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Time Series Analyses of Climatological Records from Auke Bay, Alaska

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B. L. Wing and J. J. Pella

U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
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ABSTRACT

Physical environmental data collected by scientists from the Auke Bay Laboratory of the National Marine Fisheries Service and the U.S. Geological Survey during 1959-93 near Auke Bay, Alaska, are summarized in tabular and graphic formats. Data include sea surface temperatures, air temperatures, precipitation (rainfall and melted snowfall), water temperatures for Auke Creek, Auke Lake, and Lake Creek, stream flows from Auke Creek and Lake Creek, and annual dates of ice-out for Auke Lake. Statistical time series methods, including spectral analysis for underlying cycles and univariate modeling for temporal dependence, were used to describe the monthly records for precipitation, snowfall, average daily high, low, and midrange air temperatures, and sea surface temperature.

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INTRODUCTION

Auke Bay is a small (11 km^2) embayment of the fjord system in southeastern Alaska, located approximately 130 km inland of the open ocean, 16 km northwest of Juneau, Alaska, and 5 km west of the Juneau International Airport (Fig. 1). Meteorological data for the latter two locales extend back to the 1880s and 1940s, respectively (Lomire 1979). Auke Bay is subject to a northern maritime climate, having moderate temperatures, high precipitation, and predominant southeasterly winds. Average monthly insolation varies greatly with day length and cloud cover density, ranging from 20 g cal $cm^{-2}day^{-1}$ in midwinter to 340 g cal $cm^{-2}day^{-1}$ in midsummer (Bruce et al. 1977). Diel photoperiod ranges from 6.4 hours at the winter solstice to 18.3 hours at the summer solstice. The mountainous terrain of southeastern Alaska causes considerable local weather variation over short distances, as is evident from comparing Auke Bay weather records to those of nearby Juneau and the Juneau International Airport. Auke Bay is protected by the surrounding hills from the prevailing southeasterly winds and in the winter from the severe, north winds associated with periods of strong atmospheric high pressure in the interior of northwestern Canada.

Auke Bay and vicinity have been the locale of biological research since the 1950s. The National Marine Fisheries Service and the University of Alaska have research laboratories at Auke Bay. The U.S. Fish and Wildlife Service, U.S. Forest Service, U.S. Geological Survey, and the Alaska Department of Fish and Game have used the area for experimental studies. The research and management projects in the Auke Bay vicinity have resulted in a diverse time series of environmental data. Few of these data sets have been summarized or are readily available to the general research community.

This report presents tabular and graphic summaries and time series analyses of the physical data gathered by scientists from the Auke Bay Laboratory of the National Marine Fisheries Service and U.S. Geological Survey since 1959. These summaries supplement, and update previously published data from Auke Bay by Bruce et al. (1977) and Coyle and Shirley (1990).

METHODS

Meteorological Records

Weather observations have been taken daily at the Auke Bay Laboratory (lat. 58º22.88’N, long. 134º38.67’W) for the National Weather Service Cooperative Observer Program since February 1963. Daily air temperatures and precipitation were recorded at 1630 hours according to procedures in the Weather Bureau Observing Handbook (ESSA 1970). Although daily climate records have been obtained, the series began before general availability of computers and only the monthly summaries have been transferred to computer-readable media. Extreme daily high and low temperatures have also been recorded.

Air Temperatures

Maximum, minimum, and current air temperatures were measured by liquid-in-glass thermometers from February 1963 through July 1988. Beginning in August 1988, air temperature observations were taken with an electronic maximum/minimum system. The liquid-in-glass thermometers serve as backup during frequent electric power outages. Since October 1979, a paper-recording battery-powered hygrothermograph has served as backup to both standard systems for occasions when an observer is unavailable. All air temperatures were recorded in degrees Fahrenheit to the nearest whole degree. For this report the temperatures have been converted to the Celsius scale.

Precipitation

Daily precipitation observations from a standard 8-inch (20.3 cm) nonrecording gage were recorded to the nearest 0.01 inch. Precipitation includes the water equivalent of any snowfall or ice pellets. Daily snowfall and snow on the ground were measured with standard 12-inch and 36-inch rulers. Snowfall was recorded to the nearest 0.1 inch and snow on the ground recorded to the nearest whole inch. For this report, average precipitation records were converted to centimeters. Snow-on-the-ground data have not been analyzed for this report.

Auke Bay Saltwater Temperatures

Auke Bay Laboratory

Daily sea surface temperatures (SSTs) for the Auke Bay Laboratory from January 1959 through April 1963 were taken on the beach at a private residence adjacent to the laboratory. These temperatures were normally taken between 0700 and 0800 hours with a mercury-in-glass thermometer at the water's edge. From May 1963 through 1969, the temperatures were taken off the laboratory float (roughly l0-20 m beyond the 0 tide line) and on a less regular schedule according to specific project needs. In 1975, daily sea surface temperature observations were reinstituted at the Auke Bay Laboratory float. To assure continuity of the data, sea surface temperatures were taken at the end of the normal work day (1630) and included as part of the daily weather observations.

The large gaps in these data resulted from changing priorities, personnel, and programs.

Auke Bay Monitor Station

The Auke Bay Monitor oceanographic station (lat. 58º21.97'N, long. 134º4O.OO'W) has been a reference for research projects in Auke Bay since 1960. Located near the middle of Auke Bay, it is considered representative of much of the bay (Bruce et al. 1977, Coyle and Shirley 1990). Oceanographic data were collected there on varying and irregular weekly to quarterly schedules according to the needs of specific projects.

Auke Lake Watershed Stream Flows and Temperatures

Auke Bay receives most of its freshwater input from the Mendenhall River, and three small watersheds drained by Auke Creek, Auke Nu Creek, and Waydelich Creek (Fig. 1). Several small permanent streams and intermittent streams contribute to the runoff to Auke Bay. Temperatures and stream flows were recorded by stream gages on Lake Creek (1963-73) flowing into Auke Lake, Auke Creek (1962-75) flowing from Auke Lake, and the Mendenhall River (1965-79) and its tributary Montana Creek (1963-76) (Chapman 1982, U.S. Geological Survey 1963-76). Zieman et al. (1990) compared stream flows of Auke Creek, Auke Nu Creek, and Waydelich Creek only for March through June (1986-89).

Lake Creek

Lake Creek is the largest stream flowing into Auke Lake. Its 6.5 km^2 (2.5 $mile^2$) watershed is relatively low and mostly hemlock-spruce forest with some open muskeg. The low-gradient first 1.5 km of the creek includes most of the known stream spawning area for salmonids inhabiting Auke Lake. Stream flows and temperatures were recorded continuously by a U.S. Geological Survey stream gage from October 1963 through September 1973.

Auke Creek

Auke Creek, the outflow from Auke Lake to Auke Bay, has a 10 km^2 (4.0 $mile^2$) watershed. Surface water from Auke Lake to Auke Creek passes through a shallow lagoon. The narrow entrance to the lagoon is often less than 50 cm deep during extended low runoff periods. The exit from the lagoon passes through a narrow channel over a bedrock sill. Water depth at the sill is often less than 30 cm. The stream is short (0.65 km) and has a steep gradient (average 26 m km^{-1}). The upper portion of the stream was modified to increase salmon spawning area in 1963, but pink salmon do not consistently spawn in the modified area.

Auke Creek temperatures and stream flows were recorded continuously by a U.S. Geological Survey stream gage at the upper end of the creek from October 1962 through

September 1975; thereafter, stream temperatures were recorded at the Auke Creek Hatchery weir at the lower end of the creek. Currently, temperatures are taken each morning with liquid-in-glass thermometers.

Auke Creek Hatchery

Until 1990, temperatures of inflow water to the Auke Creek Hatchery were recorded each morning by liquid-in-glass thermometers at the hatchery trough. The water was drawn from 6 m (20 feet) depth in Auke Lake and flowed though an insulated 35 cm diameter pipe to the hatchery. Flow rate into the hatchery was approximately 0.06 $m^3 s^{-1}$ (0.5 cfs). Although some heat exchange occurred during flow through the pipe, heat exchange was considered minimal. Therefore, Auke Creek Hatchery temperatures were probably representative of the Auke Lake temperatures at 6 m through the spring of 1990, when the Auke Bay Laboratory ceased using water from the same pipe line for domestic and experimental use.

Auke Lake Freeze-Up and Ice-Out

Specific records of freeze-up or ice-over (date of first complete ice cover) were not routinely maintained. Several individuals kept private records of the last day of the year that float planes could land and take off from Auke Lake.[1]

Ice-out (last day of ice on the lake) was followed more closely than freeze-up because it is associated with the emigration of fish from Auke Lake. The dates of ice-out from 1960 through 1995 were taken from field notes of Auke Bay Laboratory fishery biologists.

Time Series Analysis

Weather variables with the longest periods of observations from the Auke Bay climate data were examined by statistical time series methods using the SAS SPECTRA (spectral decomposition), AUTOREG (autoregressive error models), and ARIMA (autoregressive integrated moving-average models) procedures (SAS Institute, Inc. 1993). Those variables available and analyzed were monthly consolidations of daily records-averages or totals (depending on the variable)-for air temperatures, precipitation (rainfall and melted snowfall), and snowfall from February 1963 to January 1993 inclusive (30 years of nearly continuous monthly records for each variable with no series missing more than 5 of the 360 months) and sea surface temperature from February 1975 to January 1993 inclusive (18 years of continuous monthly records). Over the span of observation

[1]Lief Lie, National Weather Service, Juneau, Alaska. Pers. commun., 3 Dec. 1992.

(say T months), the monthly values for any variable or its transform will be denoted as z_t; fitted values from ARIMA modeling, by $\hat{z}_t$; and the residual from the fit, by $\hat{a}_t = z_t - \hat{z}_t$, $t = 1, 2, \ldots, T$. The forecast value for one month beyond the span T will be denoted as $\tilde{z}$.

SPECTRA was used to decompose the total variation in a time series into cyclical components of time (months). That proportion of the total variation due to the annual cycle was extracted and tested for statistical significance using an F-test for a known period (Fuller 1976). Missing values (except at the beginning of the series) were estimated by cubic spline interpolation using the SAS EXPAND procedure before analysis of untransformed variables by SPECTRA.

AUTOREG was used to fit and test statistical significance of linear trend models to annual totals (precipitation and snowfall) or averages (temperatures). The procedure allowed for estimating autocorrelation structure in residuals about the line. The Durbin-Watson statistic was used to test for serial correlation of residuals. These regression analyses omitted the beginning year of each series (1963 for precipitation, snowfall, and air temperatures; 1975 for sea surface temperature) because the January observation was missing.

Standard Box-Jenkins methods of time series modeling (Box and Jenkins 1976, Pankratz 1983) were used to further describe the time series using the SAS ARIMA Procedure (SAS Institute, Inc. 1993): 1) examination of the sample autocorrelation function (SACF) and sample partial autocorrelation function (SPACF) to identify candidate ARIMA (autoregressive integrated moving-average) models; 2) estimation of parameters of the model(s) chosen; and 3) checking for adequacy of the model(s) by testing whether the time series of residuals were distinguishable from white noise using the SACF and SPACF of residuals and the Ljung-Box (1978) statistic. The conditional least-squares method was used for parameter estimation. When residual analyses indicated a proposed model was inadequate, the model was revised, parameters reestimated, and adequacy rechecked.

Statistics were computed up to a maximum lag of 60 months for precipitation and temperature series, up to a maximum lag of 35 months for snowfall (5 of the 12 months, May through September, with no or very low snowfall were omitted from the series), and up to a maximum lag of 45 months for SST, thereby meeting the usual recommendation not to exceed a lag equal to one-fourth of the total observations.

In a preliminary examination, the SACF and SPACF for monthly time series of each weather variable were computed using interannual month differences ($w_t = z_t - z_{t-12}$), intra-annual month differences ($w'_t = z_t - z_{t-1}$), or the combined differences ($w'' = z_t - z_{t-12} - z_{t-1} + z_{t-13}$) for untransformed and logarithm-transformed observations. So that the logarithm transformation (which can be applied only to positive values) could be used, monthly precipitation and snowfall measurements (cm) were increased by 1 cm and monthly temperature measurements (°C) were increased by 20°C. Interannual month differences of logarithm-transformed observations were chosen for analyzing all the time series because reasonably simple SACFs and SPACFs that were helpful for modeling (Box and Jenkins 1976) generally resulted.

After the models were chosen by standard Box-Jenkins methods, their forecast accuracy was compared with that from simpler models in which one or more of the coefficients of the chosen models were omitted. Forecast performance for each weather variable during the last 5 years was the basis of the comparison. For each test year and weather variable, the chosen models, as well as the simpler models, were fit by conditional least squares to data available at the beginning of the test year. The parameter estimates and the weather variable values preceding the test year were used to forecast the weather variable for each of the 12 months of the test year. These forecasts were compared with the actual values of the weather variable; the mean square of forecast errors (average squared errors) was used as a summary statistic.

The autocorrelation coefficients of the SACF are denoted as $\{r_k, k = 1, 2, \ldots, K)$, and the partial autocorrelation coefficients of the SPACF are denoted as $\{\hat{\phi}_{kk}, k = 1, 2, \ldots, K\}$. Precision of autocorrelation coefficients was determined from the approximation for standard error (SE) (Bartlett 1946),

$$\mathrm{SE}\ (r_k) = \left[1 + 2\sum_{j=1}^{k-1} r_j^2\right]^{1/2} n^{-1/2}. \qquad (1)$$

Precision of partial autocorrelation coefficients was approximated by (Box and Jenkins 1976)

$$\mathrm{SE}\ (\hat{\phi}_{kk}) = n^{-1/2}. \qquad (2)$$

In Equations (1 and 2), n is the number of values in the time series, reduced for missing values and losses during differencing.

Forecast equations for weather variables were derived using the difference equations approach (Box and Jenkins 1976). The one-month ahead forecast equations were included to clarify important temporal relationships within time series. Although these equations could be used in forecasting one-month ahead and they could be modified easily to forecast an arbitrary number of months ahead (see chapter 10 of Pankratz 1983), the time elapsed after the final information included requires updating with the most recent observations available from the National Weather Service, Western Regional Climate Center, on the internet (http://www.wrcc.dri.edu/summary/climsmak.html (22 Jan. 1998)). This intemet web site includes daily observations for 1961-97, which were not available for our time analyses. Also, the logarithm transformation requires special methods to translate forecasts to original measurement scales (see section 10.3 of Pankratz 1983).

RESULTS AND DISCUSSION

Meteorological Records

Daily meteorological records were nearly complete from February 1963 through December 1993. The accompanying tables and figures summarize the monthly means, maxima, and minima.

Air Temperatures

The monthly averages of daily high temperature (MADHTs) (Figs. 2a, 3; Table l), daily low temperature (MADLTs) (Figs. 2b, 3; Table 2), and daily midrange temperature (MADMTs); that is, the temperature midway between the daily high and low for the 24 hours preceding the observation (Figs. 2c, 3; Table 3), exhibited lesser variation superimposed on annual cycling. The annual cycles were discerned easily *($p < 0.001$)* and accounted for more than 80% of the total variation in each temperature series (Table 4). January was the coldest month (-4.16ºC) and July was the warmest month (13.12ºC) by average MADMT (Table 3). Annual variation was evident from l-month shifts of monthly extremes such that in exceptionally cold winters, December or February was colder than January; in exceptionally warm summers, August was warmer than July. Daily extremes showed that frost occurred in all months except August, and that temperatures occasionally approached or fell below -20°C from December through March (Table 2). Above freezing temperatures occurred in all months. Maximum daily air temperatures approaching or exceeding 30°C were recorded in June, July, and August (Table 1).

Annual averages of the three temperature series (MADHT, MADLT, and MADMT) between 1963 and 1993 (missing months were estimated by cubic spline interpolation) contained an irregular upward trend (Table 4, Fig. 4). Annual average MADHT ranged from a low of 7.43ºC in 1972 to a high of 10.96ºC in 1993 (Table 4, Fig. 4) with a series average of 8.52ºC (+0.77ºC). Annual average MADLT ranged from a low of 0.33ºC in 1972 to a high of 3.88ºC in 1981 (Fig. 4) with a series average of 1.9OºC (+0.91ºC). Annual average MADMT temperatures ranged from a low of 3.85ºC in 1972 to a high of 7.31ºC in 1993 (Fig. 4) with a series average of 4.91ºC (+0.84ºC). Slopes of the trend lines (Table 4, Fig. 4) for MADHT, MADLT, and MADMT showed that temperatures increased over the 29 years fitted (1964-92) at a rate of 0.029ºC yr^{-1} (SE = 0.014, $p =$ 0.057), 0.066ºC yr^{-1} (SE = 0.016, $p <$ O.OOl), and 0.047ºC yr^{-1} (SE = 0.015, $p <$ O.OOl), respectively. The Durbin-Watson statistics equaled 1.887, 1.638, and 1.717 for the three series, respectively, and provided no evidence of lag-l autocorrelation in residuals from the fitted lines.

Interannual month differences in the logarithm-transformed high, low, and midrange temperature series produced SACFs and SPACFs indicating presence of an annual component composed of pure or mixed moving-average and autoregressive processes. For the MADHTs, the SACF (Fig. 5) had a large negative spike (r_{12} = -0.516, SE = 0.062) at a lag of 12 months and no further significant values at lag multiples of 12 months. The SPACF (Fig. 6) had a slowly decaying (more slowly than exponential decay) series of spikes at lag multiples of 12 months. For the MADLTs, the SACF (Fig. 7) had an apparent oscillating series of spikes (significant spikes are starred in the following coefficients) at lag multiples of 12 months: r_{12}* = -0.515, SE = 0.058; r_{24}, = -0.104, SE = 0.071; r_{36}* = 0.207, SE = 0.073; r_{48} = 0.026, SE = 0.076; and r_{60}* = -0.20, SE = 0.077. The SPACF (Fig. 8) for the MADLTs had a slowly decaying (more slowly than exponential decay) series of spikes at lag multiples of 12 months. For MADMTs, the SACF (Fig. 9) had a large negative spike (r_{12} = -0.516, SE = 0.059) and no further significant spikes at lag multiples of 12 months. The SPACF (Fig. 10) had slowly decaying spikes at multiples of 12 months.

Intra-annual variation for the high, low, and midrange temperature series included a first-order autoregressive process. The SACFs had decaying coefficients at lags 1 month through 3 or more months, and the SPACFs had significant coefficients at lag 1 month, followed by a cutoff at higher lags. An initial model consisting of a first-order moving average process for interannual variation and a first-order autoregressive process for intra-annual variation was fit to each temperature series and tested for adequacy. Generally, the SACF and SPACF of the residuals indicated either or both interannual and intra-annual variation were more complex than provided for in the initial model.

For MADHTs, an intra-annual autoregressive term at lag 6 months was added after examination of the SACF and SPACF for residuals of the initial model. Statistics of the fit (Table 5) showed all coefficients (excluding the constant) were significant and weakly correlated. The l-month ahead forecast for transformed high temperature (MADHT) in January 1994 (Table 5) included linear terms of the transformed MADHT for the previous January (1993), the difference in transformed December MADHTs of the two previous years (1992 and 1993), the difference in transformed July MADHTs of the two previous years (1992 and 1993), and the residual for the previous January (1993). A general forecast equation for any month would show that events 1, 6, 12, 13, and 18 months previous to that month were of value for predicting MADHTs. Little or no additional information occurred in the residuals as evidenced by their SACF and SPACF (not shown). Two autocorrelation coefficients (at lags of 47 and 50 months) for residuals from this final MADHT model were statistically significant (three were expected by chance); and five partial autocorrelation coefficients (at lags of 22, 32, 47, 50, and 60 months) for the residuals were significant (three were expected by chance). The Ljung-Box test supported the conclusion that the residuals were indistinguishable from white noise for lags up to 60 months (Table 5).

For MADLTs, an interannual autoregressive term at lag 36 months was added to the initial model. Statistics of the fit (Table 6) showed all coefficients (excluding the constant) were significant and all but one pair were weakly correlated. The one-month ahead forecast for transformed low temperature (MADLT) in January 1994 (Table 6) included linear terms of the transformed MADLT for the previous January (1993), the difference in transformed December MADLTs of the two previous years (1992 and 1993), the difference in transformed January MADLTs of three and four years previous (1990 and 1991), and the residual for the previous January (1993). A general forecast equation for any month would show events 1, 12, 13, 36, and 48 months earlier than that month were of value to predicting MADLTs. Little or no additional information occurred in the residuals as evidenced by their SACF and SPACF (not shown). Two autocorrelation coefficients (at lags of 47 and 60 months) for residuals from this final low temperatures model were statistically significant (three were expected by chance); and four partial autocorrelation coefficients (at lags of 47, 49, 58, and 60 months) for the residuals were significant (three were expected by chance). The Ljung-Box test supported the conclusion that the residuals were indistinguishable from white noise for lags up to 60 months (Table 6.h

For MADMTs, an interannual autoregressive term at lag 36 months was added to the initial model just as had been done for MADLTs. Statistics of the fit (Table 7) showed all coefficients (excluding the constant) were significant and all but one pair were weakly correlated. Just as was the case for the low temperature series (MADLTs), the one-month ahead forecast for the transformed midrange temperature (MADMT) in January 1994 (Table 7) included linear terms of the transformed MADMT for the previous January (1993), the difference in transformed December MADMTs of the two previous years (1992 and 1993), the difference in transformed January MADMTs of 3 and 4 years previous (1990 and 1991), and the residual for January 1993. A general forecast equation for any month would show that events 1, 12, 13, 36, and 48 months prior to that month were of value to predicting MADMTs. Little or no additional information occurred in the residuals as evidenced by their SACF and SPACF (not shown). One autocorrelation coefficient (at lag of 47 months) for residuals from this final midrange temperatures model was statistically significant (three were expected by chance); and three partial autocorrelation coefficients (at lags of 47, 58, and 60 months) for the residuals were significant (three were expected by chance). The Ljung-Box test supported the conclusion that the residuals were indistinguishable from white noise for lags up to 60 months (Table 7).

The SACFs and SPACFs for residuals of the final models for the three temperature series indicated possible need of additional terms with high lags. The SACFs for MADHTs, MADLTs, and MADMTs contained significant coefficients at lags of 47 and 50 months, 47 and 60 months, and 47 months, respectively. Also, the corresponding SPACFs contained significant coefficients at the following lags: 22, 32, 47, 50, and 60 months; 47, 49, 58, and 60; and 47, 58, and 60 months. All functions shared a significant coefficient at lag of 47 months. However, when the final models were augmented by an autoregressive term with lag of 47 months, this fitted coefficient was not statistically significant for any of the three series.

The final models for the three temperature series shared first-order moving-average terms for interannual variation and first-order autoregressive terms for intra-annual variation. The midrange and low temperature series shared an autoregressive coefficient of 36 months lag, whereas the high temperature series contained an autoregressive coefficient of 6 months lag.

Test-year forecasts from the final models and three simpler models supported certain of the simpler models. For MADHTs, mean square of forecast errors by the final model (parameterized by μ, θ_{12}, ϕ_1, and ϕ_6)was smallest in two test years; that of the next simpler model (parameterized by μ, θ_{12}, and ϕ_1) was smallest in one test year; and that of the simplest model (parameterized by μ and θ_{12}) was smallest in two test years as well as overall (5 years combined). For MADLTs, the mean square of forecast errors by the final model (parameterized by μ, θ_{12}, ϕ_1, and ϕ_{36})was smallest in two test years; that of the next simpler model (parameterized by μ, θ_{12}, and ϕ_1) was smallest in two test years as well as overall (5 years combined); and that of the simplest model (parameterized by μ and θ_{12}) was smallest in one test year. For MADMTs, the mean square of forecast errors by the final model (parameterized by μ, θ_{12}, ϕ_1, and ϕ_{36})was smallest in one test year; that of the next simpler model (parameterized by μ, θ_{12}, and ϕ_1) was smallest in two test years as well as overall (5 years combined); and that of the simplest model (parameterized by μ and θ_{12}) was smallest in two test years. For high, low, and midrange daily temperatures, the final model was surpassed in overall (5 years combined) forecast accuracy and matched in certain years for best forecast accuracy by one of the simpler models.

