10.3		
					10.6	10.4		
					9.8	10.7		
					10.6	10.5		
1885					11.2			
					10.2			

Annual Temperatures of the States of Hawaii and California and the Cities of Eureka and San Francisco

YEAR	CALIFORNIA STATE ANNUAL TEMPERATURE		EUREKA ANNUAL TEMPERATURE		SAN FRANCISCO ANNUAL TEMPERATURE		HAWAII ANNUAL TEMPERATURE	
	MEAN	SMOOTHED MEAN	MEAN	SMOOTHED MEAN	MEAN	SMOOTHED MEAN	MEAN	SMOOTHED MEAN
1934	15.5		12.3		14.9		22.6	
	13.9		10.4		13.5		21.8	
	14.1	14.5	10.7	11.2	13.9	14.3	22.2	22.2
	14.9	14.3	11.4	10.9	14.6	14.1	22.3	22.2
1930	14.1	14.4	11.3	11.1	14.4	14.2	22.4	22.3
	14.3	14.5	10.7	11.2	14.1	14.2	22.5	22.4
	14.8	14.7	11.3	11.4	13.9	14.3	22.3	22.5
	14.5	14.9	11.2	11.4	14.0	14.3	22.6	22.4
	15.8	15.0	11.3	11.4	14.9	14.2	22.6	22.3
1925	14.9	14.9	11.5	11.4	14.4	14.2	22.2	22.3
	14.8	14.9	10.8	11.2	13.8	14.1	22.0	22.2
	14.5	14.7	11.2	10.9	14.1	13.9	22.1	22.1
	14.3	14.7	10.3	10.8	13.3	13.7	22.1	22.1
	15.1	14.6	10.9	10.8	13.8	13.6	22.2	22.2
1920	14.7	14.6	10.8	10.7	13.4	13.5	22.2	22.2
	14.4	14.7	10.6	10.7	13.2	13.5	22.2	22.2
	14.7	14.4	10.9	10.5	13.8	13.4	22.1	22.1
	14.4	14.3	10.1	10.6	13.5	13.6	22.2	22.1
	13.6	14.4	10.2	10.7	13.3	13.7	21.9	22.0
1915	14.5	14.4	11.3	10.6	14.1	13.6	22.0	22.0
	14.7	14.3	10.9	10.8	13.7	13.7	21.8	21.9
	14.6	14.3	10.6	10.7	13.6	13.6	22.1	21.8
	14.1	14.5	10.9	10.6	13.7	13.4	21.8	21.7
	13.8	14.4	9.9	10.5	12.9	13.2	21.4	21.6
1910	15.2	14.4	10.5	10.5	****	****	21.2	21.5
	14.4	14.6	10.6	10.5	12.9	13.2	21.3	21.6
	14.6	14.9	10.4	10.8	12.8	13.1	21.7	21.7
	14.8	14.9	11.3	11.0	13.6	13.2	22.2	21.9
	15.3	15.1	11.3	11.1	13.4	13.4	22.2	
1905	15.3	15.2	11.6	11.3	13.5	13.4	22.0	
	15.7	15.3	11.1	11.3	13.6	13.3		
	15.1	15.3	11.0	11.2	12.9	13.2		
	14.9	15.3	11.4	11.3	13.0	13.2		
	15.4	15.2	11.0	11.1	12.9	13.0		
1900	15.4	15.2	11.8	11.0	13.4	12.9		
	15.2	15.3	10.5	10.9	12.8	12.9		
	15.3		10.4	11.0	12.6	13.0		
	15.0		10.9	10.7	12.8	12.9		
			11.3	10.7	13.3	12.9		
1895			10.5	10.7	13.1	12.9		
			10.4	10.7	12.8	13.0		
			10.3	10.6	12.4	13.1		
			10.8	10.6	13.3	13.1		
			11.2	10.8	13.7	13.5		
1890			10.3	11.1	13.5	13.8		
			11.6	11.0	14.4	13.8		
			11.7		14.1	13.9		
			10.1		13.6	14.1		
					14.1	14.0		
1885					14.3	13.8		
					13.7	13.6		
					13.1	13.5		
					12.9	13.2		
					13.7	13.2		
1880					12.7	13.4		
					13.7	13.6		
					13.8	13.6		
					14.3	13.8		
					13.7	13.6		
1875					13.3	13.5		
					13.1	13.4		
					13.3	13.3		
					13.4			
					13.3			