Precipitation and Snowfall

Precipitation was recorded as the monthly sum of amounts of liquid water collected daily (rainfall and melted snowfall). Precipitation (Fig. lla, Table 8) and snowfall (Fig. 11b, Table 9) were computed for each month of the calendar year (January through December). In addition, snowfall was computed for the snow year of July through June (Table 10). Although this snow year differs from the U.S. Geological Survey hydrological year of October through September, it placed the rare September snowfalls at the beginning of the oncoming winter rather than the end of the passing summer. Mean monthly precipitation ranged from 7.27 cm in April to 22.02 cm in October (Fig. 12). The monthly extremes were 0.18 cm in February 1989 and 41.81 cm in September 1991. The annual cycle was discerned easily ($p < 0.001$) but accounted for only about 32% of the total variation (Table 4). Snowfall occurred from September through May (Fig. 12), although May, September, and October normally received only trace amounts. Mean monthly snowfall for November through April was 39 cm. January has the highest average snowfall (mean of 71 cm with a range of 5 cm in 1987 to 180 cm in 1982). The annual cycle was evident ($p < 0.001$) but accounted for only about 43% of total variation.

Annual precipitation between 1963 and 1993 (Table 8) ranged from a low of 128.45 cm in 1965 to a high of 215.39 cm in 1991. Average annual precipitation was 157.93 cm (SD = +43.46 cm). The annual series contained an irregular upward trend, interrupted about the time of the 1982-83 El Niño (Fig. 13). Slope of the trend line (Table 4) showed that precipitation increased over the 29 years (1964-92) fitted at a rate of 1.128 cm y^{-1} (SE = 0.400, $p < 0.01$). The Durbin-Watson statistic was 1.914 and provided no evidence of lag-l autocorrelation in residuals from the fitted line.

Interannual month differences in logarithm-transformed precipitation values produced simple SACF and SPACF (Figs. 14, 15). An annual component of the transformed precipitation series was included as a first-order moving-average process: the SACF had a highly significant spike (r_{12} = -0.489, SE = 0.055) at lag equal to 12 months (and no further significant autocorrelation coefficients at higher lag multiples of 12 months); and the SPACF decayed toward zero at lags of 12, 24, and 36 months. Inconsistent with the simple first-order annual moving-average process was the slow decay (slower than exponential decay) of the simple partial autocorrelation coefficients at lags of 48 and 60 months. None of the remaining sample autocorrelation coefficients were significant. The simple first-order annual moving-average model was fit to the series of interannual month differences in annual precipitation. The SACF and SPACF of the residuals indicated an autoregressive coefficient of lag equal to 48 months was needed: both functions contained significant coefficients at that lag.

A revised model with a moving-average parameter of lag equal to 12 months and autoregressive parameter of lag equal to 48 months was fit. Both the annual moving-average parameter, θ_{12}, ($p < 0.001$) and autoregressive parameter , ϕ_{48}, ($p < 0.05$) were detected (Table 11); but the estimate for p did not differ significantly from zero. The parameter estimates were weakly correlated. The one-month ahead forecast for transformed precipitation in January 1994 (Table 11) included linear terms of the transformed precipitation during the previous January (1993), the difference in transformed January precipitation 4 and 5 years earlier (1989 and 1990), and the residual for the previous January (1993). A general forecast equation for any month would show events 12, 48, and 60 months in advance of the current month were of value to predicting precipitation. Contrary to the temperature series, precipitation of the previous month was not useful in prediction. Apparently little or no additional information occurred in the residuals as evidenced by their SACF and SPACF (not shown); none of the residual autocorrelation coefficients nor partial autocorrelation coefficients was significant. The Ljung-Box test supported the conclusion that the residuals were indistinguishable from white noise for lags up to 60 months (Table 11).

Test-year forecasts from the final model (parameterized by θ_{12}, and ϕ_{48}) and a simpler model (parameterized by μ and θ_{12}) were inconclusive: the mean square of forecast errors of the simpler model was smaller in four of the five test years, but the overall (5 years combined) mean square of forecast errors of the final model was smaller.

Annual snowfall (calendar year) between 1963 and 1993 (Table 9) ranged from a low of 50.55 cm (1987) to a high of 438.66 cm (1971) with an average of 236.28 cm (SD = +99.41 cm). The series contained an irregular downward trend until the mid-1980s, whereafter snowfall rose above the long-term mean in 1989, 1990, and 1991 before falling below the mean again in 1992 and 1993 (Fig. 16). Slope of the trend line (Table 4, Fig. 16) indicated snowfall decreased over the 29 years fitted (1964-92) at a rate of 3.8 15 cm yr^{-1} (SE = 2.165, $p < 0.1$); however, this slope was not statistically significant at the usual 0.05 level. The Durbin-Watson statistic was 1.452 and was inconclusive regarding lag-l autocorrelation in residuals from the fitted line. Inclusion of first-order autocorrelated error into the model structure did not alter the slope substantially (decrease in snowfall of 3.771 cm yr^{-1}) , but reduced its statistical significance (SE = 2.773, $p < 0.19$). Differences in annual snowfall in successive years reached more than 250 cm twice (1970-71 and 1988-89) and more than 100 cm 11 times (Table 9). Snowfall during the snow year (July through June, but essentially late September through early May) ranged from a low of 84.58 cm (1976-77) to a high of 421.64 cm (1975-76) the preceding year, with an average of 223.78 cm (SD = +109.14 cm) (Table 10).

No snow fell during June, July, and August, and average snowfall for May and September was less than 0.2 cm. Therefore, these 5 months were omitted from the time series for ARIMA modeling, and snowfall for the remaining 7 months was analyzed. Interannual (7 months) differences in logarithm-transformed snowfall produced simple SACF (Fig. 17) and SPACF (Fig. 18). The functions provided clear indication of an interannual moving-average process of order 1: the SACF had a highly significant spike at lag of 7 months (r_7, = -0.531, SE = 0.077), and the SPACF decayed regularly at lag multiples of 7 months. Less clear from the two functions was the process within years: the SACF had three significant spikes at lags of 2, 9, and 26 months, and the SPACF had significant spikes at nonannual lags of 2, 6, 19, and 30 months. The SACF and SPACF spikes at lag 2 months (r_2 = 0.262, SE = 0.070 ; $\hat{\phi}_{22}$ = 0.262, SE = 0.070) exceeded three standard errors, and were further remarkable for absence of adjoining significant values. Intra-annual processes of moving average, autoregressive, and their mixture up to order 2 were fit; an autoregressive coefficient for a lag of 2 months best described the series. Statistics of the fit of an annual, first-order, moving-average process and an intra-annual autoregressive process with a lag of 2 months (Table 12) indicated the annual moving-average parameter, θ_7, was highly significant ($p < 0.001$) and its estimate was only weakly correlated with that of the other parameters; that is, the constant, μ, and the autoregressive coefficient of lag 2 months, ϕ_2. The estimate of the intra-annual autoregressive parameter, ϕ_2, was also significant ($p < 0.01$). A general forecast equation for any month (Table 12) would show that snowfall 2, 7 (= 1 year), and 9 (= 1 year and 2 months) months in advance of that month was of value to predicting snowfall. The estimate for μ did not differ significantly from zero. Little or no additional information occurred in the residuals as evidenced by their SACF and SPACF (not shown). None of the residual autocorrelations to lag 35 months (5 years) was significant at $\alpha = 0.05$, although that at lag 26 months would have been significant at $\alpha = 0.10$; about two significant tests were expected from sampling error even when all autocorrelations were actually zero. The Ljung-Box test confirmed that the residuals were indistinguishable from white noise for lags up to 35 months (5 years) (Table 12).

Test-year forecasts from the final model (parameterized by μ, θ_7, and ϕ_2) and a simpler model (parameterized by μ and θ_7) supported the final model: the mean square of forecast errors for the final model was smaller in three of the five test years, and the overall (5 years combined) mean square of forecast errors for the final model was smaller as well.

Auke Bay Saltwater Temperatures

Auke Bay Laboratory

Sea surface temperatures of Auke Bay are affected by several factors, most important of which are daily solar heating, the annual cycle of cooling and heating, exchange of water with adjacent channels, exposure to wind mixing, proximity to streams and surface freshwater sources, and rain and snowfall conditions. Because the Auke Bay Laboratory is located in the northeastern corner of Auke Bay and is well protected from the prevailing southeasterly winds, surface waters at the Auke Bay Laboratory float are poorly mixed by the winds, strongly influenced by the outflow of Auke Creek, and subject to accumulation of a freshwater lens during heavy rains and snowfall. Surface temperatures at the Auke Bay Laboratory tend to be lower in the winter and higher in the summer than those in either the middle of Auke Bay (see Auke Bay Monitor Station below) or the more exposed waters of Lynn Canal and Stephens Passage (Williamson 1965, Jones 1978). Sea surface temperatures for 1959-69 were taken in the morning, whereas temperatures were recorded in the afternoon from 1975 to present. Some differences in the temperatures of these two series are apparent (Figs. 19a-19c). Because these differences may have been caused by die1 warming effects, the 1959-69 data (Table 13) were summarized separately from the 1975-93 data (Table 14).

According to Hagen[2], oscillations in the daily recorded Auke Bay sea surface temperatures and in a 4-day running average of these values did not appear to be related to tidal cycles. The oscillations of the averaged data could be artifacts of smoothing called the Slutzky-file effect (Kendall and Stuart 1966).

Monthly averages of daily sea surface temperatures (MADSSTs) fluctuated very regularly (Fig. 20), with 92% of the variation explained by the annual cycle ($p < 0.001$, Table 4). MADSST ranged from a minimum of 2°C in February to a maximum of 16°C in July. Annual average of MADSSTs between 1975 and 1992 ranged from a low of 6.9ºC in 1976 to a high of 8.9ºC in 1993 (Fig. 21). Long-term average of MADSSTs was 8.1ºC. The annual series began with lowest annual temperatures in 1975 and 1976 and thereafter fluctuated with increasing variation (Fig. 21). The slope of the trend line suggested sea surface temperature increased over the 17 years fitted at a rate of 0.031 ºC $year^{-1}$, but that increase was not statistically significant (SE = 0.019, $p < 0.12$). The Durbin-Watson statistic was 1.768 and provided no evidence of lag-l autocorrelation in residuals from the fitted line.

Interannual month differences in logarithm-transformed MADSST produced simple SACF and SPACF (Figs. 22, 23). The annual component of the transformed MADSST series was a first-order moving-average process: the SACF had a highly significant spike ($r_{12} = -0.405$, SE = 0.092) at lag equal to 12 months (and no further significant autocorrelation coefficients at higher lag multiples of 12 months), and the SPACF decayed

[2]Hagen, P. T. 1988. Time series analysis of sea surface temperatures in Auke Bay, Alaska. Juneau Center for Fisheries and Ocean Sciences, University of Alaska-Fairbanks, 29 p., unpublished.

toward zero at lags of 12, 24, and 36 months. The intra-annual component was a first-order autoregressive process; the SACF appeared to decay exponentially from lags 1 through 5 months (those for lags of 1 and 2 months were highly significant); and the SPACF had a spike at lag of 1 month [$\hat{\phi}_{11}$ = 0.520, SE = 0.0701. In addition, the SACF had one additional significant coefficient at lag equal to 13 months, and the SPACF had three significant coefficients at lags of 13, 23, and 25 months; roughly two significant coefficients were expected from sampling variation for either case if all remaining actual coefficients were zero. The simple model with first-order annual moving-average and first-order intra-annual autoregressive terms was fit to the series of interannual month differences in MADSST. Statistics of the estimation (Table 15) indicated the annual moving-average parameter, θ_{12}, and the intra-annual autoregressive parameter, ϕ_1, were highly significant ($p < 0.001$). The estimate for μ was significantly different from zero, although its value was small, meaning a slight deterministic trend underlay the differenced series. All parameter estimates were weakly correlated. The one-month ahead forecast for transformed SST in January 1994 (Table 15) included linear terms of transformed SST during the previous January (1993), the difference in transformed December SST of the two previous years (1992 and 1993), and the residual for the previous January (1993). A general forecast equation for any month would show that events 1, 12, and 13 months prior were of value in predicting sea surface temperature. Apparently little or no additional information occurred in the residuals, as evidenced by their SACF and SPACF (not shown). None of the residual autocorrelations to lag 45 months were significant at α = 0.05 (about two significant tests were expected by chance), although that at lag of 10 months would be significant at α = 0.10 (roughly four significant tests at this level would have been expected by chance alone). The Ljung-Box test (Table 15) supported the conclusion that the residuals were indistinguishable from white noise for lags up to 45 months.

Mean square of forecast errors for the final model (parameterized by μ, θ_{12}, and ϕ) was smallest in all 5 test years as compared to that of the simpler model (parameterized by μ and θ_{12}).

Auke Bay Monitor Station

Although the records for sea surface temperature extend back to 1959, the observations were not taken on a regular schedule nor was the method of observation constant (Table 16). The irregular nature of the data did not permit clear interpretation of interannual variation; therefore, only the means and extremes for the annual surface temperature cycle at the Auke Bay Monitor Station are presented (Fig. 24).

Auke Lake Watershed Stream Flows and Temperatures

Lake Creek

Average daily discharge of Lake Creek (1963-73) was 0.36 m3s-^{1} (12.9 cfs) (U.S.G.S. 1974). Average daily discharge is lowest (0.10 m3s-‘) from December through February and highest in May (0.81 m^3s^{-1}) following the annual increase in runoff from melting snow (Fig. 25). Maximum instantaneous stream discharges up to 27.75 m^3s^{-1} (980 cfs) typically followed heavy rains in September and October (Table 17). No measurable surface flow occurred during hard winter freezes and summer dry spells (e.g., March, June, and July 1969).

The available temperature records (Table 18, Fig. 26) for October 1963 through September 1973 showed that Lake Creek was strongly influenced by seasonal snow melt and runoff. Lake Creek stream temperatures were generally lower than Auke Creek and Auke Lake throughout the year. Freezing or near-freezing conditions occurred from November through early May of most years, when flows were at annual minima and often not evident as a surface flow at the gage site.

Auke Creek

Average daily discharge of Auke Creek (1962-75) was 0.49 m^3s^{-1} (17.8 cfs) (U.S.G.S. 1976). Average daily discharges are lowest from December through March (0.22-0.26 m^3s^{-1}) and highest in May (0.89 m^3s^{-1}) following the annual increase in runoff from melting snow (Fig. 27). Stream discharges ranged from no measurable surface flow during hard winter freezes and summer dry periods to maximum instantaneous flows up to 9.85 m^3s^{-1} (348 cfs) following late summer and early fall rain storms (Table 19).

Auke Creek stream temperatures, like those of Lake Creek, were strongly influenced by seasonal snow melt and runoff. Temperatures were at the annual minima from late December through mid-March, when stream flows were lowest and Auke Lake was ice-covered (Table 20, Fig. 28). Maximum temperatures occurred from June through August during periods of low runoff and when the surface waters of Auke Lake were strongly warmed by incident sunlight.

Auke Creek Hatchery and Auke Lake

Temperature of the freshwater flow into the Auke Creek Hatchery was lowest in January and February and highest in July and August (Table 21, Fig. 29). Temperatures were near 3°C from late November through late April, approximately the same period as total ice cover on Auke Lake. During winter, daily temperatures varied from 1.9ºC to 3.8ºC. During the warmest part of the summer, temperatures averaged near 8.OºC and ranged from near 5.OºC in early July to near 14.OºC in late July and early August.

Auke Lake Freeze-Up and Ice-Out

Dates of freeze-up and ice-out are indicators of heat loss and accumulation in Auke Lake and of autumnal and vernal turnover. Freeze-up (complete ice cover) does not occur until after turnover in November and surface waters cool to 0°C. Frequently, ice formed intermittently around the edge of the lake for several days to 2 weeks before the lake iced over completely. November 25 was the average last day of float plane operations in Auke Lake and was usually 2 weeks before the lake froze over completely.[3] Freeze-up occurred as early as 15 November (1963) to as late as 2 January (1994).

Ice-out is associated with the vernal turnover and often is quite rapid. Auke Lake may go from less than 10% open water to over 95% open water within 3 or 4 days. For our purposes, we have determined ice-out as the day the lake surface was 90% open water. Ice-out (Table 22) on Auke Lake normally occurred in late April or early May; 20 April was the average date of ice-out for the 33 years of available data. Earliest date of ice-out was 11 January 1978 and latest ice-out date was 20 May 1972.

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[3]Lief Lie, National Weather Service, Juneau, Alaska. Pers. commun., 3 Dec. 1992.

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TABLES

Table 1 .--Monthly averages of daily high temperature (°C) (MADHTs) at Auke Bay, Alaska, 1963-93.

	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975
Jan		0.84	–1.85	–6.83	–1.90	–2.07	–8.40	–1.96	–6.10	–4.48	–2.74	–4.48	–1.79
Feb	3.36	4.03	0.06	2.18	2.69	1.96	1.18	5.21	2.02	–1.85	0.73	2.30	–0.28
Mar	3.98	2.46	6.22	4.09	1.96	5.54	4.09	6.22	3.36	1.34	4.48	3.42	4.48
Apr	9.30	7.95	9.13	8.79	9.80	7.45	9.58	8.40	8.23	5.94	8.85	8.18	8.06
May	16.35	12.82	10.98	10.64	14.62	15.62	15.85	12.71	11.03	11.82	12.54	13.89	13.16
Jun	14.73	17.58	16.13		19.82	17.53	21.11	15.40	18.54	15.01	15.85	15.23	14.73
Jul	18.14	17.25	19.82	20.78	17.70	19.88	16.07	16.35	20.78	21.17	16.35	17.53	17.75
Aug	19.54	16.41	20.05		17.02	19.82	14.06	15.29	17.86	17.02	15.46	18.26	17.25
Sep	14.22	14.34	15.34	13.38	13.89	12.10	15.79	11.98	12.66	13.10	13.89	14.78	13.10
Oct	9.86	9.18	9.07	7.00	9.24	7.95	10.42	8.51	6.94	7.50	7.56	8.12	8.74
Nov	0.45	2.24	2.74	1.12		4.31	3.86	2.46	2.46	3.98	–1.12	4.59	0.78
Dec	3.02	–5.26	0.28	–0.34		–2.8	4.14	–2.35	–1.18	–1.4	0.90	3.25	–1.51

	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988
Jan	0.56	2.91	–0.73	–3.14	–3.86	5.49	–6.66	0.78	1.68	4.14	2.97	2.56	–0.65
Feb	0.62	6.38	3.81	–5.82	4.37	2.80	–1.68	2.80	3.92	–0.34	1.85	3.11	2.70
Mar	3.58	5.38	5.32	6.44	4.09	7.56	4.31	6.50	6.94	4.70	4.87	4.72	6.22
Apr	9.63	9.18	11.54	11.76	9.46	8.01	6.78	11.14	11.52	7.00	8.06	9.18	9.89
May	11.98	14.56	12.88	12.77	15.06	16.13	11.37	14.67	15.74	11.76	13.44	13.33	14.33
Jun	15.34	17.47	17.86	15.62	18.03	17.19	19.66	18.65	16.24	15.90	17.36	14.95	17.92
Jul	19.04	18.93	17.08	18.42	16.69	17.42	19.38	19.60	17.53	18.42	18.48	20.29	16.78
Aug	18.03	20.55	19.77	21.39	17.92	17.70	17.25	16.07	18.87	16.46	16.00	19.19	15.99
Sep	14.22	15.23	14.06	14.73	13.33	13.50	13.61	13.05	14.56	13.55	15.62	12.21	7.61
Oct	8.57	9.07	9.46	10.64	9.41	8.57	7.28	7.73	7.78	6.50	9.45	8.27	9.03
Nov	6.55	2.13	2.13	4.93	5.43	4.59	1.29	2.35	1.96	–2.07	1.40	5.25	3.94
Dec	3.14	–3.64	1.18	–0.06	–3.25	–0.11	1.74	–3.53	–1.51	2.74	3.42	2.74	1.50

Table 1.--Continued.

	1989	1990	1991	1992	1993	Mean[1]	Max.[1]	Min.[1]	Extreme[1]
Jan	–0.96	–1.99	–1.68	3.33	–1.15	–1.81	5.49	–8.40	12.88
Feb	1.01	–1.06	3.68	2.95	2.96	1.86	6.38	–5.82	14.56
Mar	3.43	5.92	4.03	5.96	5.58	4.75	17.56	1.34	12.88
Apr	12.25	11.41	9.69	9.59	12.47	9.30	12.47	5.94	20.72
May	14.02	14.77	13.97	12.72	17.74	13.65	17.74	10.64	24.64
Jun	18.55	17.38	17.43	19.45	19.21	15.96	21.11	14.73	29.68
Jul	21.35	20.19	17.06	18.10	21.15	18.42	21.35	16.07	31.36
Aug	19.82	19.47	16.86	18.07	19.86	16.65	21.39	14.06	28.00
Sep	15.08	13.54	12.61	11.31	15.52	13.55	15.79	7.61	21.84
Oct	8.51	7.73	7.99	6.85	10.18	8.43	10.64	6.50	15.68
Nov	1.72	–1.10	3.63	4.72	4.57	1.96	6.55	–2.07	12.32
Dec	3.92	–2.46	2.02	–1.55	3.39	–0.50	4.14	–5.26	9.52

[1]Mean is the average of the MADHTs, Max. is the highest MADHT, Min. is the lowest MADHT, Extreme is the highest daily high temperature observed.

Table 2.--Monthly averages of daily low temperature (ºC) (MADLTs) at Auke Bay, Alaska, 1963-93.

	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975
Jan		–3.64	–7.84	–13.40	–7.78	–8.62	–16.30	–7.39	–11.80	–12.00	–8.51	–10.60	–6.05
Feb	–2.69	0.00	–6.50	–4.59	–2.41	–5.04	–6.94	–0.45	–3.14	–9.41	–6.16	–2.91	–7.39
Mar	–3.08	–4.59	–2.35	–3.08	–6.89	–0.73	–2.18	0.17	–3.86	–5.21	–1.06	–7.34	–3.19
Apr	–1.85	0.17	–0.56	–0.73	–1.29	0.22	0.67	0.90	–0.34	–2.41	0.90	0.28	–0.11
May	3.86	2.52	2.52	3.19	3.86	4.59	4.76	4.2	2.13	2.24	3.92	3.19	3.58
Jun	6.78	8.46	5.82	7.56	9.02	7.90	9.63	7.67	7.45	6.27	6.83	6.27	7.00
Jul	9.46	9.18	9.86	10.36	9.46	9.74	9.41	8.85	10.42	9.80	9.13	7.95	10.02
Aug	9.69	8.79	9.52	8.96	9.91	9.41	7.28	8.68	10.08	9.91	7.90	8.51	8.62
Sep	9.24	6.16	7.56	7.73	8.12	6.83	7.73	6.10	6.66	5.60	5.94	6.72	8.18
Oct	4.37	3.98	3.98	2.07	3.86	1.96	3.64	3.02	1.85	5.66	2.97	3.42	2.58
Nov	–4.54	–1.74	–2.91	–4.65		0.00	–1.40	–3.02	–1.74	–0.45	–7.78	0.67	–3.19
Dec	–2.52	–12.00	–3.98	–5.15		–8.29	–0.06	–6.89	–7.84	–6.05	–3.19	0.73	–6.05

	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988
Jan	–3.81	0.28	–5.77	–6.44	–8.90	1.06	–12.30	–3.42	–1.90	0.50	–0.45	–1.32	–4.59
Feb	–6.10	2.97	–2.91	–13.70	–1.62	–1.68	–8.01	–1.46	0.06	–4.93	–4.70	–0.86	–2.49
Mar	–2.24	0.00	–1.46	0.11	–1.46	0.90	–2.58	–2.13	1.62	–1.62	–0.34	–3.79	0.29
Apr	0.73	2.46	0.84	–0.17	2.13	0.56	–1.01	1.40	2.07	–0.28	–0.67	1.89	1.64
May	3.92	4.14	4.82	5.26	5.71	6.66	3.25	5.94	4.82	3.75	4.14	5.43	4.77
Jun	7.06	8.68	8.57	8.23	8.85	8.57	8.79	9.18	9.41	5.77	7.62	7.24	7.95
Jul	8.96	10.58	9.63	10.64	10.25	10.70	10.25	10.19	9.63	5.43	9.80	9.86	9.09
Aug	9.74	11.14	10.08	10.81	8.96	10.42	9.02	9.86	9.35	8.06	8.97	9.18	9.16
Sep	7.17	7.56	7.45	7.06	7.17	7.17	7.84	5.77	6.27	5.15	5.86	7.74	6.54
Oct	4.03	3.64	5.77	5.77	5.10	3.81	3.47	3.75	1.85	2.30	5.35	4.35	5.24
Nov	2.86	–2.41	–2.30	1.40	2.58	1.01	–2.46	–1.68	–2.35	–7.78	–2.54	1.96	–0.13
Dec	0.06	–8.12	–2.63	–4.26	–8.23	–2.24	–1.79	–8.12	–6.38	–1.12	–0.06	–0.81	–2.17

Table 2.--Continued.

	1989	1990	1991	1992	1993	Mean[1]	Max.[1]	Min.[1]	Extreme[1]
Jan	–4.72	–5.44	–6.61	0.03	–6.47	–6.52	1.06	–16.30	–24.60
Feb	–7.84	–6.82	–0.38	–2.24	–4.14	–4.01	2.97	–13.70	–26.30
Mar	–5.45	–0.65	–2.51	–0.27	–1.39	–2.14	1.62	–7.34	–19.60
Apr	0.62	2.00	0.77	1.89	2.17	0.48	2.46	–2.41	–11.20
May	5.32	6.53	9.74	4.35	6.78	4.51	9.74	2.13	–2.80
Jun	9.11	9.65	0.77	8.44	9.74	7.68	9.65	0.77	0.00
Jul	11.83	11.20	4.68	10.73	11.38	9.57	11.83	4.68	–1.12
Aug	10.79	10.91	9.26	9.54	10.29	9.42	11.14	7.28	2.80
Sep	8.44	8.70	10.10	5.25	8.17	7.13	10.10	5.15	–2.80
Oct	3.29	2.69	2.22	1.70	5.82	3.59	5.77	1.70	–10.60
Nov	–1.66	–5.54	0.25	1.23	0.43	–2.2	2.86	–7.78	–20.20
Dec	0.11	–7.36	–0.99	–6.03	0.31	–4.65	0.73	–12.00	–25.80

‘Mean is the average of the MADLTs, Max. is the highest MADLT, Min. is the lowest MADLT, Extreme is the lowest daily low temperature observed.

Table 3.--Monthly averages of daily midrange temperature (°C) (MADMTs) at Auke Bay, Alaska, 1963-93.

	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975
Jan		−1.40	−4.84	−10.10	−4.84	−5.35	−12.30	−4.68	−8.96	−8.23	−5.63	−7.53	−3.92
Feb	0.34	2.02	−3.22	−1.20	0.14	−1.54	−2.88	2.38	−0.56	−5.63	−2.72	−0.31	−3.84
Mar	0.45	−1.06	1.93	0.50	−2.4	2.41	0.95	3.19	−0.25	−1.93	1.71	−1.96	0.64
Apr	3.72	4.06	4.28	4.03	4.26	3.84	5.12	4.65	3.95	1.76	4.87	4.23	3.98
May	7.25	6.50	5.21	4.96	6.66	7.92	8.26	6.80	5.35	4.70	6.72	7.08	6.52
Jun	10.75	13.02	10.98		14.42	12.71	15.37	11.54	12.99	10.64	11.34	10.75	10.86
Jul	12.46	12.85	12.82	14.17	13.36	13.89	12.85	12.01	14.11	13.72	11.59	11.90	12.38
Aug	14.62	12.60	14.78		13.47	14.62	10.67	11.98	13.97	13.47	11.68	13.38	12.94
Sep	11.73	10.25	11.45	10.56	11.00	9.46	11.76	9.04	9.66	9.35	9.91	10.75	10.64
Oct	7.11	6.58	6.52	4.54	6.55	4.96	7.03	5.77	4.40	6.58	5.26	5.77	5.66
Nov	−2.04	0.25	−0.08	−1.76		2.16	1.23	−0.28	0.36	1.76	−4.45	2.63	−1.20
Dec	0.25	−8.65	−1.85	−2.74		−5.54	2.04	−4.62	−4.51	−3.72	−1.15	1.99	−3.78

	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988
Jan	−1.62	1.60	−3.25	−4.79	−6.38	3.28	−9.49	−1.32	−0.11	2.32	1.26	0.62	−2.62
Feb	−2.74	4.68	0.45	−9.74	1.37	0.56	−4.84	0.67	1.99	−2.63	−1.43	1.12	0.11
Mar	0.67	2.69	1.93	3.28	1.32	4.23	0.87	2.18	4.28	1.54	2.27	0.46	3.26
Apr	5.18	5.82	6.19	5.80	5.80	4.28	2.88	6.27	6.80	3.36	3.70	5.54	5.77
May	6.36	8.51	6.86	6.30	8.60	8.34	5.18	8.04	8.90	5.74	6.38	7.61	7.99
Jun	11.20	13.08	13.22	11.93	13.44	12.88	14.22	13.92	12.82	10.84	12.49	11.10	12.94
Jul	13.05	13.80	12.82	13.33	12.77	12.99	14.08	14.39	13.47	12.10	13.05	13.76	12.37
Aug	13.89	15.85	14.92	16.10	13.44	14.06	13.13	12.96	14.11	12.26	12.49	14.19	12.57
Sep	10.70	11.40	10.75	10.89	10.25	10.33	10.72	9.41	10.42	9.35	10.74	9.98	7.07
Oct	6.30	6.36	7.62	8.20	7.25	6.19	5.38	5.74	4.82	4.40	7.40	6.31	7.13
Nov	4.70	−0.14	−0.08	3.16	4.00	2.80	−0.59	0.33	−0.20	−4.93	−0.57	3.60	1.90
Dec	1.60	−5.88	−0.73	−2.16	−5.74	−1.18	−0.03	−5.82	−3.95	0.81	1.68	0.97	−0.33

Table 3 .--Continued.

	1989	1990	1991	1992	1993	Mean[1]	Max.[1]	Min.[1]
Jan	–2.84	–3.71	–4.14	1.68	–3.81	–4.16	3.28	–12.30
Feb	–3.41	–3.94	1.65	0.36	–0.59	–1.08	4.68	–9.74
Mar	–1.01	2.64	0.76	2.84	2.09	1.30	4.28	–2.46
Apr	6.43	6.70	5.23	5.74	7.32	4.89	6.80	1.76
May	7.32	8.38	7.37	8.53	12.26	7.18	8.90	4.70
Jun	13.83	13.52	9.10	13.94	14.48	11.40	15.37	9.10
Jul	15.23	14.92	8.92	14.41	16.26	13.12	15.23	8.92
Aug	15.31	15.19	13.06	13.80	15.07	12.59	16.10	10.67
Sep	11.76	11.12	11.35	8.28	11.84	10.34	11.76	7.07
Oct	5.90	5.21	5.10	4.27	8.00	6.01	8.20	4.27
Nov	0.03	–3.32	1.94	3.06	2.50	–0.12	4.70	–4.93
Dec	2.01	–4.91	0.52	–3.74	1.84	–2.57	2.04	–8.68

[1]Mean is the average of the MADMTs, Max. is the highest MADMT, Min. is the lowest MADLT.

Table 4.--Annual means, extremes, percentage of total variation (%) in weather variable due to an annual cycle and its statistical significance (p), and slope of long-term trend and its statistical significance (p), for monthly values of average daily high (MADHT), low (MADLT), and midrange (MADMT) temperatures, precipitation, snowfall, and average daily sea surface temperature (MADSST).

Variable	Mean annual	Minimum annual	Maximum annual	Variation due to annual cycle		Trend	
				%	*p*	slope	*p*
MADHT	8.52°C	7.43°C	10.96°C	88.9	<0.001	0.029°C yr^{-1}	0.057
MADLT	1.90°C	0.33°C	3.88°C	83.5	<0.001	0.066°C yr^{-1}	<0.001
MADMT	4.91°C	3.85°C	7.31°C	88.5	<0.001	0.047°C yr^{-1}	<0.001
Precipitation	157.93 cm	128.45 cm	215.39 cm	31.6	<0.001	1.128 cm yr^{-1}	<0.01
Snowfall	236.28 cm	50.55 cm	438.66 cm	42.8	<0.001	-3.815 cm yr^{-1}	<0.1
MADSST	8.1°C	6.9°C	8.9°C	92.1	<0.001	0.031°C yr^{-1}	<0.12

Table 5.--Conditional least-squares estimates of the moving-average and autoregressive parameters necessary to describe interannual month differences in average daily high temperature series, and statistics of the fit.

Model: $(1-B^{12})z_t = \mu + \dfrac{1-\theta_{12}B^{12}}{1-\phi_1 B^1 - \phi_6 B^6} a_t$, where $z_t = \ln(\mathrm{MADHT}_t + 20°\mathrm{C})$, $t = 1, 2, \ldots, 360$.

Parameter	Estimate	Standard Error	t statistic	Probability	Lag
μ	0.0001686	0.0013787	0.12	>0.9	0
ϕ_1	0.26481	0.05287	5.01	<0.001	1
ϕ_6	–0.10711	0.05175	-2.07	<0.05	6
θ_{12}	0.81791	0.03198	25.57	<0.001	12

Correlations of Estimates

Parameter	μ	ϕ_1	ϕ_6	θ_{12}
μ	1	–0.018	–0.008	–0.071
ϕ_1	–0.018	1	0.116	–0.049
ϕ_6	–0.008	0.116	1	–0.074
θ_{12}	–0.071	–0.049	–0.074	1

Ljung-Box autocorrelation check of residuals

To Lag	Chi Square	Degrees of Freedom	Probability
6	3.80	3	0.284
12	6.78	9	0.660
18	12.89	15	0.610
24	20.56	21	0.486
30	24.37	27	0.610
36	30.50	33	0.592
42	34.86	39	0.659
48	45.85	45	0.437
54	53.36	51	0.384
60	57.91	57	0.441

One-month-ahead forecast equation for transformed temperature of January 1994 from December 1993 (T = 360):

$$\tilde{z} = 0.00142 + z_{T-11} + 0.26481(z_T - z_{T-12}) - 0.10711(z_{T-5} - z_{T-17}) - 0.81791\hat{a}_{T-11}.$$

Table 6.--Conditional least-squares estimates of the moving-average and autoregressive parameters necessary to describe the interannual month differences in average daily low temperature series (MADLTs), and statistics of the fit.

Model: $(1-B^{12})z_t = \mu + \dfrac{1-\theta_{12}B^{12}}{1-\phi_1 B^1 - \phi_{36}B^{36}} a_t$, where $z_t = \ln(\mathrm{MADLT}_t + 20°\mathrm{C})$, $t = 1, 2, \ldots, 360$.

Parameter	Estimate	Standard Error	t statistic	Probability	Lag
μ	0.0015995	0.0025111	0.64	>0.9	0
ϕ_1	0.15721	0.05220	3.01	<0.01	1
ϕ_{36}	0.24941	0.06165	4.05	<0.001	36
θ_{12}	0.85871	0.03211	26.74	<0.001	12

Correlations of Estimates

Parameter	μ	ϕ_1	ϕ_{36}	θ_{12}
μ	1	–0.013	–0.009	–0.036
ϕ_1	–0.013	1	–0.090	–0.095
ϕ_{36}	–0.009	–0.090	1	0.453
θ_{12}	–0.036	–0.095	0.453	1

Ljung-Box autocorrelation check of residuals

To Lag	Chi Square	Degrees of Freedom	Probability
6	2.64	3	0.451
12	6.44	9	0.695
18	9.34	15	0.859
24	14.25	21	0.859
30	18.43	27	0.890
36	20.57	33	0.955
42	24.42	39	0.967
48	36.20	45	0.822
54	44.37	51	0.732
60	59.02	57	0.402

One-month-ahead forecast equation for transformed temperature of January 1994 from December 1993 (T = 360):

$$\tilde{z}=0.000949+z_{T-11}+0.15721(z_T-z_{T-12})-0.24941(z_{T-5}-z_{T-17})-0.85871\hat{a}_{T-11}.$$

Table 7.--Conditional least-squares estimates of the moving-average and autoregressive parameters necessary to describe the interannual month differences in average daily midrange temperature series, and statistics of the fit.

Model: $(1-B^{12})z_t = \mu + \frac{1 - \theta_{12}B^{12}}{1 - \phi_1 B^1 - \phi_{36}B^{36}}a_t$, where $z_t = \ln(\text{MADMT}_t + 20°\text{C})$, $t = 1, 2, \ldots, 360$.

Parameter	Estimate	Standard Error	t statistic	Probability	Lag
μ	0.0005791	0.0018886	0.31	>0.9	0
ϕ_1	0.18669	0.05311	3.51	<0.001	1
ϕ_{36}	0.18843	0.06139	3.07	<0.01	36
θ_{12}	0.84367	0.03339	25.27	<0.001	12

Correlations of Estimates

Parameter	μ	ϕ_1	ϕ_{36}	θ_{12}
μ	1	–0.006	–0.023	–0.062
ϕ_1	–0.006	1	–0.085	–0.085
ϕ_{36}	–0.023	–0.085	1	0.444
θ_{12}	–0.062	–0.085	0.444	1

Ljung-Box autocorrelation check of residuals

To Lag	Chi Square	Degrees of Freedom	Probability
6	3.93	3	0.269
12	8.02	9	0.532
18	12.50	15	0.641
24	18.62	21	0.610
30	23.16	27	0.677
36	26.04	33	0.800
42	31.17	39	0.810
48	46.31	45	0.418
54	51.15	51	0.468
60	60.23	57	0.360

One-month-ahead forecast equation for transformed temperature of January 1994 from December 1993 (T= 360):

$$\tilde{z}=0.000362 + z_{T-11} + 0.18669(z_T - z_{T-12}) + 0.18843(z_{T-35} - z_{T-47}) - 0.84367\hat{a}_{T-11}.$$

Table 8.--Monthly precipitation (cm) at Auke Bay, Alaska, 1963-93.

	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975
Jan		7.04	18.77	9.96	11.40	6.73	4.85	7.85	14.83	15.14	12.01	9.63	13.28
Feb	16.05	16.18	11.81	7.47	10.72	8.89	3.10	7.09	10.77	7.90	8.86	18.08	7.90
Mar	9.17	12.24	4.29	12.47	3.56	7.54	8.26	10.41	9.78	12.75	7.47	3.78	8.74
Apr	6.32	10.26	7.54	7.92	3.45	6.96	4.34	10.03	5.77	8.46	8.15	9.55	8.18
May	4.75	12.22	7.90	14.50	11.61	6.20	8.86	10.36	11.23	14.88	13.84	5.87	12.34
Jun	14.10	10.29	10.67	6.43	9.12	7.60	8.71	10.74	6.15	12.50	8.58	20.57	13.51
Jul	15.75	23.27	6.43	10.59	14.17	15.47	30.30	13.56	7.57	4.78	13.82	12.57	15.80
Aug	3.45	14.12	16.54	25.15	20.75	7.31	23.27	26.67	20.45	27.84	23.55	18.01	10.57
Sep	22.48	8.79	8.46	21.39	26.70	30.76	16.38	33.99	16.99	21.31	13.79	20.55	25.58
Oct	18.34	22.15	22.05	17.88	14.50	13.41	11.30	18.47	23.83	24.49	15.90	39.75	10.87
Nov	9.04	12.47	3.89	11.48		14.76	23.47	7.06	10.85	8.61	5.08	19.02	9.37
Dec	10.46	10.41	10.11	9.91		5.59	10.74	5.97	11.15	9.88	8.89	15.60	16.28
Annual		159.44	128.45	155.14		131.22	153.59	162.20	149.35	168.53	139.95	192.99	152.43

	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988
Jan	21.67	14.40	4.95	8.36	10.59	13.49	15.24	14.20	18.75	23.83	14.53	9.40	7.67
Feb	13.79	12.07	3.20	5.03	5.49	9.37	5.41	6.81	9.02	19.53	6.96	8.33	18.54
Mar	10.46	14.33	6.35	10.87	8.13	3.76	9.22	1.80	8.18	9.25	17.35	5.41	11.48
Apr	5.31	13.51	6.04	3.61	10.24	6.53	7.64	8.33	4.29	8.84	9.37	6.68	8.00
May	11.48	4.17	9.37	7.62	6.76	9.47	12.45	16.79	5.64	10.80	10.13	9.37	13.64
Jun	9.50	11.07	13.34	13.84	15.19	9.73	4.27	11.79	11.86	8.81	9.40	17.83	7.49
Jul	9.55	11.81	15.01	20.96	16.61	12.17	5.41	12.98	14.00	11.81	10.36	8.38	16.33
Aug	12.19	9.47	13.84	8.20	17.60	17.65	14.55	24.08	14.15	11.79	26.62	15.77	17.78
Sep	24.64	18.36	9.32	22.94	22.48	32.49	20.88	19.33	10.54	17.35	9.02	27.00	16.81
Oct	17.14	21.03	39.47	27.71	32.11	20.78	23.04	16.21	15.70	18.21	36.42	30.56	30.89
Nov	14.76	13.21	14.30	16.00	17.91	20.78	7.49	4.55	8.18	4.50	17.07	21.26	20.37
Dec	18.69	7.16	13.21	17.35	11.79	6.98	5.00	3.61	12.75	22.45	14.58	11.81	11.46
Annual	169.19	150.60	148.41	162.48	174.88	163.20	130.61	140.46	133.05	167.16	181.81	171.81	180.47

Table 8.--Continued.

	1989	1990	1991	1992	1993	Mean	Max.	Min.
Jan	16.00	10.36	11.61	15.14	14.91	12.15	23.83	4.85
Feb	0.18	10.49	18.54	12.27	14.22	10.13	19.53	0.18
Mar	5.92	11.68	7.67	10.24	6.40	8.68	17.35	1.80
Apr	4.75	4.55	8.36	7.11	5.18	7.27	13.51	3.45
May	14.20	5.79	11.33	18.90	5.06	10.24	18.90	4.17
Jun	6.45	11.53	8.53	8.99	9.40	10.62	20.57	4.27
Jul	11.61	13.61	13.94	13.97	5.54	13.16	30.30	4.78
Aug	9.12	17.25	25.32	15.06	8.43	16.94	27.84	3.45
Sep	20.70	35.41	41.81	23.98	27.10	21.34	41.81	8.46
Oct	20.47	20.40	22.94	14.50	21.69	22.02	39.75	10.87
Nov	22.40	15.65	21.11	16.69	26.29	13.04	23.47	3.89
Dec	20.90	18.62	24.23	13.11	15.04	11.96	24.23	3.61
Annual	152.70	175.34	215.39	169.95	144.35	157.93	215.39	128.45

Table 9.--Monthly snowfall (cm) at Auke Bay, Alaska, 1963-93.

	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975
Jan		40.64	94.23	128.02	120.40	83.06	52.07	39.37	118.62	101.35	125.98	106.43	96.27
Feb	53.85	27.69	137.41	30.48	74.93	34.29	55.12	10.16	43.18	93.98	48.77	81.28	36.83
Mar	35.31	62.99	11.43	110.49	16.76	16.51	40.64	2.54	132.59	56.39	19.81	36.83	48.26
Apr	82.55	6.86	6.35	5.08	trace	5.08	0.00	7.62	1.27	17.78	trace	0.00	12.70
May	0.00	3.81	trace	0.00	0.00	trace	0.00	trace	0.00	trace	0.00	0.00	0.00
Jun	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Jul	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Aug	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sep	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.27	0.00
Oct	0.00	0.00	trace	5.08	0.00	trace	0.00	1.27	6.35	2.54	0.00	trace	2.54
Nov	22.86	trace	26.67	44.45		10.16	38.10	58.17	48.26	8.89	46.23	12.70	80.01
Dec	39.12	81.28	35.56	36.83		68.83	4.57	55.37	88.39	77.98	50.80	23.88	116.84
Annual		223.37	311.66	360.43		217.93	190.50	174.50	438.66	358.90	291.59	262.38	393.45

	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988
Jan	92.71	5.08	20.32	46.99	101.60	7.87	180.34	92.96	108.71	16.26	33.27	5.08	10.16
Feb	78.74	trace	3.81	71.12	11.18	48.51	48.51	41.66	7.37	88.39	22.10	2.79	30.23
Mar	50.80	12.70	3.81	19.05	3.81	2.29	21.34	3.81	1.27	23.11	59.94	17.78	0.25
Apr	trace	1.27	2.54	1.27	trace	5.84	4.57	1.27	3.81	2.03	11.18	0.51	0.76
May	0.00	0.00	0.00	0.00	trace	0.00	trace	0.00	trace	0.00	trace	trace	0.00
Jun	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Jul	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Aug	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sep	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Oct	0.00	0.00	0.00	0.00	0.00	0.00	3.56	0.00	0.00	2.54	0.00	0.51	0.00
Nov	0.00	88.90	30.99	8.13	trace	10.67	4.57	17.27	13.97	17.78	63.25	9.14	12.95
Dec	65.53	53.34	29.21	110.74	137.67	18.29	22.61	29.72	66.55	14.22	4.83	14.73	28.70
Annual	287.78	161.29	90.68	257.30	254.25	93.47	285.50	186.69	201.68	164.34	194.56	50.55	83.06

Table 9.--Continued.

	1989	1990	1991	1992	1993	Mean	Max.	Min.
Jan	118.62	90.68	69.09	37.85	48.01	70.71	180.34	5.08
Feb	0.51	91.19	38.61	18.54	65.53	45.06	137.41	0.00
Mar	56.64	4.57	23.11	2.03	7.87	29.19	132.59	0.25
Apr	trace	0.00	0.76	trace	0.00	5.84	82.55	0.00
May	0.00	0.00	0.00	0.00	0.00	0.12	3.81	0.00
Jun	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Jul	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Aug	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sep	0.00	0.00	0.00	0.00	0.00	0.04	1.27	0.00
Oct	trace	trace	16.76	5.08	0.00	1.54	16.76	0.00
Nov	85.09	112.27	25.91	10.92	3.81	30.28	112.27	0.00
Dec	22.86	95.00	151.64	59.94	23.88	53.50	151.64	4.57
Annual	283.72	393.70	325.88	134.37	149.10	236.28	438.66	50.55

Table 10.--Seasonal snowfall (cm) at Auke Bay, Alaska, 1963-93.

	62–63	63–64	64–65	65–66	66–67	67–68	68–69	69–70	70–71	71–72	72–73	73–74	74–75
Jul	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Aug	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sep	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.27
Oct	0.00	0.00	0.00	trace	5.08	0.00	trace	0.00	1.27	6.35	2.54	0.00	trace
Nov		22.86	trace	26.67	44.45		10.16	38.10	58.17	48.26	8.89	46.23	12.70
Dec		39.12	81.28	35.56	36.83		68.83	4.57	55.37	88.39	77.98	50.80	23.88
Jan		40.64	94.23	128.02	120.40	83.06	52.07	39.37	118.62	101.35	125.98	106.43	96.27
Feb	53.85	27.69	137.41	30.48	74.93	34.29	55.12	10.16	43.18	93.98	48.77	81.28	36.83
Mar	35.31	62.99	11.43	110.49	16.76	16.51	40.64	2.54	132.60	56.39	19.81	36.83	48.26
Apr	82.55	6.86	6.35	5.08	trace	5.08	0.00	7.62	1.27	17.78	trace	0.00	12.70
May	0.00	3.81	trace	0.00	0.00	trace	0.00	trace	0.00	trace	0.00	0.00	0.00
Jun	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total		203.96	330.71	336.30	298.45		226.82	102.36	410.48	412.50	283.97	321.56	231.90

	75–76	76–77	77–78	78–79	79–80	80–81	81–82	82–83	83–84	84–85	85–86	86–87	87–88
Jul	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Aug	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sep	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Oct	2.54	0.00	0.00	0.00	0.00	0.00	0.00	3.56	0.00	0.00	2.54	0.00	0.51
Nov	80.01	0.00	88.9	30.99	8.13	trace	10.67	4.57	17.27	0.00	17.78	63.25	9.14
Dec	116.84	65.53	53.34	29.21	110.74	137.67	19.05	22.61	29.72	13.97	14.22	4.83	14.73
Jan	92.71	5.08	20.32	46.99	101.60	7.87	180.34	92.96	108.71	66.55	33.27	5.08	10.16
Feb	78.74	trace	3.81	71.12	11.18	48.51	48.51	41.66	7.37	16.26	22.10	2.79	30.23
Mar	50.80	12.7	3.81	19.05	3.81	2.29	21.34	3.81	1.27	88.39	59.94	17.78	0.25
Apr	trace	1.27	2.54	1.27	trace	5.84	4.57	1.27	3.81	23.11	11.43	0.51	0.76
May	0.00	0.00	0.00	0.00	trace	0.00	trace	0.00	trace	2.03	trace	trace	0.00
Jun	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total	421.64	84.58	172.72	198.63	235.46	202.18	284.48	170.43	168.15	210.31	161.29	94.23	65.79

Table 10.--Continued.