Reconstructed Annual Snowfall - Southern Alaska Climatological Division

YEAR	SNOWFALL (cm)	YEAR	SNOWFALL (cm)	YEAR	SNOWFALL (cm)	YEAR	SNOWFALL (cm)	YEAR	SNOWFALL (cm)	YEAR	SNOWFALL (cm)
1906	248										
1905	254	1865	348	1825	331	1785	193	1745	348	1705	353
	254		364		353		231		353		309
	204		392		342		270		336		276
	215		397		353		259		314		254
	187		386		359		287		298		243
1900	176	1860	375	1820	353	1780	292	1740	276	1700	254
	149		359		336		292		276		
	198		342		348		287		298		
	176		336		342		287		314		
	204		342		342		243		325		
1895	209	1855	364	1815	331	1775	254	1735	348		
	237		364		320		243		348		
	220		342		292		243		353		
	237		342		303		259		353		
	243		336		303		342		353		
1890	231	1850	303	1810	309	1770	336	1730	336		
	187		287		336		348		342		
	226		314		370		348		342		
	231		320		364		331		359		
	231		331		320		325		359		
1885	243	1845	353	1805	325	1765	303	1725	320		
	309		375		398		287		331		
	287		375		303		287		298		
	254		370		309		303		287		
	276		353		342		287		298		
1880	281	1840	348	1800	342	1760	303	1720	353		
	276		353		370		320		342		
	292		336		353		320		370		
	309		348		348		331		348		
	309		364		342		348		336		
1875	298	1835	370	1795	353	1755	348	1715	298		
	298		370		342		359		303		
	287		381		320		359		298		
	303		364		331		359		320		
	303		342		336		364		331		
1870	320	1830	331	1790	298	1750	359	1710	370		
	320		303		265		342		375		
	325		309		248		342		375		
	331		314		237		331		370		
	348		314		176		336		364		

Reconstructed Annual Temperature - Southern Alaska Climatological Division

YEAR	TEMPERATURE (°C)	YEAR	TEMPERATURE (°C)	YEAR	TEMPERATURE (°C)	YEAR	TEMPERATURE (°C)	YEAR	TEMPERATURE (°C)	YEAR	TEMPERATURE (°C)
1906	5.1										
1905	5.0	1865	4.0	1825	4.2	1785	5.6	1745	4.0	1705	3.9
	5.0		3.8		4.0		5.2		4.0		4.4
	5.5		3.5		4.0		4.8		4.1		4.8
	5.4		3.5		4.0		4.9		4.4		5.0
	5.7		3.6		3.9		4.6		4.5		5.1
1900	5.8	1860	3.7	1820	4.0	1780	4.6	1740	4.8	1700	5.0
	6.1		3.9		4.1		4.6		4.8		
	5.6		4.1		4.0		4.6		4.5		
	5.8		4.1		4.1		4.6		4.4		
	5.5		4.1		4.1		5.1		4.2		
1895	5.5	1855	3.8	1815	4.2	1775	5.0	1735	4.0		
	5.2		3.8		4.3		5.1		4.0		
	5.4		4.1		4.6		5.1		4.0		
	5.2		4.1		4.5		4.9		4.0		
	5.1		4.1		4.5		4.1		4.0		
1890	5.2	1850	4.5	1810	4.4	1770	4.1	1730	4.1		
	5.7		4.6		4.1		4.0		4.1		
	5.3		4.4		3.8		4.0		4.1		
	5.2		4.3		3.8		4.2		3.9		
	5.2		4.2		4.3		4.2		3.9		
1885	5.1	1845	4.0	1805	4.2	1765	4.5	1725	4.3		
	4.4		3.7		4.5		4.6		4.2		
	4.6		3.7		4.5		4.6		4.5		
	5.0		3.8		4.4		4.5		4.6		
	4.8		4.0		4.1		4.6		4.5		
1880	4.7	1840	4.0	1800	4.1	1760	4.5	1720	3.9		
	4.8		4.0		3.8		4.3		4.1		
	4.6		4.1		3.9		4.3		3.8		
	4.4		4.0		4.0		4.2		4.0		
	4.4		3.8		4.1		4.0		4.1		
1775	4.5	1835	3.8	1795	3.9	1755	4.0	1715	4.5		
	4.5		3.8		4.1		3.9		4.5		
	4.6		3.7		4.3		3.9		4.5		
	4.5		3.8		4.2		3.9		4.3		
	4.5		4.1		4.1		3.8		4.2		
1870	4.3	1830	4.2	1790	4.5	1750	3.9	1710	3.8		
	4.3		4.5		4.9		4.1		3.7		
	4.2		4.4		5.1		4.1		3.7		
	4.2		4.4		5.2		4.2		3.8		
	4.0		4.4		5.8		4.1		3.8		