	88–89	89–90	90–91	91–92	92–93	93–94	Mean	Max.	Min.
Jul	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Aug	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sep	0.00	0.00	0.00	0.00	0.00	0.00	0.041	1.27	0.00
Oct	0.00	trace	trace	16.76	5.08	0.00	1.49	16.76	0.00
Nov	12.95	85.09	112.27	25.91	10.92	3.81	28.85	112.27	0.00
Dec	28.70	22.86	95.00	151.64	59.94	23.88	50.10	151.64	4.57
Jan	118.62	90.68	69.09	37.85	48.01		72.33	180.34	5.08
Feb	0.51	91.19	38.61	18.54	65.53		42.73	137.41	0.00
Mar	56.64	4.572	23.11	2.03	7.87		31.54	132.60	0.25
Apr	trace	0.00	0.76	trace	0.00		6.53	82.55	0.00
May	0.00	0.00	0.00	0.00	0.00		0.19	3.81	0.00
Jun	0.00	0.00	0.00	0.00	0.00		0.00	0.00	0.00
Total	217.42	294.39	338.84	252.73	197.36		223.78	421.64	65.79

Table 11 .--Conditional least-squares estimates of the moving-average and autoregressive parameters necessary to describe the interannual month differences in precipitation series, and statistics of the fit.

Model: $(1-B^{12})z_t = \mu + \dfrac{1-\theta_{12}B^{12}}{1-\phi_{48}B^{48}}a_t,$ where $z_t = \ln(\text{rainfall}_t + 1\text{ cm}),\ t = 1, 2, \ldots, 360.$

Parameter	Estimate	Standard Error	t statistic	Probability	Lag
μ	0.008031	0.0062231	1.30	>0.2	0
ϕ_{48}	-0.12688	0.06033	-2.10	<0.05	48
θ_{12}	0.75089	0.03785	19.84	<0.001	12

Correlations of Estimates

Parameter	μ	ϕ_{48}	θ_{12}
μ	1	-0.007	-0.028
ϕ_{48}	-0.007	1	0.273
θ_{12}	-0.028	0.273	1

Ljung-Box autocorrelation check of residuals

To Lag	Chi Square	Degrees of Freedom	Probability
6	3.26	4	0.515
12	8.28	10	0.601
18	12.02	16	0.742
24	15.87	22	0.822
30	26.25	28	0.559
36	29.05	34	0.709
42	36.33	40	0.636
48	37.32	46	0.815
54	41.24	52	0.858
60	45.11	58	0.892

One-month-ahead forecast equation for transformed rainfall of January 1994 from December 1993 (T= 360):

$$\tilde{z}=0.009097+z_{T-11}-0.12688(z_{T-47}-z_{T-59})-0.75089\hat{a}_{T-11}.$$

Table 12.--Conditional least-squares estimates of the moving-average and autoregressive parameters necessary to describe the interannual month differences in snowfall series, and statistics of the fit.[1]

Model: $(1-B^{12})z_t = \mu + \dfrac{1-\theta_7 B^7}{1-\phi_2 B^2} a_t$, where z_t = ln(snowfall$_t$ + 1 cm), t = 1, 2, ..., 360.

Parameter	Estimate	Standard Error	t statistic	Probability	Lag
μ	-0.02673	0.02526	−1.07	>0.2	0
ϕ_2	0.21286	0.07127	2.99	<0.01	2
θ_7	0.78609	0.04627	16.99	<0.001	7

Correlations of Estimates

Parameter	μ	ϕ_2	θ_7
μ	1	–0.021	–0.100
ϕ_2	–0.021	1	–0.017
θ_7	–0.100	–0.017	1

Ljung-Box autocorrelation check of residuals

To Lag	Chi Square	Degrees of Freedom	Probability
6	3.75	4	0.441
12	7.50	10	0.677
18	13.33	16	0.649
24	15.12	22	0.857
30	26.40	28	0.551
36	31.79	34	0.576

One-month-ahead forecast equation for transformed snowfall of January 1994 from December 1993 (T= 210):

$$\tilde{z} = 0.021040 + z_{T-6} + 0.21286(z_{T-1} - z_{T-8}) - 0.78609\hat{a}_{T-6}\,.$$

[1]Time variable t values and calendar months: 1 = October, 2 = November, 3 = December, 4 = January, 5 = February, 6 = March, and 7 = April.

Table 13.--Monthly averages of daily morning observations of sea surface temperatures (°C) (MADSSTs), Auke Bay Laboratory, 1959-69. Means were calculated only for those months with five or more observations.

	1959	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	Mean	Max.	Min.
Jan	3.04	3.59	3.80	2.51			2.70	2.42	1.52	3.59	2.10	3.07	3.80	1.52
Feb	2.79	3.86	3.66	1.86			2.14	2.34	1.98	2.17		2.83	3.86	1.86
Mar	3.27	4.01	3.82	2.29	3.73	3.33	2.94	2.67	2.19	3.42		3.26	4.01	2.19
Apr	4.20	5.11	4.67	4.26	4.68		4.82	5.57	4.25	4.62		4.64	5.57	4.20
May	8.13	10.28	8.60	7.48		9.30	6.76	7.56	9.77	8.50		8.56	10.28	6.76
Jun	13.82	12.05	10.76	10.61		13.78	9.91	14.20	14.58	12.80	16.95	12.12	16.95	9.99
Jul	13.83	12.00	12.64	13.08		13.53	13.64	16.33	14.71	16.10	10.33	13.57	16.33	10.33
Aug	11.59	12.08	12.92	13.45		12.66	14.25	12.85	13.85	14.66	12.98	12.90	14.66	11.59
Sep	10.04	9.88	10.62				10.73	10.34	10.52	10.53		10.29	10.73	9.88
Oct	6.97	7.80	6.79				7.34	6.74	7.38	7.43		7.17	7.80	6.74
Nov	4.72	5.27	5.00				5.35	4.17	5.58	6.07		4.96	6.07	4.17
Dec	4.14	4.04	3.28				3.76	2.32	5.06	3.47		3.72	5.06	2.32

Table 14.--Monthly averages of daily afternoon observations of sea surface temperatures (°C) (MADSSTs), Auke Bay Laboratory, 1975-93.

	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987
Jan		2.56	4.04	3.31	3.56	3.63	4.15	3.66	3.57	3.50	3.70	3.10	3.65
Feb	2.53	2.09	4.78	3.10	2.36	3.15	3.71	2.56	3.36	2.99	2.69	3.12	3.71
Mar	2.77	2.32	4.70	3.29	3.45	3.74	4.65	3.12	4.04	4.43	3.48	3.68	4.48
Apr	4.34	4.42	5.68	5.54	5.98	5.63	5.98	4.88	6.96	7.10	5.02	4.97	6.30
May	7.94	6.86	9.18	8.30	9.21	10.16	11.25	7.91	10.63	10.52	8.70	9.44	9.40
Jun	11.31	11.28	12.96	12.37	11.55	14.36	14.01	14.54	14.08	13.06	12.13	13.25	11.85
Jul	13.28	12.54	13.95	13.11	13.22	14.09	13.74	15.27	15.36	14.35	14.65	15.12	15.93
Aug	12.26	13.32	14.36	14.04	15.18	13.16	13.55	14.16	12.34	14.36	13.77	12.88	15.25
Sep	9.95	10.47	11.26	11.13	11.21	11.16	10.50	11.59	10.57	11.44	10.94	11.32	10.33
Oct	7.45	7.31	7.27	7.41	8.00	7.41	8.06	7.56	7.60	8.24	7.54	7.40	7.61
Nov	4.32	5.71	5.47	5.64	6.13	6.20	6.19	5.26	6.00	5.24	4.60	4.43	5.97
Dec	3.41	4.58	4.40	4.38	5.02	4.65	5.09	4.30	4.98	4.08	3.32	3.86	4.98

	1988	1989	1990	1991	1992	1993	Mean	Max.	Min.
Jan	4.56	3.73	3.03	2.58	3.96	3.74	3.62	4.56	2.56
Feb	4.47	3.24	3.05	2.80	4.29	2.68	3.25	4.78	2.09
Mar	4.59	3.80	3.60	3.40	4.77	3.82	3.87	4.77	2.32
Apr	6.46	7.64	6.83	6.27	6.78	7.93	6.14	7.93	4.34
May	10.67	10.41	10.98	10.83	9.65	12.85	9.92	12.85	6.86
Jun	12.81	14.33	13.88	13.86	14.35	15.00	13.40	15.00	11.28
Jul	13.66	16.03	15.20	14.46	14.93	15.74	14.63	16.03	12.54
Aug	13.05	15.62	14.77	13.07	13.65	15.15	13.93	15.62	12.26
Sep	10.72	12.28	11.23	10.16	10.07	11.53	10.9	12.28	9.95
Oct	8.03	8.28	7.54	7.68	6.75	8.40	7.69	8.40	6.75
Nov	6.30	4.93	5.12	5.41	5.47	5.96	5.51	6.30	4.32
Dec	4.42	4.16	3.27	3.89	4.43	4.38	4.30	5.09	3.27

Table 15.--Conditional least-squares estimates of the moving-average and autoregressive parameters necessary to describe interannual month differences in monthly average daily sea surface temperature series (MADSSTs), and statistics of the fit.

Model: $(1-B^{12})z_t = \mu + \dfrac{1-\theta_{12}B^{12}}{1-\phi_1 B^1}a_t,$ where $z_t = \ln(\text{MADSST}_t + 20°\text{C})$, $t = 1, 2, \ldots, 216$.

Parameter	Estimate	Standard Error	*t* statistic	Probability	Lag
μ	0.0024762	0.0012056	2.05	<0.05	0
ϕ_1	0.55238	0.05884	9.39	<0.001	1
θ_{12}	0.74408	0.05064	14.69	<0.001	12

Correlations of Estimates

Parameter	μ	ϕ_1	θ_{12}
μ	1	–0.004	0.165
ϕ_1	–0.004	1	0.038
θ_{12}	0.165	0.038	1

Ljung-Box autocorrelation check of residuals

To Lag	Chi Square	Degrees of Freedom	Probability
6	0.68	4	0.954
12	6.48	10	0.774
18	9.43	16	0.895
24	15.61	22	0.835
30	18.02	28	0.926
36	23.53	34	0.911
42	29.72	40	0.883

One-month-ahead forecast equation for transformed temperature of January 1994 from December 1993 ($T = 216$):

$$\tilde{z} = 0.001108 + z_{T-11} + 0.55238(z_T - z_{T-12}) - 0.74408\hat{a}_{T-11}\,.$$

Table 16.--Monthly averages of sea surface temperature (°C), Auke Bay Monitor, 1959-93.

	1959	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971
Jan												2.9	
Feb		4.3	4.3	4.0		4.2	2.7	2.1				2.4	1.8
Mar			3.4	1.7	3.7	3.0	2.8	2.7		2.6	2.2	3.6	
Apr		8.2	4.5	4.6	6.5	4.0	4.5	4.2	3.3	4.6	3.1	4.6	
May			7.7	6.7	7.1	6.0	5.9	7.8	7.9	5.1	11.0	5.2	
Jun			10.4		10.1	13.2	9.8	13.0	14.3	11.7	13.9	11.2	12.8
Jul			13.9			13.1	14.4		13.9		11.4	11.2	14.2
Aug			13.4		14.7	12.6	14.9	11.3			11.6	10.9	13.7
Sep			11.2			13.1	10.5	9.2			9.9	9.0	11.4
Oct			7.3		7.8	8.1	7.2	5.6		5.5	6.9	5.6	
Nov	5.1		3.8		6.6	6.0	4.6	3.6			5.7		
Dec							4.1	3.2			2.6		2.0

	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984
Jan			1.7	2.7	2.1	3.4	2.8	3.1					
Feb			2.2	2.7	2.0	4.3	2.7	2.1	3.3	3.3			
Mar			1.8	2.2	2.5	4.2	3.6	3.0	3.6	4.5	2.6	3.6	4.4
Apr			3.8	4.2	4.4	6.1	5.4	5.0	5.5	5.5	4.5	5.9	5.5
May	6.9	5.1	9.4	7.7	5.8	9.0	9.4	8.5	9.4	10.5	7.6	9.1	
Jun			10.5	11.0	11.4	12.5	12.9	12.1	12.7	11.8	13.0	13.7	11.1
Jul	14.0		13.1	12.4	12.1	12.8	13.2					16.0	
Aug	11.5	10.9	13.7	11.9	13.4	14.0	12.4		11.1				
Sep	9.9		9.8	9.4	10.1	12.9		9.5					
Oct	5.4	6.7	7.0	7.6	7.3	6.4	7.6						
Nov	4.5	3.0	5.2	4.0	5.8		4.4						
Dec		3.2	3.5	2.9	4.3	3.9	4.7						3.7

Table 16.--Continued.

	1985	1986	1987	1988	1989	1990	1991	1992	1993	Mean	Max.	Min.
Jan										2.7	3.4	1.7
Feb										3.0	4.3	1.8
Mar		3.5		4.3	3.6					3.3	4.4	1.7
Apr		3.8	6.8	5.9	5.5			5.9	7.8	5.1	8.2	3.1
May		7.8		9.0	8.5	11.6	9.7	9.5	11.5	8.2	12.5	5.1
Jun		10.8	11.5	11.1	10.8	11.8	12.2	12.5		11.9	14.3	9.8
Jul	16.1					14.1	13.7	13.4		13.2	16.1	11.2
Aug	11.6					12.8	12.4	13.4		12.8	14.9	10.9
Sep	8.4					10.6	11.3			10.3	13.1	8.4
Oct	5.4									7.0	8.1	5.4
Nov	4.4									5.0	6.6	3.0
Dec										3.6	4.7	2.0

Table 17.--Monthly averages of Lake Creek stream flows (m^3s^{-1}), 1963-73. The observed instantaneous maximum flow was 27.75 m^3s^{-1}, on 23 August 1966.

	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973
					Average Monthly Flow						
Jan		0.09	0.59	0.02	0.08	0.10	0.00	0.08	0.21	0.04	0.03
Feb		0.28	0.03	0.03	0.04	0.21	0.00	0.20	0.12	0.02	0.06
Mar		0.48	0.26	0.12	0.03	0.15	0.11	0.23	0.06	0.08	0.06
Apr		0.33	0.29	0.29	0.18	0.17	0.35	0.28	0.18	0.14	0.33
May		0.77	0.56	0.89	1.30	0.54	0.69	0.55	0.69	1.27	0.82
Jun		0.87	0.50	0.57	0.81	0.10	0.25	0.32	0.53	1.23	0.36
Jul		0.70	0.17	0.24	0.39	0.35	0.70	0.35	0.11	0.26	0.24
Aug		0.59	0.40	1.02	0.82	0.11	0.57	0.58	0.57	0.92	0.48
Sep		0.15	0.29	0.72	0.78	1.20	0.32	0.73	0.60	0.78	0.21
Oct	0.36	0.48	0.51	0.61	0.46	0.27	0.31	0.32	0.51	0.57	
Nov	0.12	0.42	0.06	0.28	0.72	0.28	0.48	0.06	0.23	0.21	
Dec	0.15	0.11	0.07	0.06	0.10	0.06	0.26	0.07	0.04	0.03	
					Maximum Flow						
Jan		0.28	5.10	0.03	0.42	0.28	0.01	0.37	1.19	0.05	0.08
Feb		1.98	0.03	0.11	0.08	1.13	0.00	0.76	0.42	0.03	0.23
Mar		5.66	1.13	0.99	0.07	0.42	0.71	1.64	0.20	0.28	0.28
Apr		0.76	1.76	0.99	0.76	0.48	0.99	0.68	0.79	0.71	0.71
May		2.58	1.36	1.93	3.79	1.27	1.56	0.85	1.76	3.54	1.53
Jun		1.87	1.95	1.36	3.09	1.13	2.60	1.53	1.08	2.52	1.10
Jul		4.84	0.62	3.60	3.88	5.66	2.80	1.25	0.65	0.91	1.22
Aug		4.25	5.46	14.04	3.09	0.57	1.84	2.29	2.12	4.28	2.83
Sep		0.82	1.95	3.34	2.27	4.25	1.93	5.72	1.64	3.48	1.56
Oct	1.22	1.81	1.59	5.86	2.01	1.42	1.76	1.47	1.02	3.54	
Nov	0.85	5.61	0.28	2.83	4.11	2.01	3.09	0.34	2.18	0.93	
Dec	0.71	0.71	0.17	0.28	0.57	0.15	1.08	0.48	0.05	0.14	

Table 17.--Continued.

	1963	1964	1965	1966	1967	1968	1969	1970	1971	1971	1973
				Average of the Daily Minimum Flows							
Jan		0.03	0.02	0.01	0.02	0.03	0.00	0.01	0.01	0.02	0.01
Feb		0.06	0.03	0.01	0.02	0.03	0.00	0.03	0.01	0.02	0.03
Mar		0.03	0.03	0.00	0.01	0.05	0.00	0.05	0.01	0.03	0.04
Apr		0.13	0.04	0.06	0.03	0.04	0.08	0.09	0.01	0.05	0.08
May		0.13	0.23	0.31	0.59	0.09	0.22	0.25	0.20	0.27	0.48
Jun		0.34	0.08	0.06	0.03	0.01	0.00	0.02	0.05	0.68	0.04
Jul		0.05	0.03	0.01	0.05	0.01	0.00	0.02	0.01	0.03	0.02
Aug		0.08	0.00	0.05	0.07	0.00	0.07	0.07	0.01	0.05	0.00
Sep		0.02	0.05	0.07	0.07	0.10	0.04	0.02	0.03	0.04	0.00
Oct	0.06	0.07	0.14	0.06	0.01	0.04	0.05	0.05	0.09	0.03	
Nov	0.00	0.05	0.02	0.02	0.04	0.05	0.06	0.01	0.04	0.02	
Dec	0.03	0.03	0.02	0.02	0.03	0.01	0.01	0.03	0.04	0.01	

	Monthly Average	Maximum Daily		Minimum Daily	
		Average	**Highest**	**Average**	**Lowest**
Jan	0.13	0.78	5.10	0.02	0.00
Feb	0.10	0.48	1.98	0.02	0.00
Mar	0.16	1.14	5.66	0.03	0.00
Apr	0.25	0.86	1.76	0.06	0.01
May	0.81	2.02	3.79	0.28	0.09
Jun	0.55	1.82	3.09	0.13	0.00
Jul	0.35	2.54	5.66	0.02	0.00
Aug	0.60	4.08	14.04	0.04	0.00
Sep	0.58	2.70	5.72	0.04	0.00
Oct	0.44	2.17	5.86	0.06	0.01
Nov	0.29	2.22	5.61	0.03	0.00
Dec	0.10	0.43	1.08	0.02	0.01

Table 18.--Monthly averages of Lake Creek stream temperatures (°C), 1963-73.

	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973
Jan		0.7	0.1	0.0	0.5	0.0	0.0	0.1	0.0	0.0	
Feb		1.6	0.2	0.0	0.5	0.7	0.0	0.1	0.0	0.0	
Mar		0.7	0.2	0.0	0.5	0.5	0.0	0.8	0.0	0.0	
Apr		1.3	0.7	0.4	0.6	1.1	0.9	1.9	0.3	0.5	
May		1.6	1.6	1.7	1.0	3.8	2.8	3.1	1.7	1.0	2.1
Jun		3.7	5.2	6.1	5.5	9.0	10.4	7.7	6.5	2.1	
Jul		9.7	10.9	11.6	10.1	12.0	10.3	9.4	12.2	9.6	9.9
Aug		11.0	11.8	10.7	10.6	12.0	8.6	10.1	11.2	8.1	
Sep		8.9	9.0	8.6	8.7	8.1	8.4	7.8	6.9	4.6	7.5
Oct	7.6	7.2	5.9	3.8	5.0	4.8	4.8	5.1	3.8		
Nov	0.6	2.6	1.0	0.6	2.6	1.7	1.9	1.9	0.4		
Dec	0.3	0.0	0.0	0.5	0.5	0.9	1.0	0.0	0.0		

	Monthly Average	Mean Daily		Extreme Daily	
		High	Low	High	Low
Jan	0.2	0.8	0.0	1.5	0.0
Feb	0.4	1.6	0.0	2.0	0.0
Mar	0.3	1.4	0.0	2.0	0.0
Apr	0.8	2.0	0.2	2.5	0.0
May	2.0	3.8	0.8	7.0	0.3
Jun	6.2	10.6	2.1	13.3	1.5
Jul	10.6	13.2	8.1	14.8	3.5
Aug	10.4	12.7	7.9	14.3	8.5
Sep	7.9	9.4	4.6	11.0	1.3
Oct	5.2	7.6	3.2	9.0	0.5
Nov	1.6	3.3	0.0	5.5	−0.3
Dec	0.4	1.3	0.0	2.0	0.0

Table 19.--Monthly averages of daily Auke Creek stream flows (m^3s^{-1}), 1962-75. The observed instantaneous maximum observed flows are 9.85 m^3s^{-1} on 2 November 1949 for 1947-50 records and 6.59 m^3s^{-1} on 29 September 1970 for 1962-75 records.

	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975
Average Monthly Flows														
Jan		0.54	0.27	0.57	0.06	0.26	0.22	0.03	0.12	0.28	0.08	0.10	0.07	0.31
Feb		0.85	0.38	0.12	0.06	0.11	0.49	0.02	0.27	0.23	0.05	0.12	0.25	0.13
Mar		0.45	0.23	0.26	0.32	0.09	0.49	0.09	0.26	0.13	0.16	0.11	0.06	0.10
Apr		0.22	0.57	0.39	0.61	0.21	0.25	0.54	0.28	0.29	0.19	0.40	0.47	0.50
May		0.86	0.92	0.74	1.10	1.23	0.54	0.72	0.63	0.69	1.35	0.96	0.93	0.97
Jun		0.53	1.12	0.71	0.60	0.68	0.25	0.41	0.39	0.50	1.28	0.52	0.96	0.99
Jul		0.48	0.95	0.24	0.19	0.37	0.27	0.81	0.42	0.24	0.31	0.33	0.39	0.40
Aug	0.42	0.14	0.57	0.32	0.92	0.82	0.11	0.91	0.80	0.48	0.83	0.91	0.41	0.35
Sep	1.08	0.41	0.27	0.47	0.79	0.99	1.05	0.49	1.38	0.61	0.74	0.50	0.61	0.86
Oct	0.60	0.69	0.73	0.82	0.77	0.52	0.46	0.43	0.84	0.54	0.90	0.80	1.43	
Nov	0.56	0.23	0.49	0.15	0.34	0.98	0.37	0.82	0.24	0.30	0.31	0.11	0.67	
Dec	0.78	0.35	0.18	0.22	0.17	0.23	0.15	0.43	0.10	0.09	0.10	0.00	0.42	
Average of the Daily Maximum Flows														
Jan		2.75	0.71	3.17	0.10	0.51	0.57	0.04	0.34	1.98	0.09	0.23	0.23	0.93
Feb		4.25	1.70	0.14	0.21	0.20	1.93	0.02	0.51	0.45	0.06	0.31	0.85	0.31
Mar		1.27	1.13	0.79	1.61	0.17	1.30	0.42	0.68	0.22	0.42	0.28	0.11	0.51
Apr		1.13	0.99	1.47	1.25	0.74	0.40	0.76	0.45	0.68	0.62	0.85	1.05	1.44
May		1.70	1.67	1.47	2.35	2.52	0.93	1.08	0.91	1.08	4.25	1.50	1.76	2.24
Jun		0.99	1.78	1.70	0.91	1.39	0.59	1.73	1.36	0.91	2.43	0.99	2.21	1.70
Jul		2.27	3.85	0.65	0.93	0.93	2.27	2.86	0.71	0.71	1.36	0.74	1.25	1.98
Aug	2.04	0.48	1.42	3.28	3.85	2.69	0.96	2.12	2.15	0.96	3.17	2.83	1.27	0.91
Sep	3.43	1.70	0.88	1.73	1.73	1.56	3.23	2.15	5.95	1.44	3.14	1.30	1.44	2.41
Oct	2.32	1.64	2.27	1.53	2.52	1.02	1.19	1.08	2.77	0.99	5.01	3.00	3.17	
Nov	2.66	0.57	2.27	0.62	1.30	2.75	1.42	2.55	0.65	1.44	0.76	0.42	2.27	
Dec	2.66	1.19	0.68	0.34	0.45	0.45	0.59	1.22	0.14	0.12	0.20	0.16	0.96	

Table 19.--Continued.

	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975
Average of the Daily Minimum Flows														
Jan		0.07	0.11	0.03	0.04	0.10	0.10	0.02	0.04	0.06	0.04	0.05	0.05	0.11
Feb		0.11	0.13	0.09	0.03	0.08	0.12	0.02	0.12	0.06	0.04	0.07	0.05	0.06
Mar		0.11	0.10	0.10	0.12	0.06	0.14	0.02	0.12	0.08	0.06	0.08	0.03	0.05
Apr		0.08	0.34	0.09	0.25	0.08	0.16	0.31	0.16	0.11	0.10	0.20	0.10	0.22
May		0.57	0.28	0.40	0.48	0.79	0.28	0.48	0.42	0.40	0.40	0.65	0.57	0.51
Jun		0.22	0.57	0.24	0.21	0.12	0.13	0.02	0.12	0.08	0.71	0.25	0.48	0.20
Jul		0.23	0.17	0.03	0.02	0.12	0.01	0.02	0.14	0.08	0.08	0.22	0.13	0.06
Aug	0.08	0.06	0.06	0.02	0.37	0.27	0.00	0.24	0.12	0.09	0.06	0.21	0.13	0.09
Sep	0.26	0.04	0.05	0.10	0.34	0.54	0.27	0.13	0.37	0.18	0.14	0.16	0.15	0.19
Oct	0.12	0.34	0.26	0.48	0.17	0.15	0.17	0.14	0.34	0.23	0.16	0.18	0.62	
Nov	0.12	0.08	0.14	0.03	0.09	0.28	0.16	0.28	0.10	0.10	0.11	0.03	0.17	
Dec	0.12	0.12	0.06	0.11	0.09	0.14	0.04	0.08	0.07	0.08	0.06	0.03	0.17	

	Monthly Average	Maximum Daily		Minimum Daily	
		Average	Highest	Average	Lowest
Jan	0.22	0.89	3.17	0.06	0.02
Feb	0.25	0.89	4.25	0.08	0.02
Mar	0.22	0.70	1.61	0.09	0.02
Apr	0.37	0.87	1.47	0.17	0.08
May	0.89	1.77	4.25	0.48	0.28
Jun	0.66	1.42	2.43	0.26	0.02
Jul	0.41	1.54	3.85	0.10	0.01
Aug	0.59	2.10	3.85	0.13	0.00
Sep	0.72	2.28	5.95	0.21	0.04
Oct	0.73	2.19	5.01	0.26	0.12
Nov	0.43	1.51	2.75	0.13	0.03
Dec	0.26	0.71	2.66	0.09	0.03

Table 20.--Monthly averages of daily Auke Creek stream temperatures (“C), 1963-93.

	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974
Jan		0.8	1.1	0.8	0.8	0.9	1.0	0.5		1.1	1.1	0.5	0.7
Feb			1.0	1.0	1.0	0.2	1.7	1.0		0.3	0.9	0.4	1.1
Mar			1.0	1.1	0.9		2.6	1.0	3.6	1.2	0.7	0.9	0.8
Apr			3.9	3.6	1.9	2.4	3.9	2.0	5.6	1.7	1.1	3.1	2.4
May			6.7	6.1	4.5	5.3	8.9	10.8	9.0	4.6	3.4	7.2	5.5
Jun			12.1	15.8	12.1	13.3	15.9	17.2	10.8	12.7	9.2	12.8	11.9
Jul			9.9	16.4	17.2	15.4	17.1	13.6	11.7	16.6	16.5	15.1	15.2
Aug				15.9	14.9	13.7	13.7	12.5	12.6	16.8	13.5		15.4
Sep			11.9	10.8	11.0		11.1	12.0		13.0	9.9		13.2
Oct	8.1	8.0	7.3	8.4	7.5		7.7	9.8		7.0	5.1	8.1	7.1
Nov	5.7	3.9	2.5	3.9	3.7	3.5	5.1	7.2		3.3	3.2		5.2
Dec	3.0	1.8	1.3	1.7	1.7	1.4	3.0	1.8		1.1	0.9		2.8

	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987
Jan	1.3	0.8	1.6	0.8	0.2	0.8	1.7	0.5	1.6	1.2	1.7	1.3	1.9
Feb	0.7	0.6	2.8	1.4	−0.1	1.1	1.8	0.5		1.4	0.6	1.5	2.1
Mar	1.1	0.8	2.7	2.2	1.3	1.7	2.7	1.1	2.5	2.9	1.0	1.9	2.2
Apr	2.4	2.6	4.8	4.9	3.8	4.1	5.0	2.4	4.9	6.1	2.5	3.0	4.7
May	7.3	6.5	10.1	7.6	9.3	11.0	12.6	5.4	10.3	11.9	7.0	8.7	9.5
Jun	12.2	11.5	13.8	12.6	14.1	16.6	15.0	14.2	15.2	13.6	10.9	13.2	12.4
Jul	16.9	14.2	18.0	13.9	15.0	15.1	15.0	16.2	16.3	14.6	14.9	15.7	16.5
Aug	13.8	15.3	17.4	15.3	16.6	14.6	14.9	15.2	14.0	14.8	14.5	13.8	16.2
Sep		11.9	12.2	12.1	12.9	11.5	11.2	12.1	10.8	12.0	11.3	11.9	11.4
Oct		8.4	7.8	8.2	8.7	8.2	7.9	7.9	7.5	8.2	7.0	8.6	7.9
Nov		5.4	3.4	3.7	5.1	5.8	5.0	4.5	3.7	2.9	2.1	3.7	5.0
Dec		2.9	0.7	1.3	2.2	1.5	1.8	1.8	0.5	1.0	1.0	2.3	3.1

Table 20.--Continued.

	1988	1989	1990	1991	1992	1993	Monthly Average	Mean Daily		Extreme Daily	
								High	Low	High	Low
Jan	1.4	1.1	1.1	0.8	1.7	0.9	1.1	2.2	0.1	2.8	0.0
Feb	1.1	0.5	0.6	1.3	1.4	1.0	1.1	2.6	–0.1	3.4	–0.2
Mar	2.8	0.4	1.8	1.3	2.6	1.2	1.7	3.5	0.3	4.4	0.0
Apr	5.2	3.1	5.0	2.2	5.4	3.6	3.6	6.3	1.0	9.8	0.3
May	9.2	9.3	11.0	8.4	9.3	12.2	8.1	13.0	3.4	15.7	1.5
Jun	13.2	15.0	15.1	13.5	15.0	16.7	13.4	18.5	8.6	21.0	5.5
Jul	13.7	18.2	17.5	16.3	16.4	16.7	15.6	19.1	10.8	20.5	9.0
Aug	13.5	16.7	16.5	14.4	15.1	6.0	15.0	18.1	11.9	21.8	11.5
Sep	11.4	13.6	12.6	11.0	11.2	12.6	11.7	13.8	9.5	16.5	6.8
Oct	8.7	8.4	8.1	7.4	7.0	8.6	7.8	9.1	5.1	11.1	4.0
Nov	5.3	4.1	3.5	3.5	4.5	5.3	4.2	6.2	1.8	7.5	0.0
Dec	2.6	2.3	1.2	2.1	1.6	2.6	1.8	3.4	0.2	4.7	0.0

Table 21 .--Monthly averages of daily Auke Creek Hatchery temperatures (°C), 1971-93.

	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983
Jan		3.7			2.5	3.4	3.3	3.4	3.0	3.3	3.5	3.7	3.6
Feb		3.7			2.5	3.3	3.1	3.4	3.1	3.4	3.5	3.5	3.5
Mar		3.8			2.6	3.5	3.2	3.4	3.1	3.4	3.7	3.8	3.6
Apr		3.7			2.7	3.6	4.1	4.1	3.7	3.8	4.4	3.7	4.1
May		3.6			4.2	4.8	5.4	5.0	5.2	6.4	5.5	4.4	5.9
Jun						6.0			8.6	7.1	6.5	5.9	8.0
Jul					8.4	7.1			10.1	7.6	6.2	6.5	7.9
Aug	8.3			7.4	8.3	8.5	8.6		9.4	7.4	6.5	6.7	7.5
Sep	7.5			7.0	7.2	7.7	7.5		7.4	6.9	6.4	6.5	7.0
Oct	6.7			6.5	6.6	7.0	7.4	6.9	7.5	7.5	6.7	6.6	7.0
Nov	4.2			5.3	4.0	5.4	4.3	4.6	5.4	5.7	5.2	4.2	4.5
Dec	3.7			3.4	3.5	3.8	3.3	3.0	3.6	3.4	3.8	3.6	3.7

	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	Mean (1971–90)
Jan	3.7	3.1	2.7	2.9	3.0	2.9	2.2	2.7	3.1	2.5	3.2
Feb	3.5	2.8	2.8	2.9	3.0	2.9	2.3	3.1	3.1	2.7	3.1
Mar	3.7	2.8	2.8	3.0	3.3	2.9	2.7	3.0	3.0	2.3	3.2
Apr	4.8	3.1	3.3	4.5	4.4	3.4	4.1	3.1	4.5	3.4	3.8
May	6.0	4.9	5.3	5.7	5.5	5.8	6.0	6.4	5.9	6.1	5.3
Jun	6.5	6.0	7.1	6.5	7.0	7.6	6.8	8.0	7.3	7.0	6.9
Jul	7.3	7.5	8.0	7.6	7.3	11.2	9.6	8.3	8.5	8.7	8.0
Aug	7.7	8.5	7.6	8.1	7.9	10.3	9.4	8.2	8.7	9.6	8.1
Sep	7.7	7.8	7.1	7.6	8.2	8.5	9.1	8.1	8.3	8.2	7.5
Oct	7.3	6.5	6.8	7.5	7.8	7.5	7.8	7.2	6.9	7.9	7.1
Nov	3.7	3.6	4.4	5.1	5.2	4.4	4.1	3.9	4.5	5.3	4.6
Dec	3.1	3.0	3.5	3.6	3.4	3.0	2.8	3.1	2.8	3.2	3.4

Table 22.--Auke Lake ice breakup dates, 1960-95.

Ice-out Date			
1960s	1970s	1980s	1990s
1960 Apr 26	1970 Mar 24	1980 Apr 19	1990 Apr 08
1961	1971 May 13	1981 Mar 26	1991 Apr 29
1962 Apr late	1972 May 20	1982 May 14	1992 Mar 18
1963 Apr 29	1973 Apr 30	1983 Apr 18	1993 Apr 23
1964	1974 May 07	1984 Mar 29	1994 Apr 11
1965	1975 May 08	1985 Apr 26	1995 Apr 25
1966	1976 Apr 28	1986 Apr 28	1996 Apr 21
1967 May 11	1977 Feb 01	1987 Mar 30	1997 Apr 25
1968 Apr 23	1978 Jan 11	1988 Apr 15	
1969 Apr 30	1979 Apr 24	1989 Apr 28	

FIGURES

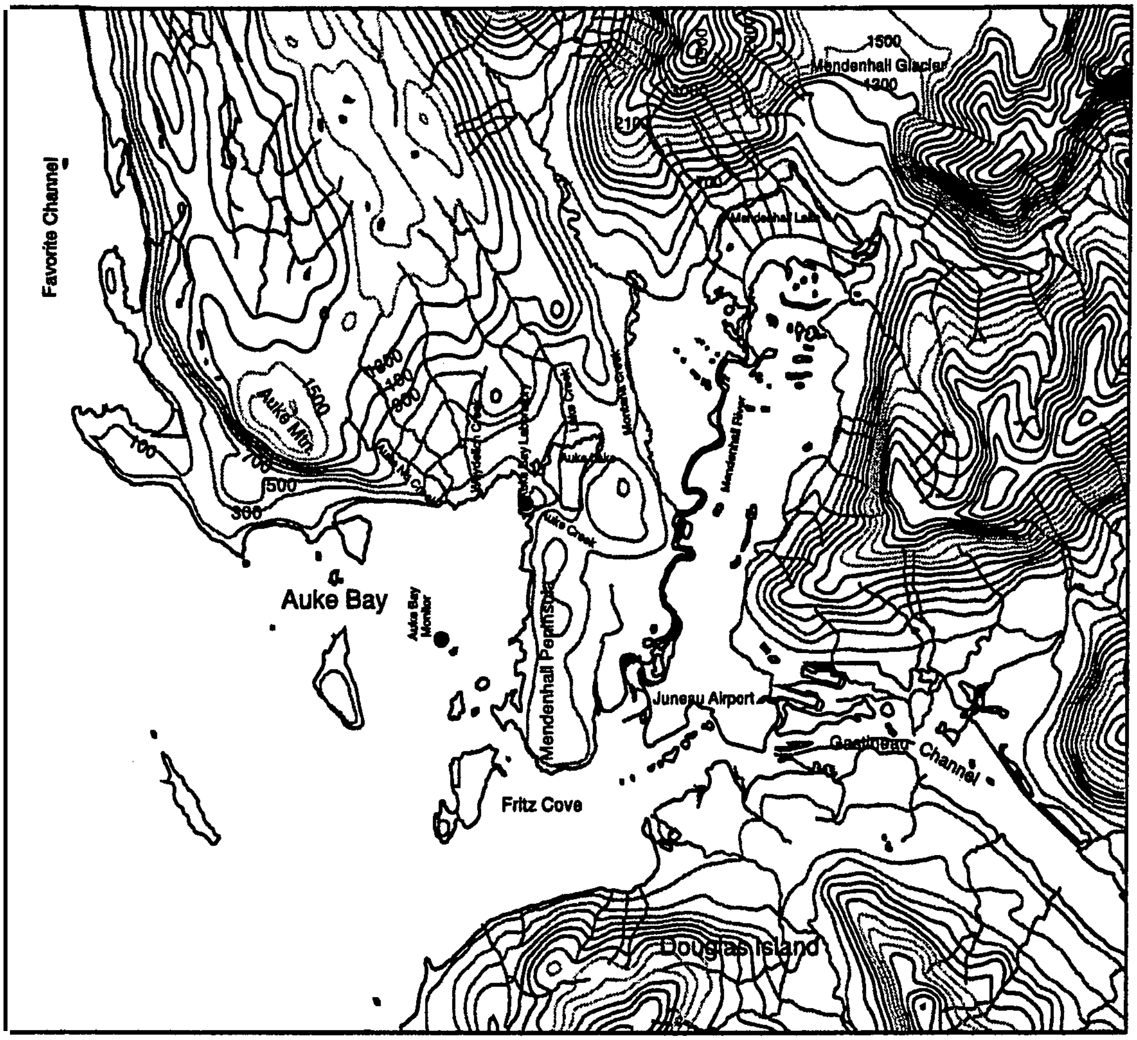

Figure 1 .--Auke Bay, Alaska, and vicinity.

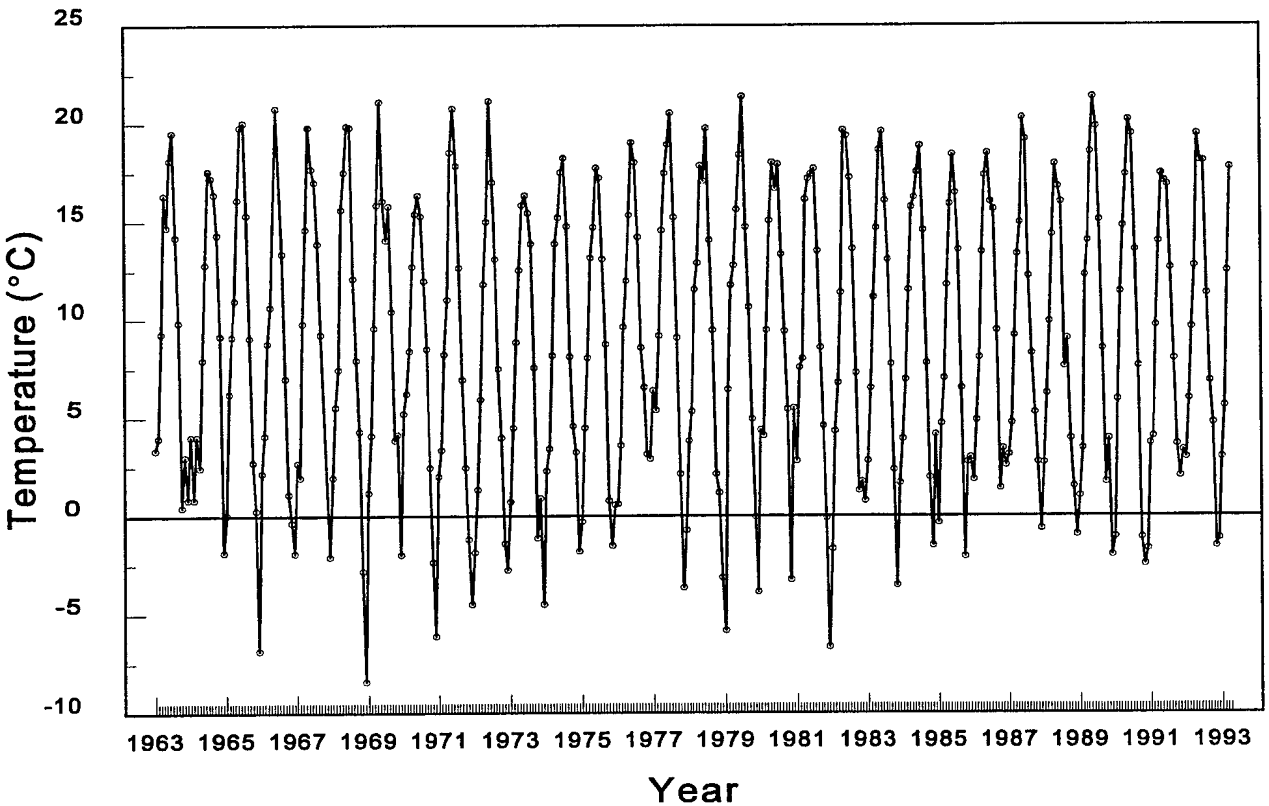

Figure 2a.--Monthly averages of daily high temperature (MADHTs) at Auke Bay Laboratory, February 1963 through May 1993.

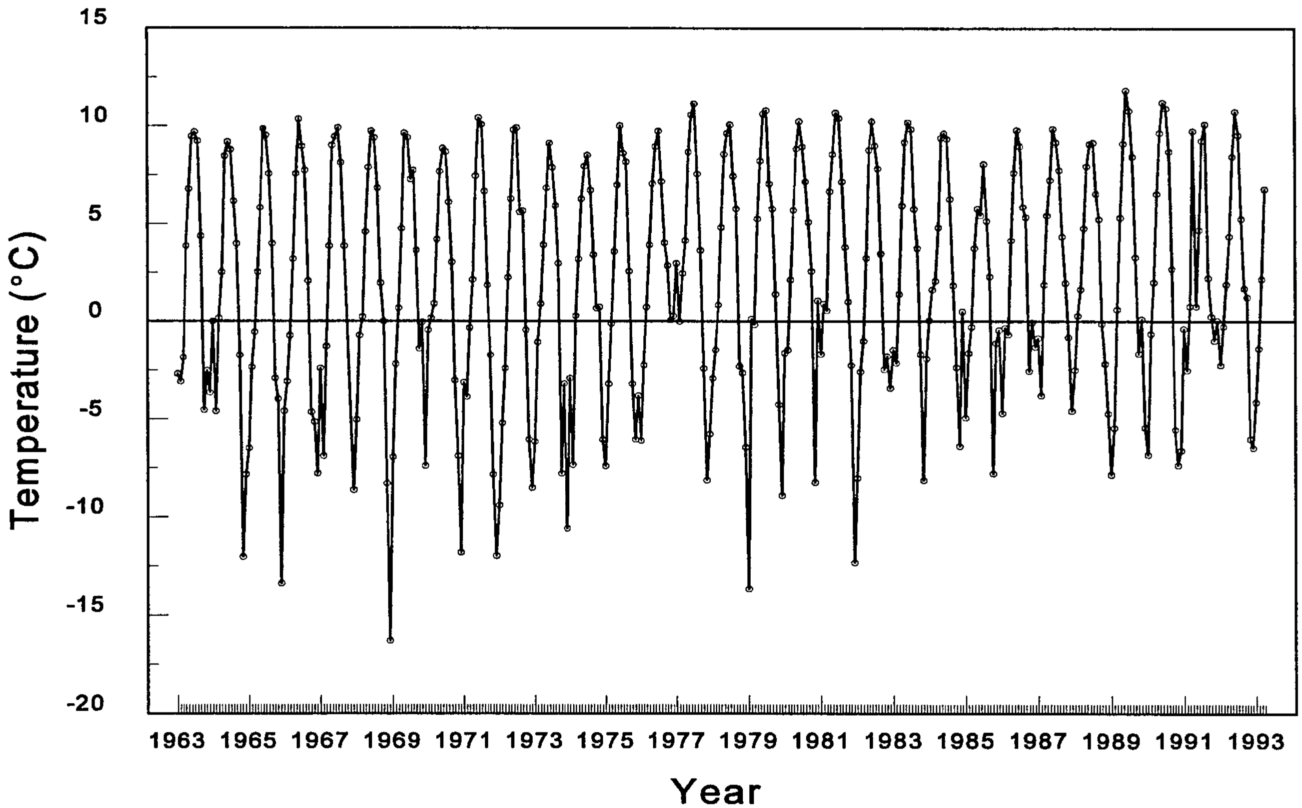

Figure 2b.--Monthly averages of daily low temperature (MADLTs) at Auke Bay Laboratory, February 1963 through May 1993.

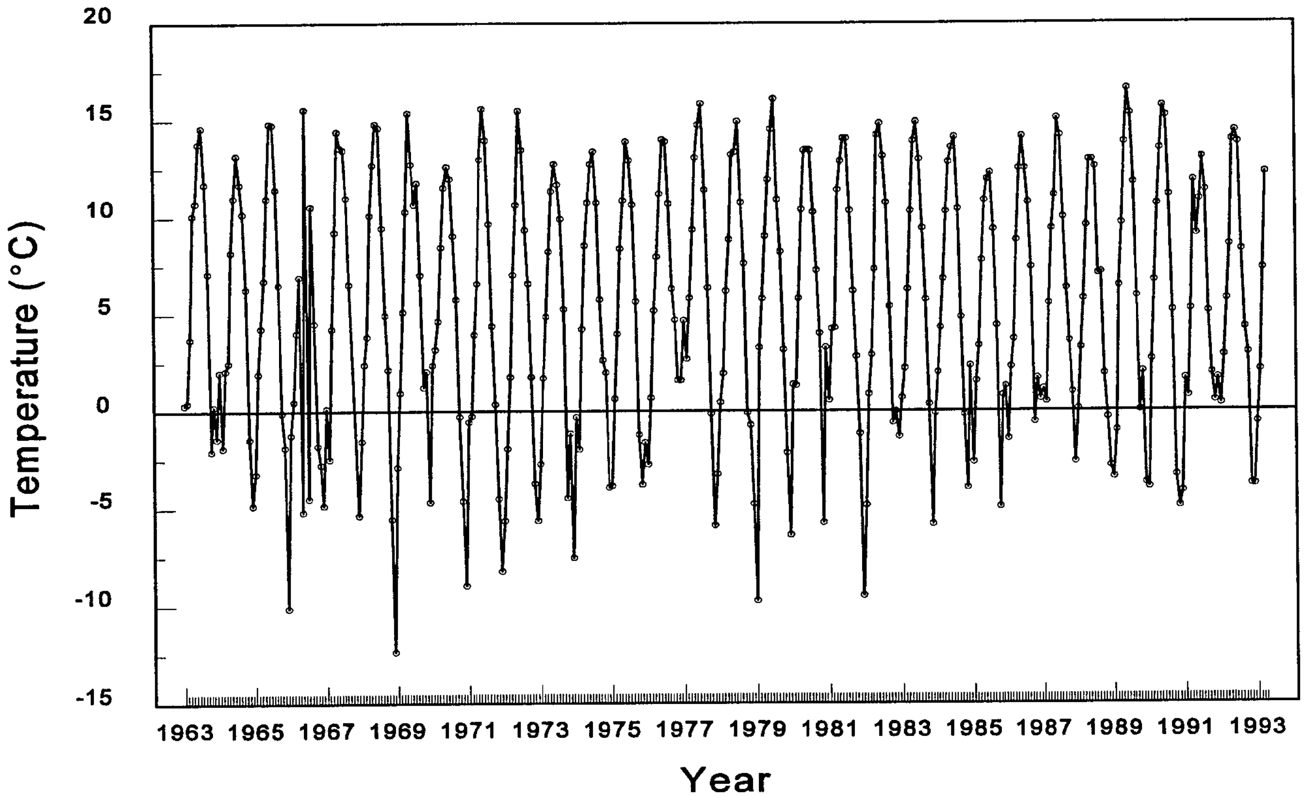

Figure 2c.--Monthly averages of daily midrange temperature (MADMTs) at Auke Bay Laboratory, February 1963 through May 1993.