RECONSTRUCTED ANNUAL TEMPERATURES - NORTHERN ALASKA CLIMATOLOGICAL DIVISION

YEAR	TEMPERATURE (°C)	YEAR	TEMPERATURE (°C)	YEAR	TEMPERATURE (°C)	YEAR	TEMPERATURE (°C)	YEAR	TEMPERATURE (°C)	YEAR	TEMPERATURE (°C)
1906	-3.2										
1905	-3.3	1865	-5.0	1825	-4.7	1785	-2.2	1745	-5.0	1705	-5.1
	-3.3		-5.3		-5.1		-2.9		-5.1		-4.3
	-2.4		-5.8		-4.9		-3.6		-4.8		-3.7
	-2.6		-5.9		-5.1		-3.4		-4.4		-3.3
	-2.1		-5.7		-5.2		-3.9		-4.1		-3.1
1900	-1.9	1860	-5.5	1820	-5.1	1780	-4.0	1740	-3.7	1700	-3.3
	-1.4		-5.2		-4.8		-4.0		-3.7		
	-2.3		-4.9		-5.0		-3.9		-4.1		
	-1.9		-4.8		-4.9		-3.9		-4.4		
	-2.4		-4.9		-4.9		-3.1		-4.6		
1895	-2.5	1855	-5.3	1815	-4.7	1775	-3.3	1735	-5.0		
	-3.0		-5.3		-4.5		-3.1		-5.0		
	-2.7		-4.9		-4.0		-3.1		-5.1		
	-3.0		-4.9		-4.2		-3.4		-5.1		
	-3.1		-4.8		-4.2		-4.9		-5.1		
1890	-2.9	1850	-4.2	1810	-4.3	1770	-4.8	1730	-4.8		
	-2.1		-3.9		-4.8		-5.0		-4.9		
	-2.8		-4.4		-5.4		-5.0		-4.9		
	-2.9		-4.5		-5.3		-4.7		-5.2		
	-2.9		-4.7		-4.5		-4.6		-5.2		
1885	-3.1	1845	-5.1	1805	-4.6	1765	-4.2	1725	-4.5		
	-4.3		-5.5		-4.1		-3.9		-4.7		
	-3.9		-5.5		-4.2		-3.9		-4.1		
	-3.3		-5.4		-4.3		-4.2		-3.9		
	-3.7		-5.1		-4.9		-3.9		-4.1		
1880	-3.8	1840	-5.0	1800	-4.9	1760	-4.2	1720	-5.1		
	-3.7		-5.1		-5.4		-4.5		-4.9		
	-4.0		-4.8		-5.1		-4.5		-5.4		
	-4.3		-5.0		-5.0		-4.7		-5.0		
	-4.3		-5.3		-4.9		-5.0		-4.8		
1875	-4.1	1835	-5.4	1795	-5.1	1755	-5.0	1715	-4.1		
	-4.1		-5.4		-4.9		-5.2		-4.2		
	-3.9		-5.6		-4.5		-5.2		-4.1		
	-4.2		-5.3		-4.7		-5.2		-4.5		
	-4.2		-4.9		-4.8		-5.3		-4.7		
1870	-4.5	1830	-4.7	1790	-4.1	1750	-5.2	1710	-5.4		
	-4.5		-4.2		-3.5		-4.9		-5.5		
	-4.6		-4.3		-3.2		-4.9		-5.5		
	-4.7		-4.4		-3.0		-4.7		-5.4		
	-5.0		-4.4		-1.9		-4.8		-5.3		