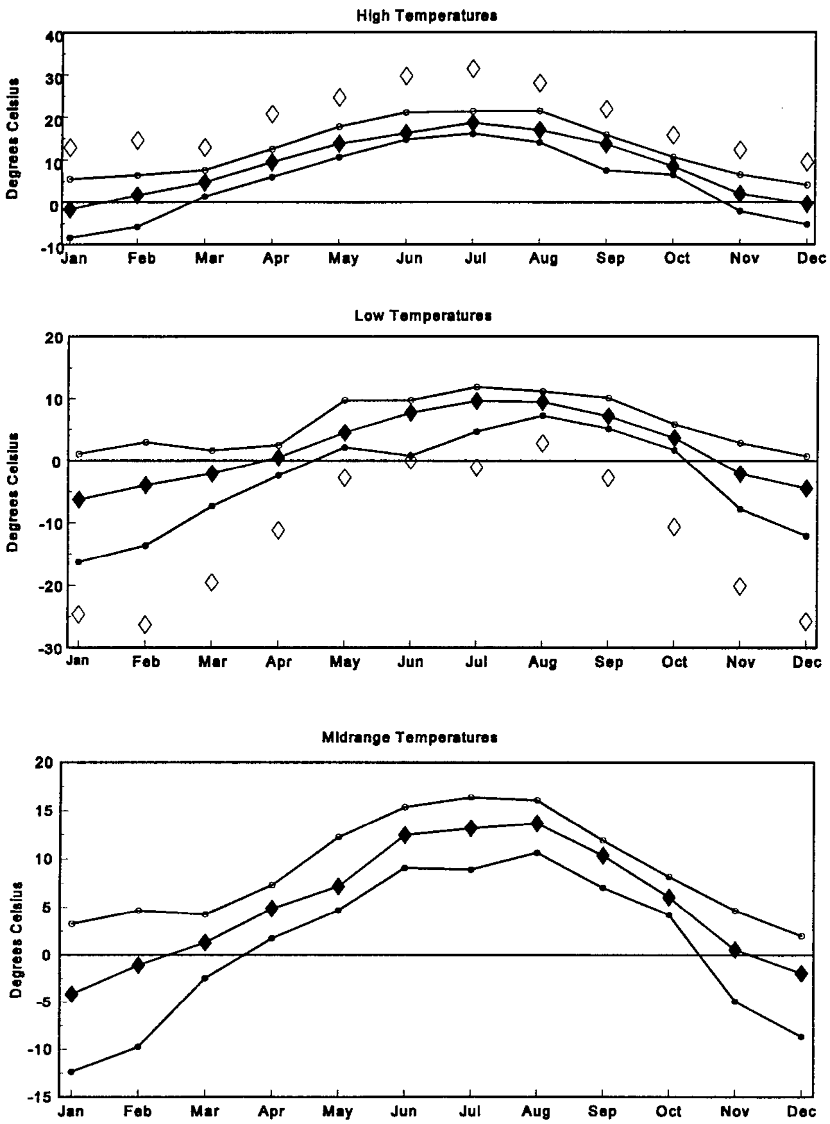

Figure 3.--Statistics of annual temperature cycle at the Auke Bay Laboratory (1963-93) including daily extremes (lowest low and highest high [0]) and monthly extrema (high[o], low [•], and series averages[♦]) for monthly average daily high (MADHT), low (MADLT), and midrange (MADMT) air temperature series.

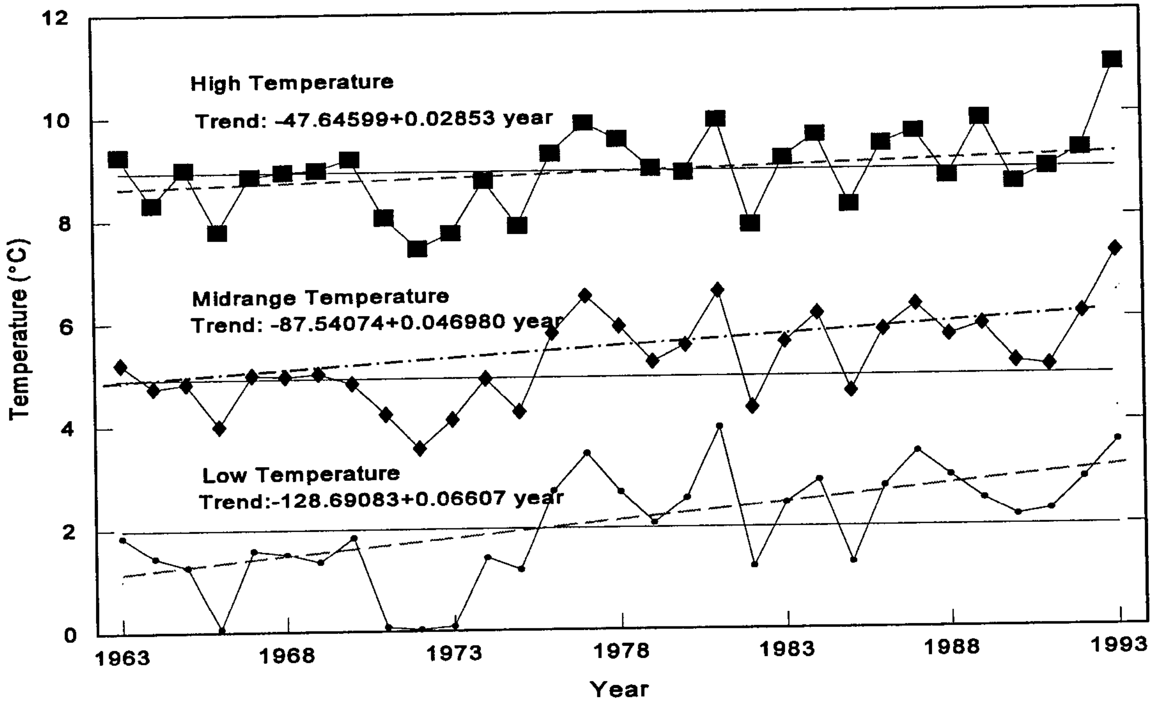

Figure 4.--Annual average of monthly average high (MADHTs [■]), midrange (MADMTs [♦]), and low (MADLTs [•]) daily air temperatures at Auke Bay, Alaska, 1963-93. Missing monthly values were estimated by cubic spline interpolation. Solid horizontal lines are the overall annual means. Dashed lines are the trends.

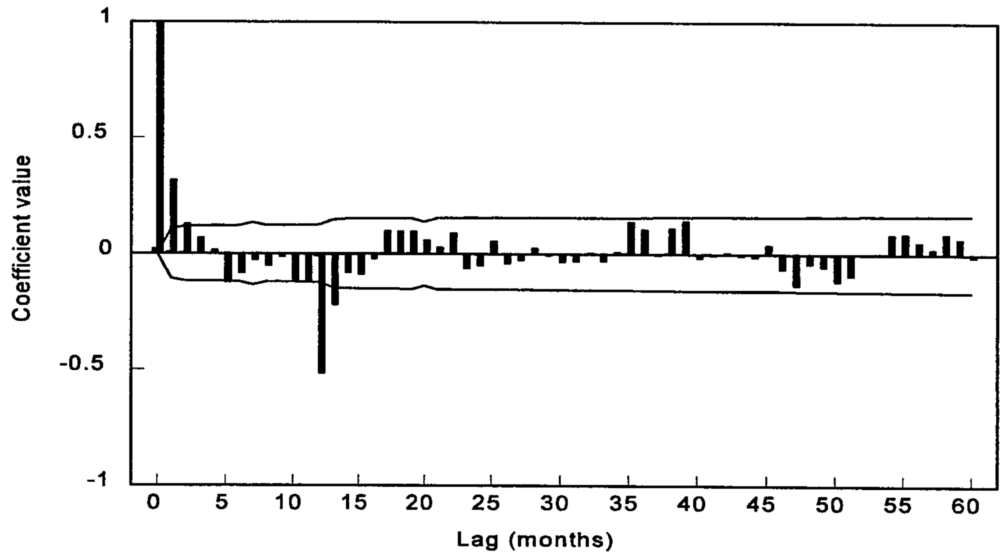

Figure 5.--Sample autocorrelation function (SACF) of interannual month differences in logarithm-transformed monthly average daily high air temperatures (MADHTs) at Auke Bay. The interval covering 2 standard errors is indicated.

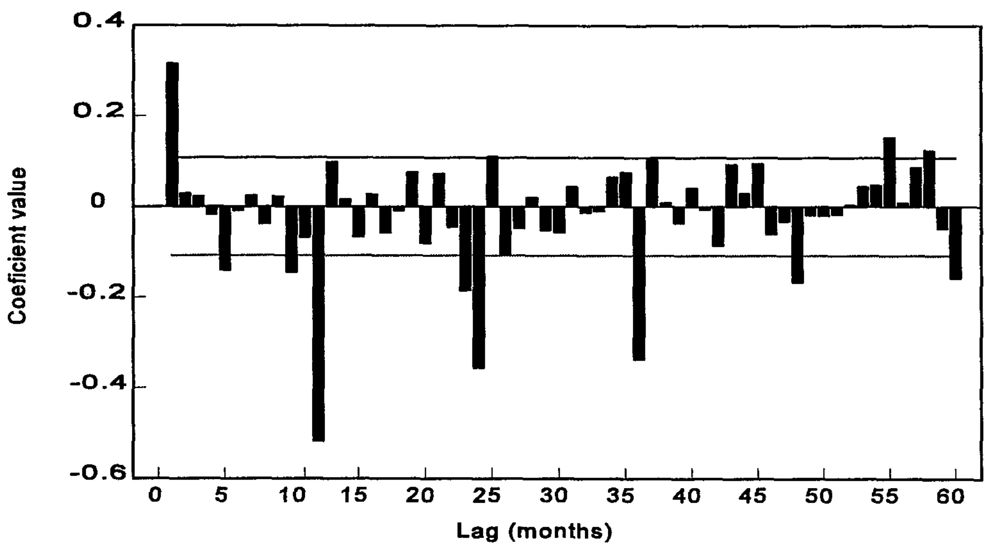

Figure 6.--Sample partial autocorrelation function (SPACF) of interannual month differences in logarithm-transformed monthly average daily high air temperatures (MADHTs) at Auke Bay. The interval covering 2 standard errors is indicated.

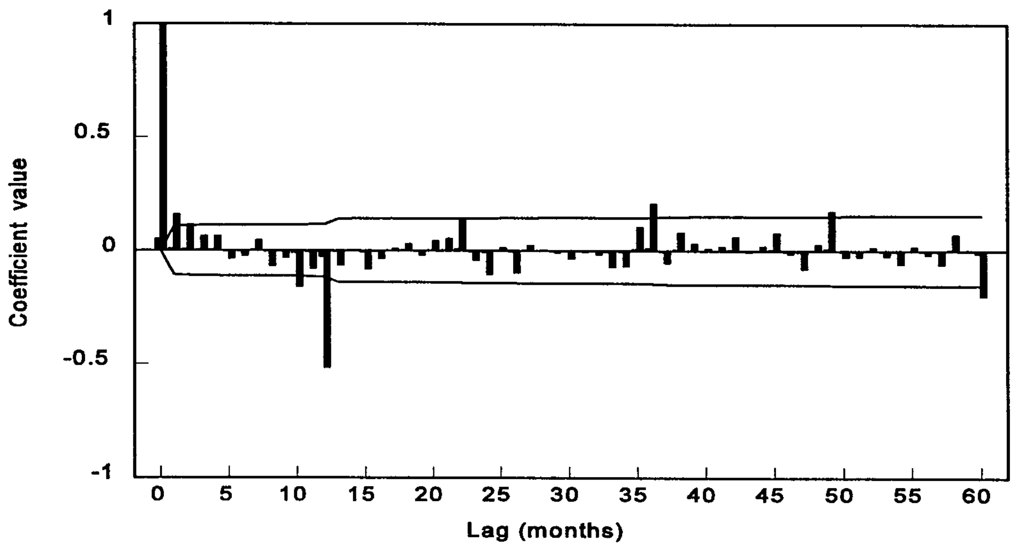

Figure 7.--Sample autocorrelation function (SACF) of interannual month differences in logarithm-transformed monthly average daily low air temperatures (MADLTs) at Auke Bay. The interval covering 2 standard errors is indicated.

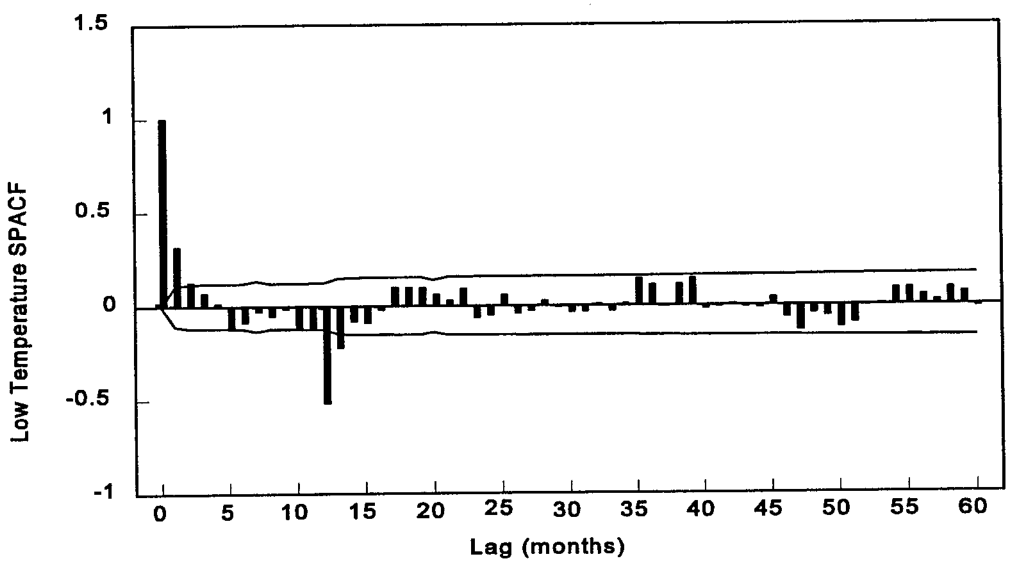

Figure 8--Sample partial autocorrelation function (SPACF) of interannual month differences in logarithm-transformed monthly average of daily low air temperatures (MALDTs) at Auke Bay. The interval covering 2 standard errors is indicated.

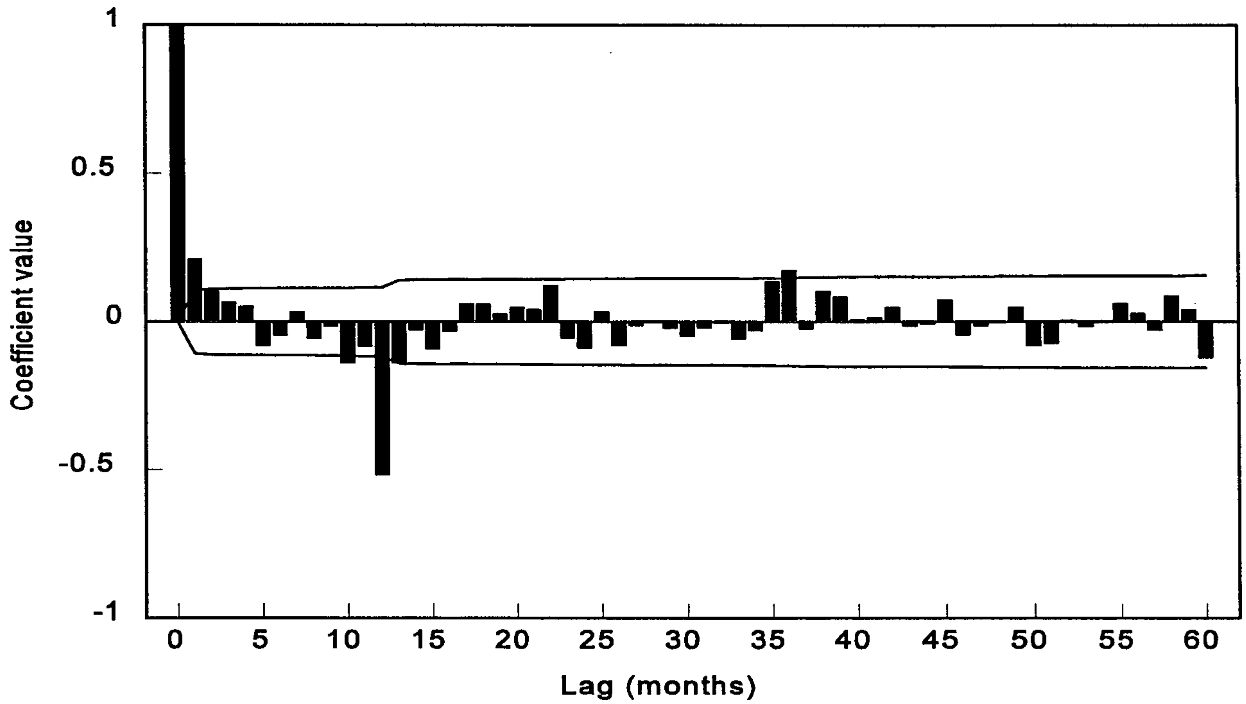

Figure 9.--Sample autocorrelation function (SACF) of interannual month differences in logarithm-transformed monthly average daily midrange air temperatures (MADMTs) at Auke Bay. The interval covering 2 standard errors is indicated.

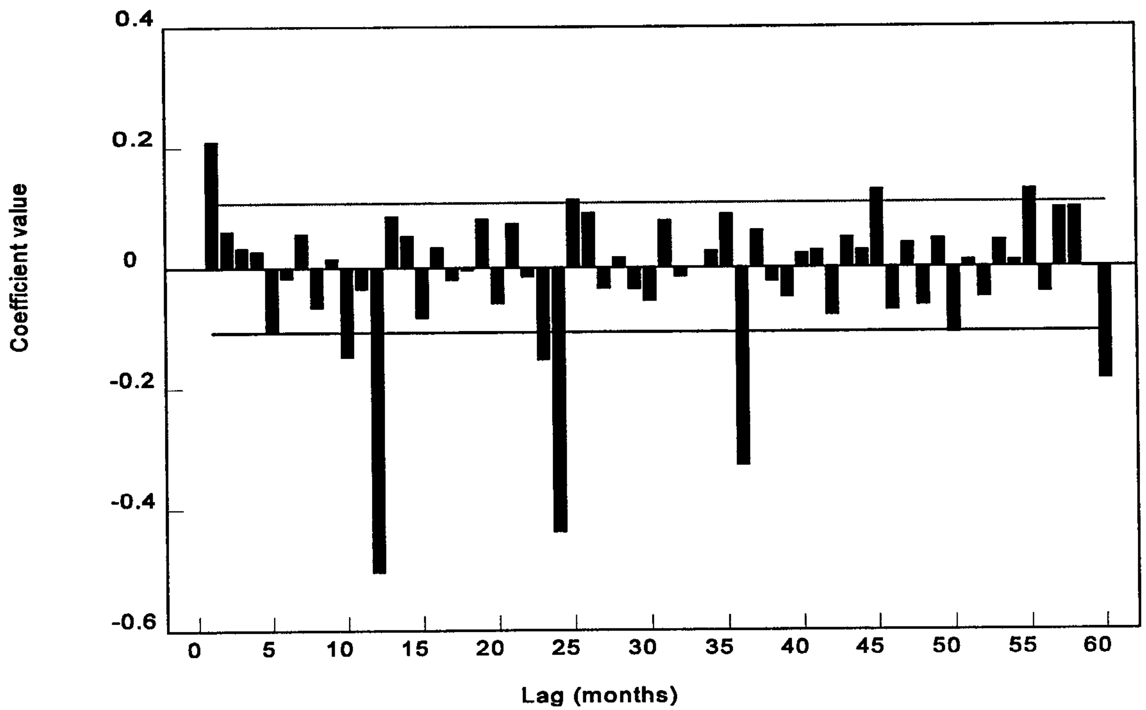

Figure 10.--Sample partial autocorrelation function (SPACF) of interannual month differences in logarithm-transformed monthly average daily midrange air temperatures (MADMTs) at Auke Bay. The interval covering 2 standard errors is indicated.

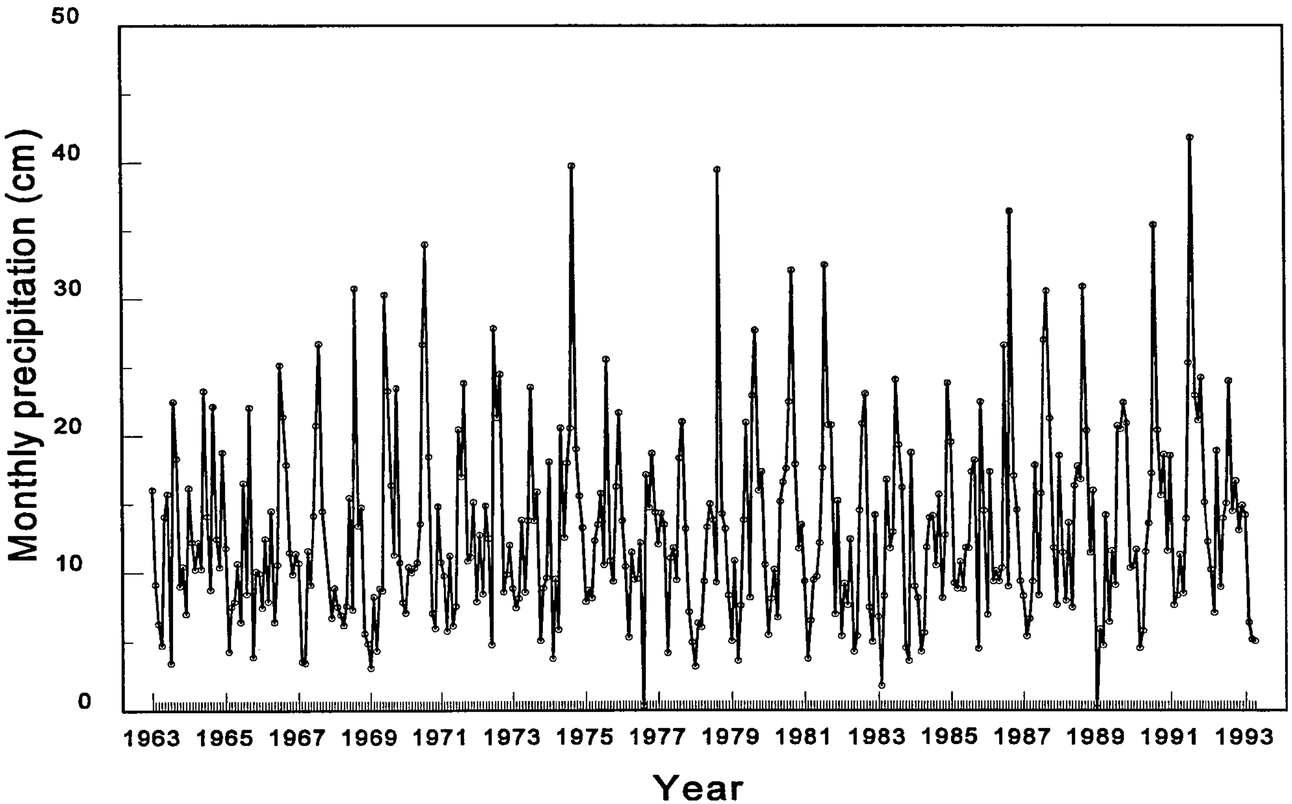

Figure 11a.--Total monthly precipitation at the Auke Bay Laboratory, February 1963 through May 1993.

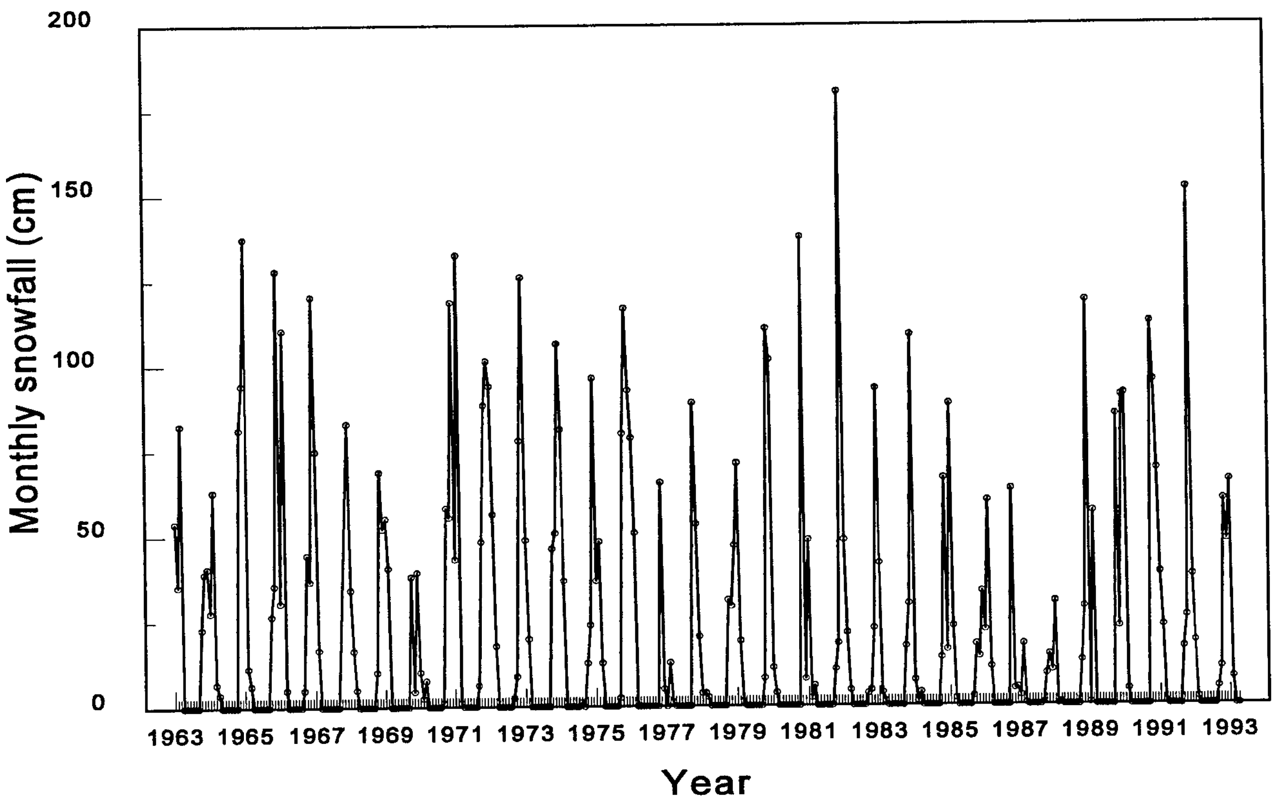

Figure 11b.--Monthly snowfall at the Auke Bay Laboratory, February 1963 through May 1993.

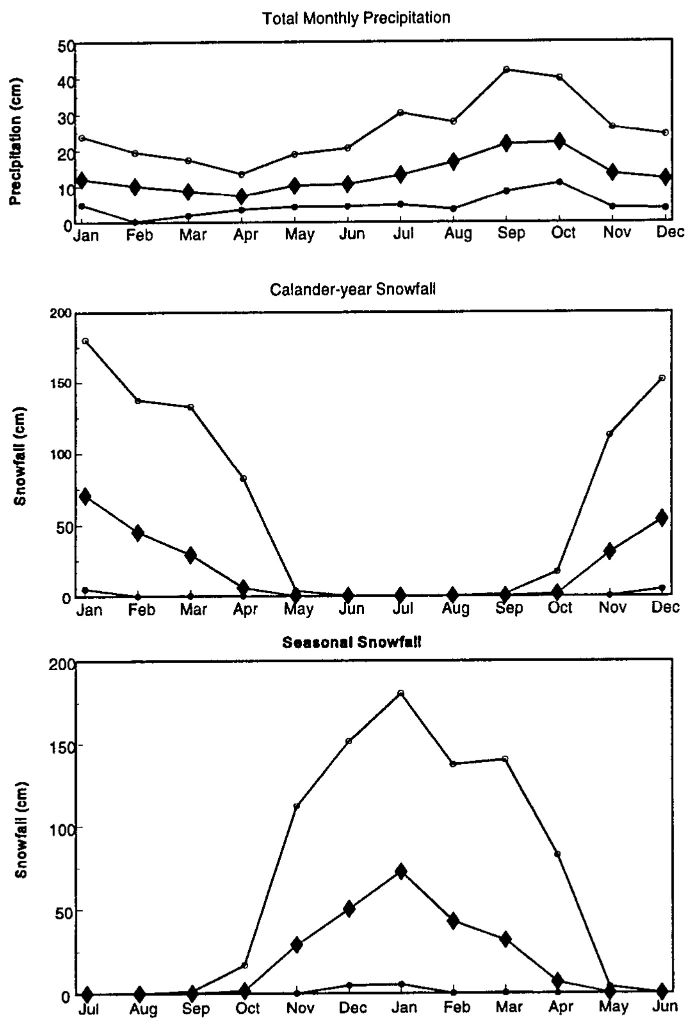

Figure 12.--Statistics of annual precipitation cycle at Auke Bay Laboratory (1963-93) from monthly precipitation (cm) (maximum [O], mean [♦]], and minimum [•]) for total precipitation, calander-year snowfall (January-December), and seasonal snowfall (July-June).

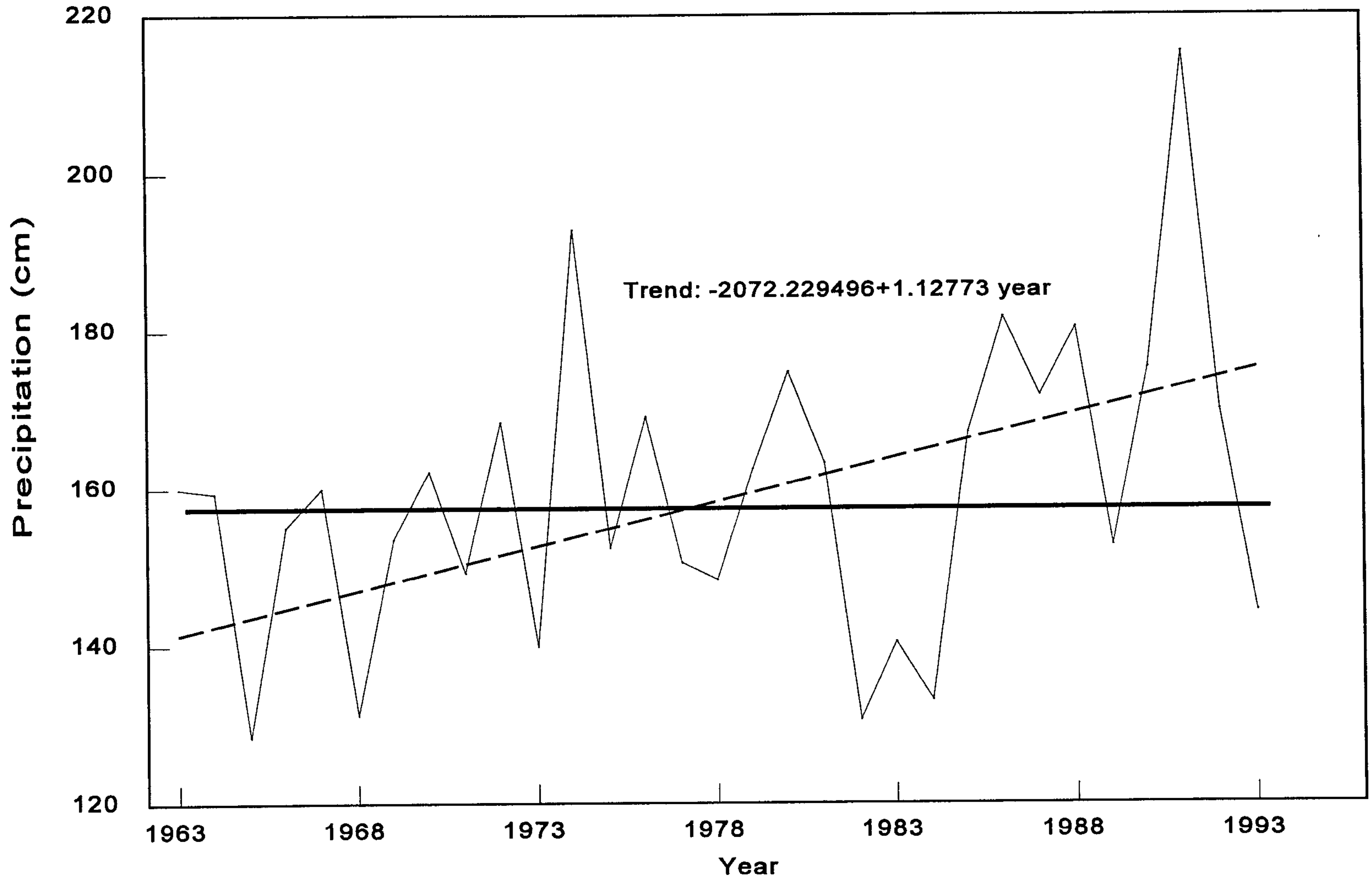

Figure 13.--Annual total precipitation at Auke Bay, 1963-93. Missing monthly values were estimated by cubic spline interpolation. Solid horizontal line is the overall mean, and the dashed line is the trend.

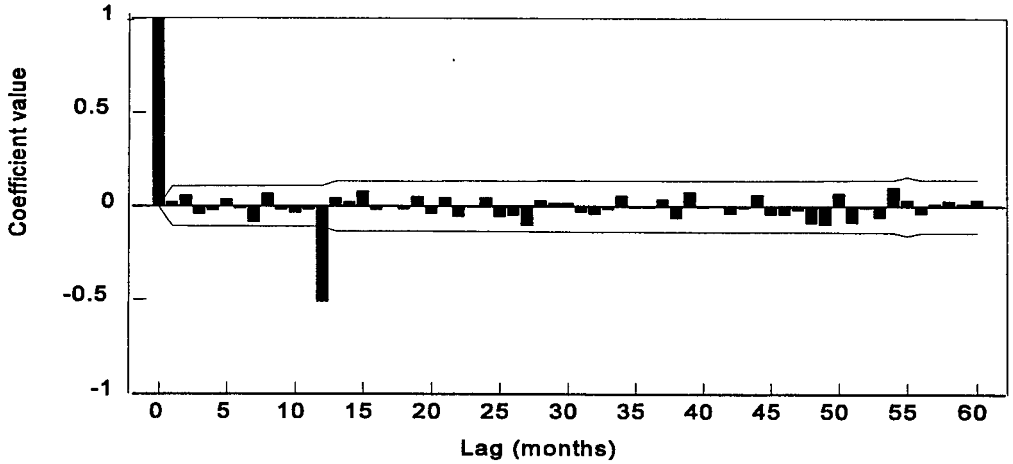

Figure 14.--Sample autocorrelation function (SACF) of interannual month differences in logarithm-transformed precipitation at Auke Bay. The interval covering 2 standard errors is indicated.

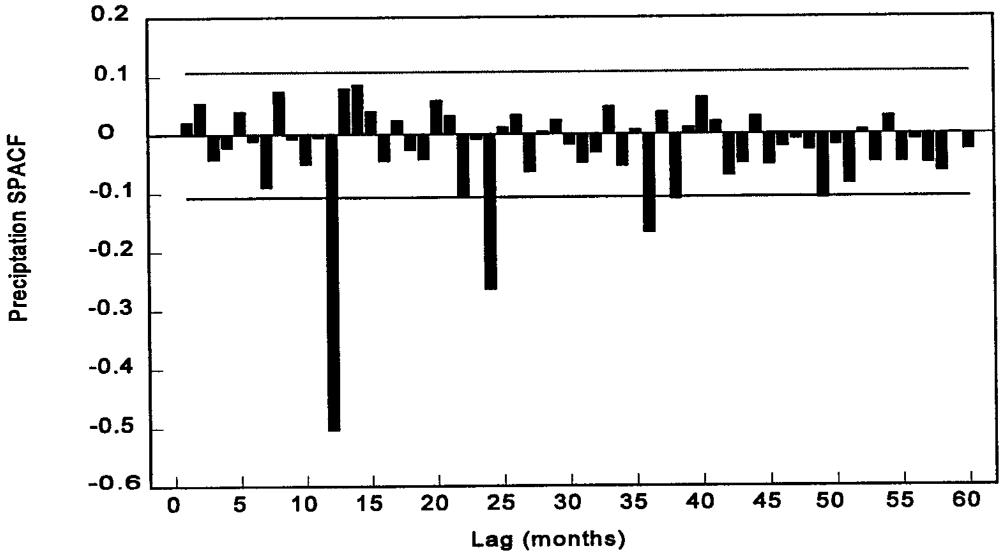

Figure 15.--Sample partial autocorrelation function (SPACF) of interannual month differences in logarithm-transformed precipitation at Auke Bay. The interval covering 2 standard errors is indicated.

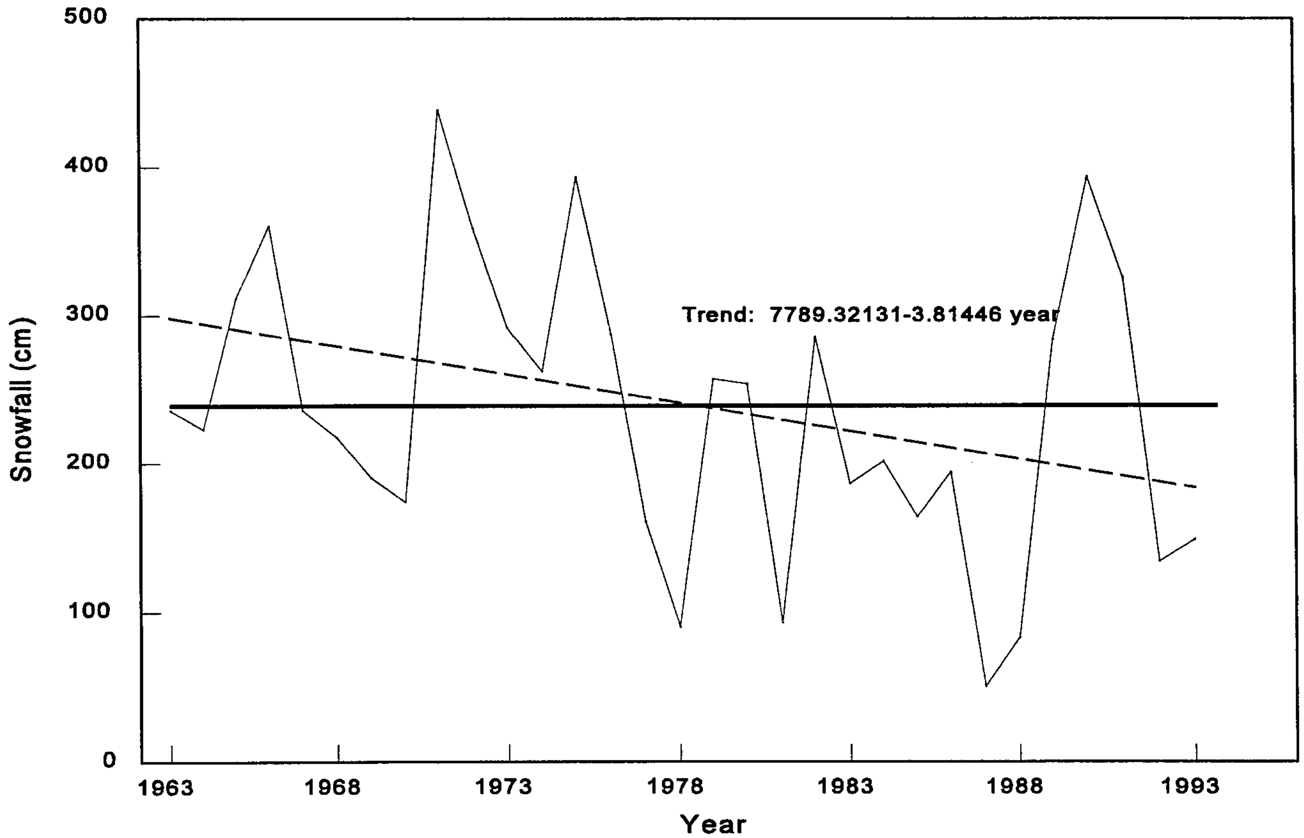

Figure 16--Annual total snowfall at Auke Bay, 1963-93. Missing monthly values were estimated by cubic spline interpolation. Slope of the trend line was not significant ($p > 0.05$). Solid line is the overall annual mean, and dashed line is the trend.

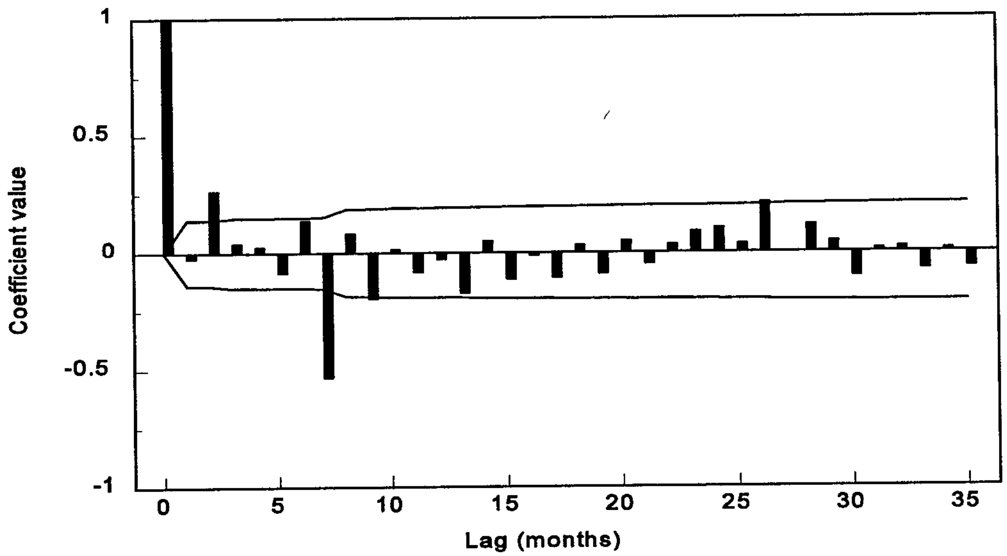

Figure 17.--Sample autocorrelation function (SACF) of interannual month differences in logarithm-transformed snowfall at Auke Bay. The interval covering 2 standard errors is indicated.

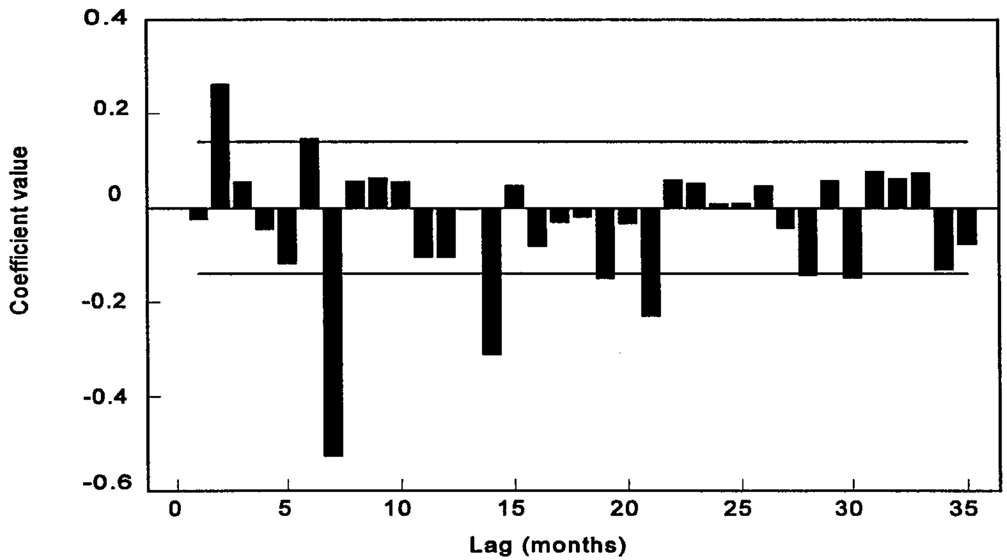

Figure l8--Sample partial autocorrelation function (SPACF) of interannual month differences in logarithm-transformed snowfall at Auke Bay. The interval covering 2 standard errors is indicated.

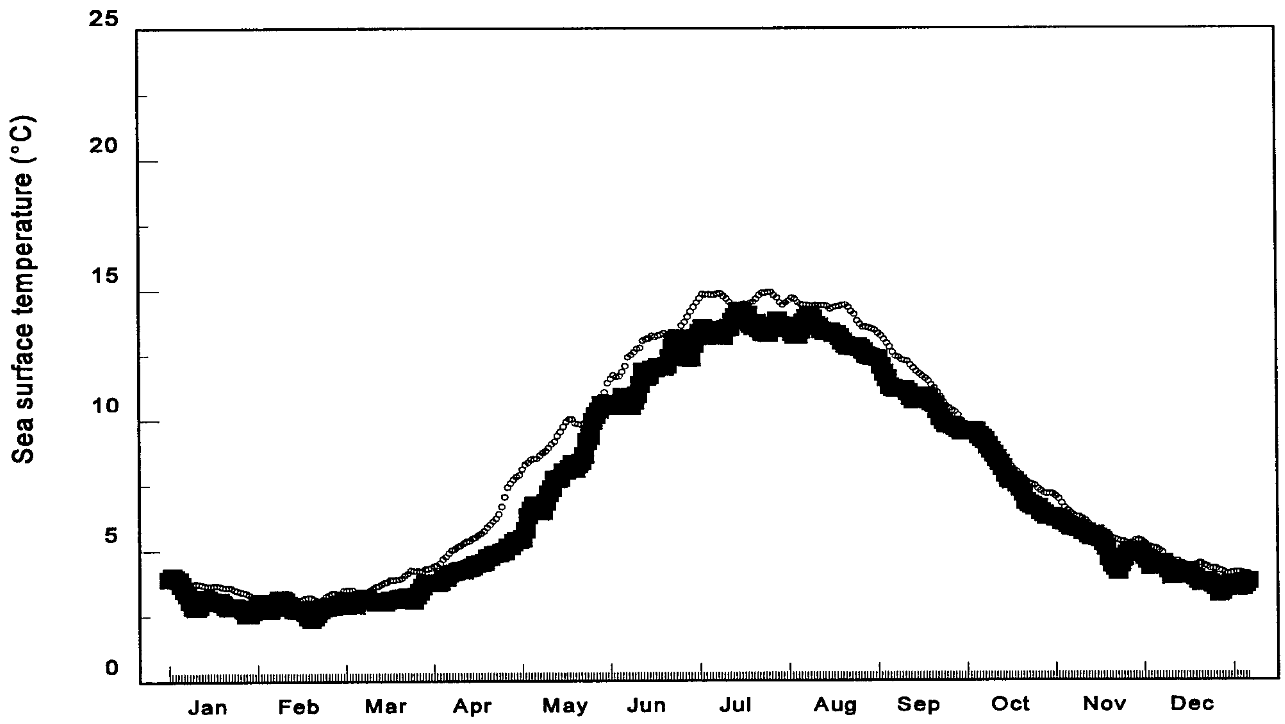

Figure 19a.--Statistics of daily sea surface temperatures at the Auke Bay Laboratory float. Comparison of the moving 4-day averages for 1959-69 (■) and 1975-93 (o). Temperatures during 1959-69 were measured in the morning, whereas temperatures during 1975-93 were measured in the afternoon.