Reconstructed Annual Temperature - North Head, Washington

YEAR	TEMPERATURE (°C)	YEAR	TEMPERATURE (°C)	YEAR	TEMPERATURE (°C)	YEAR	TEMPERATURE (°C)	YEAR	TEMPERATURE (°C)	YEAR	TEMPERATURE (°C)
1906	10.1										
1905	10.1	1865	9.2	1825	9.3	1785	10.6	1745	9.2	1705	9.1
	10.1		9.0		9.1		10.3		9.1		9.5
	10.5		9.8		9.2		9.9		9.3		9.8
	10.4		9.7		9.1		10.0		9.5		10.1
	10.7		9.8		9.1		9.7		9.6		10.2
1900	10.8	1860	9.9	1820	9.1	1780	9.7	1740	9.8	1700	10.1
	11.0		9.1		9.3		9.7		9.8		
	10.6		9.2		9.2		9.7		9.6		
	10.8		9.3		9.2		9.7		9.5		
	10.5		9.2		9.2		10.2		9.4		
1895	10.5	1855	9.0	1815	9.3	1775	10.1	1735	9.2		
	10.2		9.0		9.4		10.2		9.2		
	10.4		9.2		9.7		10.2		9.1		
	10.2		9.2		9.6		10.0		9.1		
	10.2		9.3		9.6		9.2		9.1		
1890	10.3	1850	9.6	1810	9.5	1770	9.3	1730	9.3		
	10.7		9.7		9.3		9.2		9.2		
	10.3		9.5		9.0		9.2		9.2		
	10.3		9.4		9.0		9.3		9.1		
	10.3		9.3		9.4		9.4		9.1		
1885	10.2	1845	9.1	1805	9.4	1765	9.6	1725	9.4		
	9.5		8.9		9.6		9.7		9.3		
	9.7		8.9		9.6		9.7		9.6		
	10.1		9.0		9.5		9.6		9.7		
	9.8		9.1		9.2		9.7		9.6		
1880	9.8	1840	9.2	1800	9.2	1760	9.6	1720	9.1		
	9.8		9.1		9.0		9.4		9.2		
	9.7		9.3		9.1		9.4		9.0		
	9.5		9.2		9.2		9.3		9.2		
	9.5		9.0		9.2	1755	9.2	1715	9.3		
1875	9.6	1835	9.0	1795	9.1		9.2		9.6		
	9.6		9.0		9.2		9.1		9.6		
	9.7		8.9		9.4		9.1		9.6		
	9.6		9.0		9.3		9.1		9.4		
	9.6		9.2		9.3		9.0		9.3		
1870	9.4	1830	9.3	1790	9.6	1750	9.1	1710	9.0		
	9.4		9.6		9.9		9.2		8.9		
	9.4		9.5		10.1		9.2		8.9		
	9.3		9.5		10.2		9.3		8.9		
	9.2		9.5		10.8		9.3		9.0		

Reconstructed Annual Temperatures - Seattle, Washington

YEAR	TEMPERATURE (°C)	YEAR	TEMPERATURE (°C)	YEAR	TEMPERATURE (°C)	YEAR	TEMPERATURE (°C)	YEAR	TEMPERATURE (°C)	YEAR	TEMPERATURE (°C)
1906	10.8										
1905	10.8	1865	10.0	1825	10.2	1785	11.3	1745	10.0	1705	10.0
	10.8		9.9		10.0		11.0		10.0		10.3
	11.2		9.7		10.1		10.7		10.1		10.6
	11.1		9.7		10.0		10.7		10.3		10.8
	11.3		9.7		10.0		10.5		10.4		10.9
1900	11.4	1860	9.8	1820	10.0	1780	10.5	1740	10.6	1700	10.8
	11.6		9.9		10.1		10.5		10.6		
	11.2		10.1		10.0		10.5		10.4		
	11.4		10.1		10.0		10.5		10.6		
	11.2		10.1		10.0		10.9		10.2		
1895	11.1	1855	9.9	1815	10.2	1775	10.8	1735	10.0		
	10.9		9.9		10.3		10.9		10.0		
	11.0		10.1		10.5		10.9		10.0		
	10.9		10.1		10.4		10.7		10.0		
	10.9		10.1		10.4		10.1		10.0		
1890	11.0	1850	10.4	1810	10.4	1770	10.1	1730	10.1		
	11.3		10.5		10.1		10.0		10.1		
	11.0		10.3		9.9		10.0		10.1		
	11.0		10.3		9.9		10.2		10.0		
	11.0		10.2		10.3		10.2		10.0		
1885	10.9	1845	10.0	1805	10.2	1765	10.4	1725	10.3		
	10.3		9.8		10.4		10.5		10.2		
	10.5		9.8		10.4		10.5		10.4		
	10.8		9.9		10.3		10.4		10.5		
	10.7		10.0		10.1		10.5		10.4		
1880	10.6	1840	10.0	1800	10.1	1760	10.4	1720	10.0		
	10.6		10.0		9.9		10.3		10.1		
	10.4		10.1		10.0		10.3		9.9		
	10.3		10.0		10.0		10.2		10.0		
	10.3		9.9		10.1		10.0		10.1		
1875	10.4	1835	9.9	1795	10.0	1755	10.0	1715	10.4		
	10.4		9.9		10.1		10.0		10.4		
	10.5		9.8		10.3		10.0		10.4		
	10.4		9.9		10.2		10.0		10.3		
	10.4		10.1		10.1		9.9		10.2		
1870	10.2	1830	10.2	1790	10.4	1750	10.0	1710	9.9		
	10.2		10.4		10.7		10.1		9.8		
	10.2		10.3		10.8		10.1		9.8		
	10.2		10.3		10.9		10.2		9.9		
	10.0		10.3		11.4		10.1		9.9		