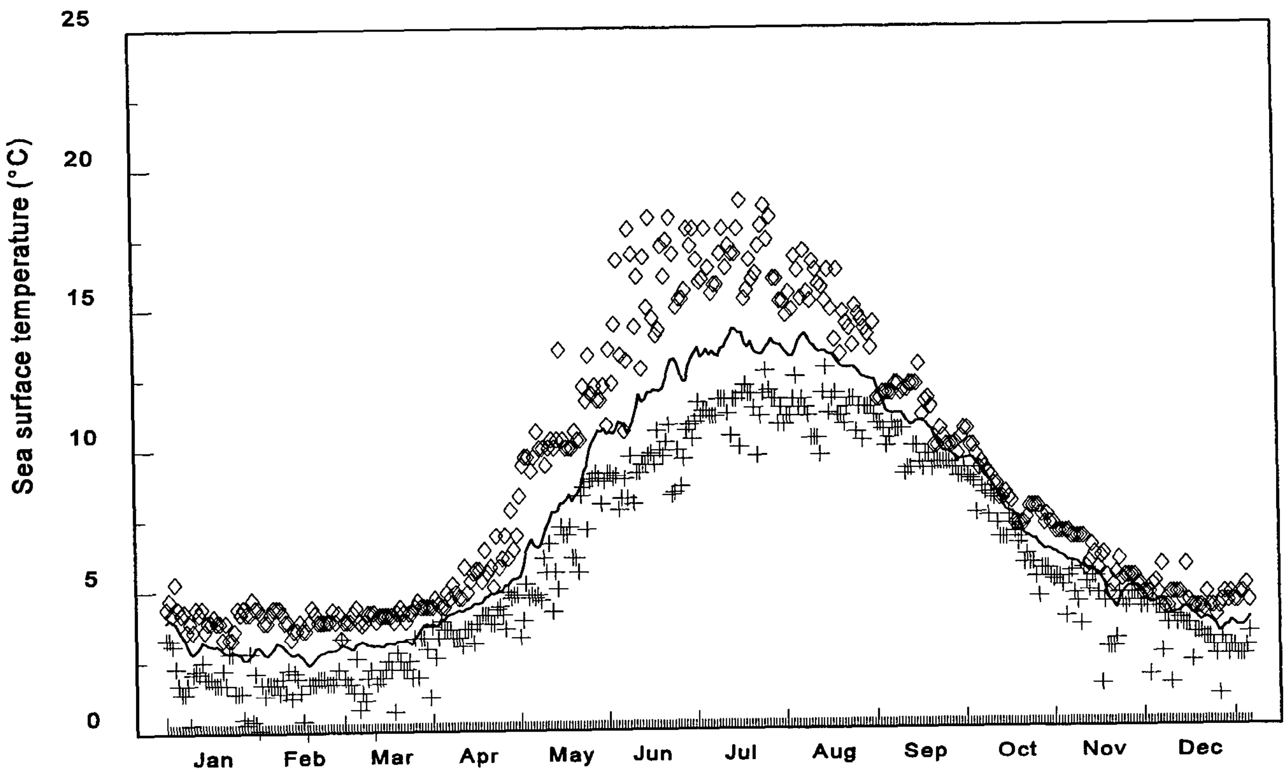

Figure 19b.--Statistics of daily sea surface temperatures at the Auke Bay Laboratory float for 1959-69. Minimum (+), mean (-), and maximum (0).

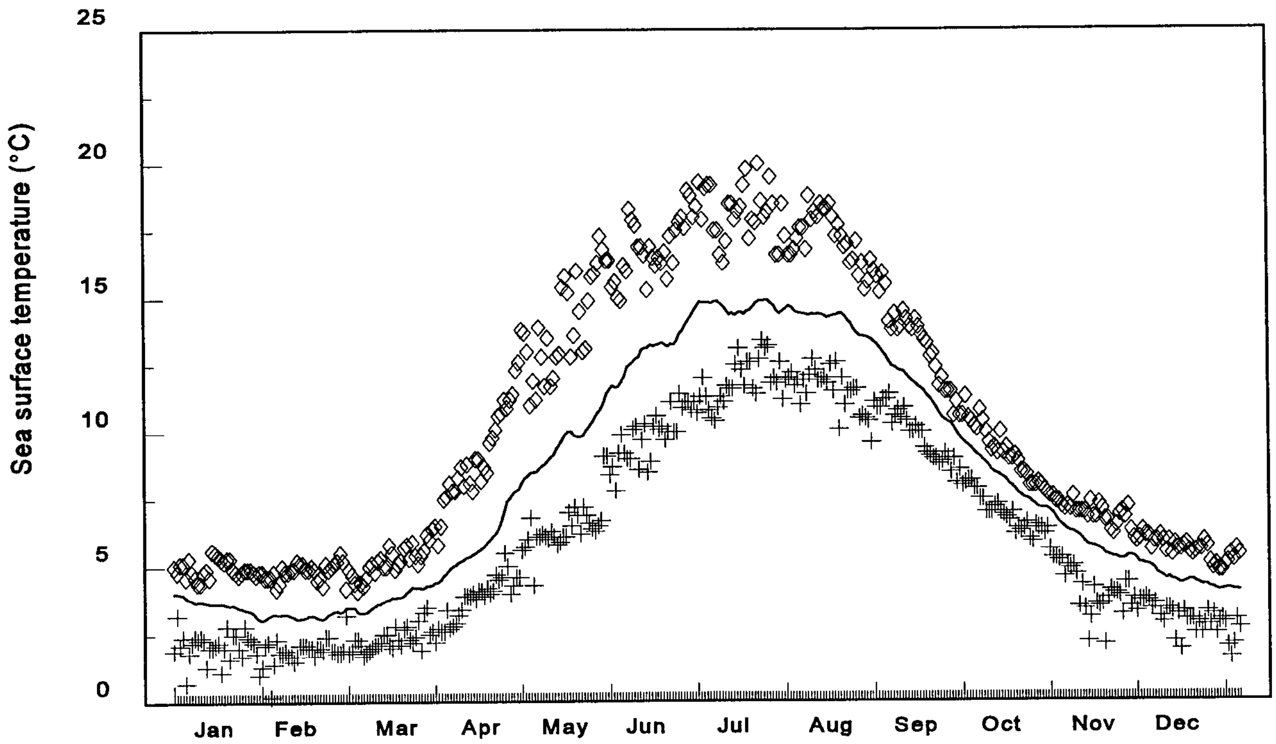

Figure 19c.--Statistics of daily sea surface temperatures at the Auke Bay Laboratory float for 1975-93. Minimum (+), mean (-), and maximum (0).

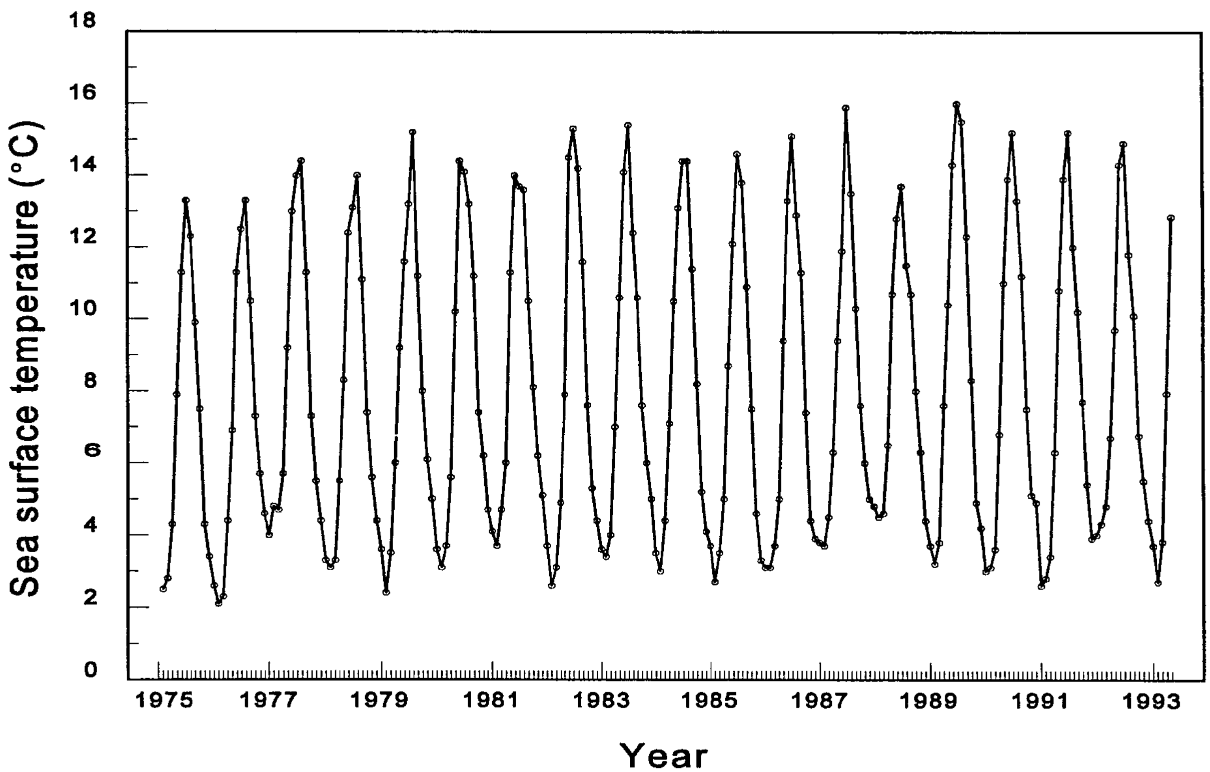

Figure 20.--Monthly averages of daily sea surface temperatures (MADSSTs) at Auke Bay Laboratory, February 1975 through May 1993.

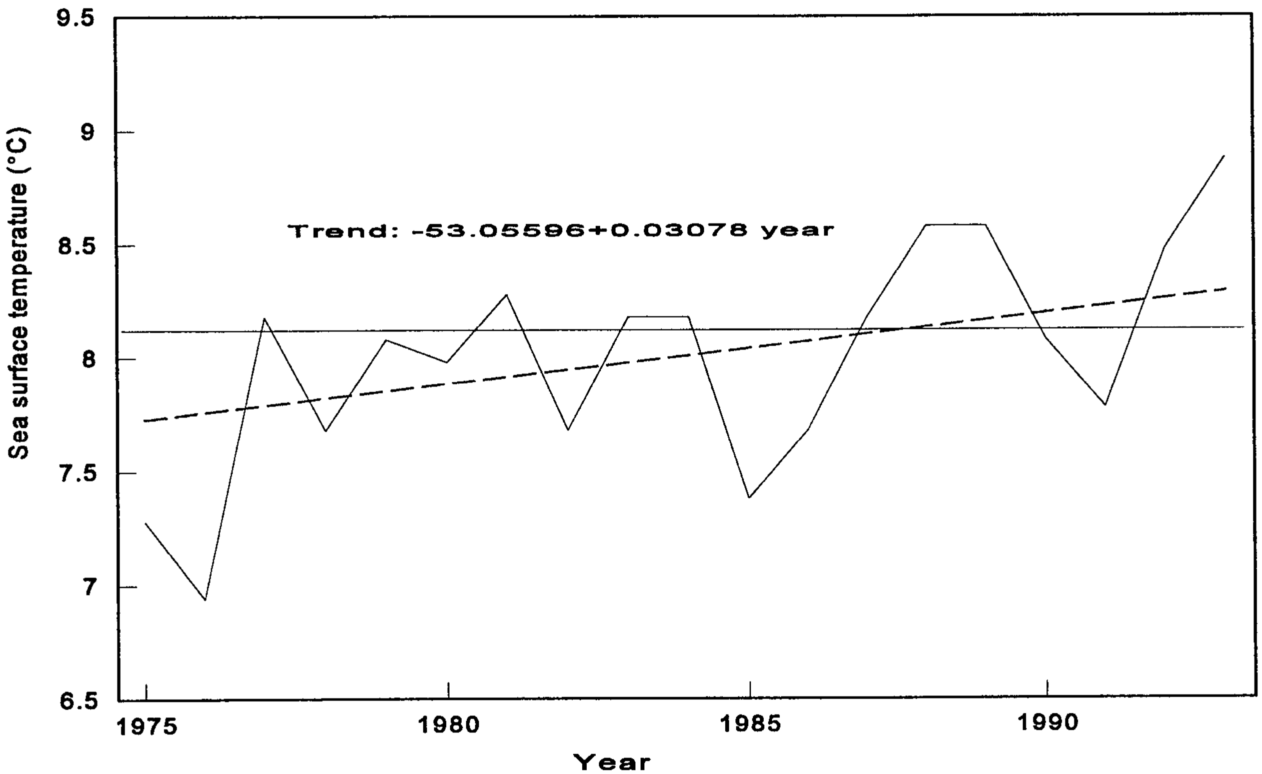

Figure 21.--Annual average of monthly average daily sea surface temperatures (MADSSTs) at Auke Bay, Alaska, 1975-93. The solid line is the overall annual mean, and the dashed line is the trend.

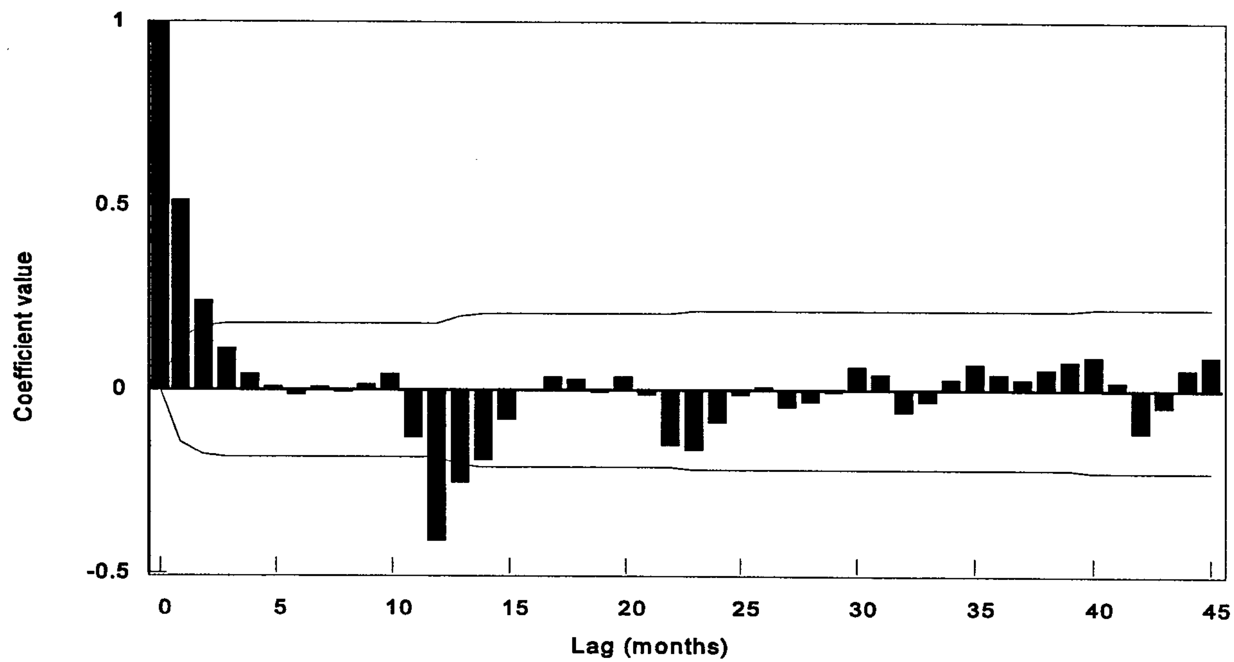

Figure 22.--Sample autocorrelation function (SACF) of interannual differences in logarithm-transformed monthly average daily sea surface temmperatures (MADSSTs) at Auke Bay. The interval covering 2 standard errors is indicated.

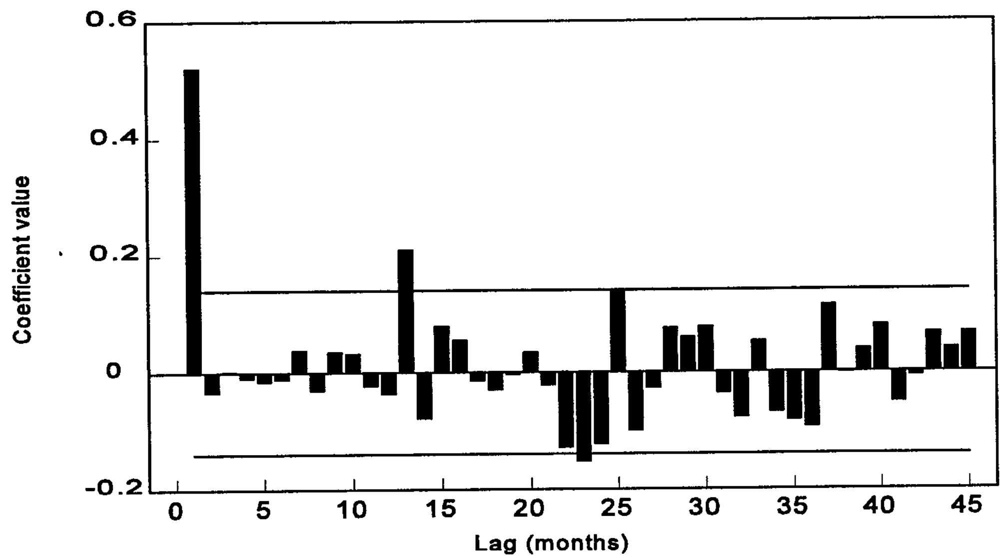

Figure 23.--Sample partial autocorrelation function (SPACF) of interannual month differences in logarithm-transformed monthly average daily sea surface temperatures (MADSSTs) at Auke Bay. The interval covering 2 standard errors is indicated.

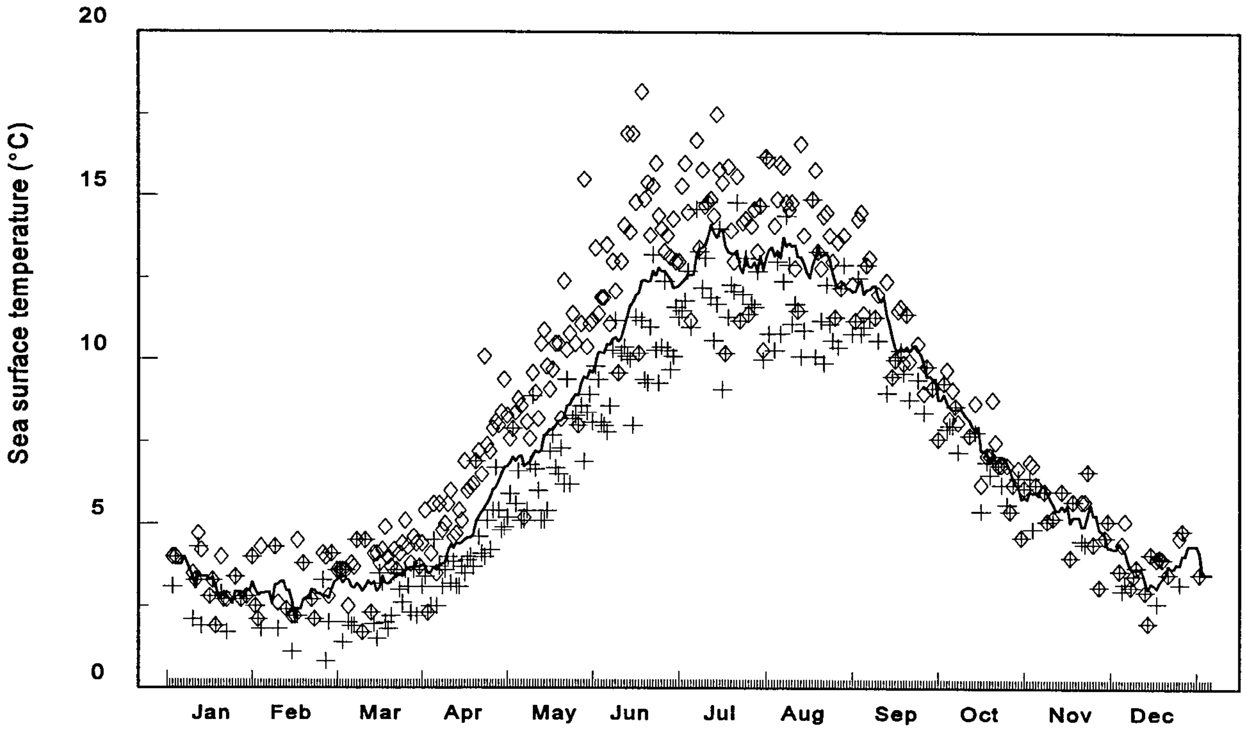

Figure 24.--Statistics of annual sea surface temperature cycles (1959-93) at Auke Bay monitor station including 7-day moving average (-) and extreme days (maximum [0] and minimum [+]).

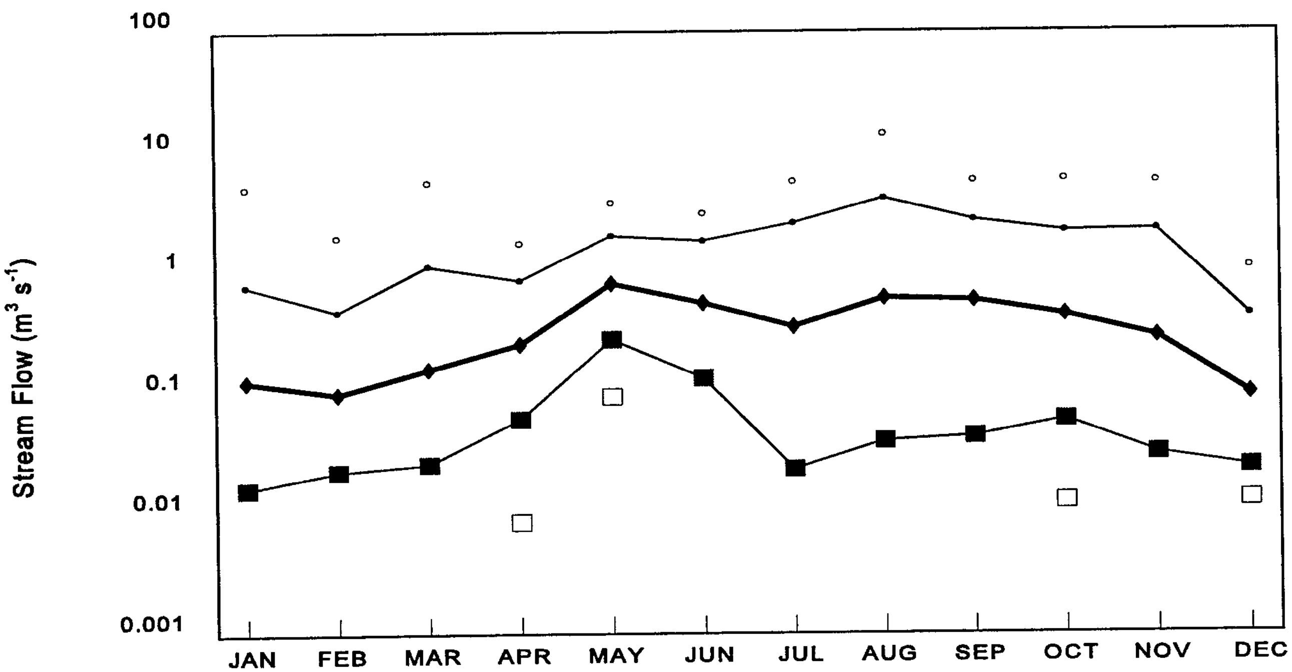

Figure 25.--Statistics of annual Lake Creek stream flow cycle (1963-73), including extreme days (maximum [O] and minimum [•]) and monthly extremes (high [•], low [■], and series average [♦]). Minima of no surface flow are not shown.

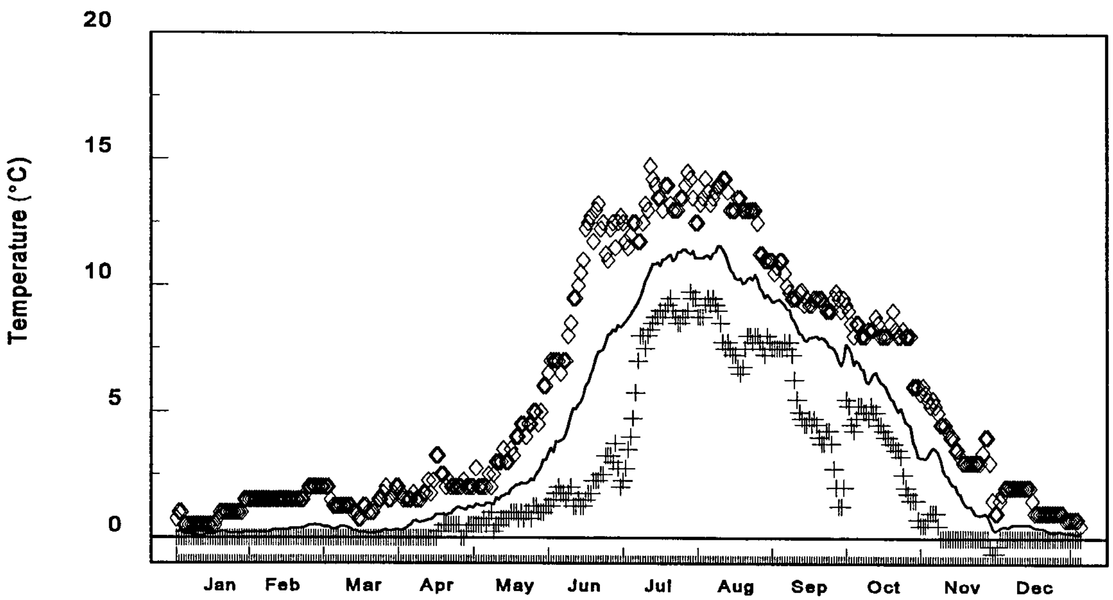

Figure 26.--Statistics of annual Lake Creek temperature cycle (1963-73), including 4-day moving average (-) and daily extremes (maximum [0] and minimum [+]).

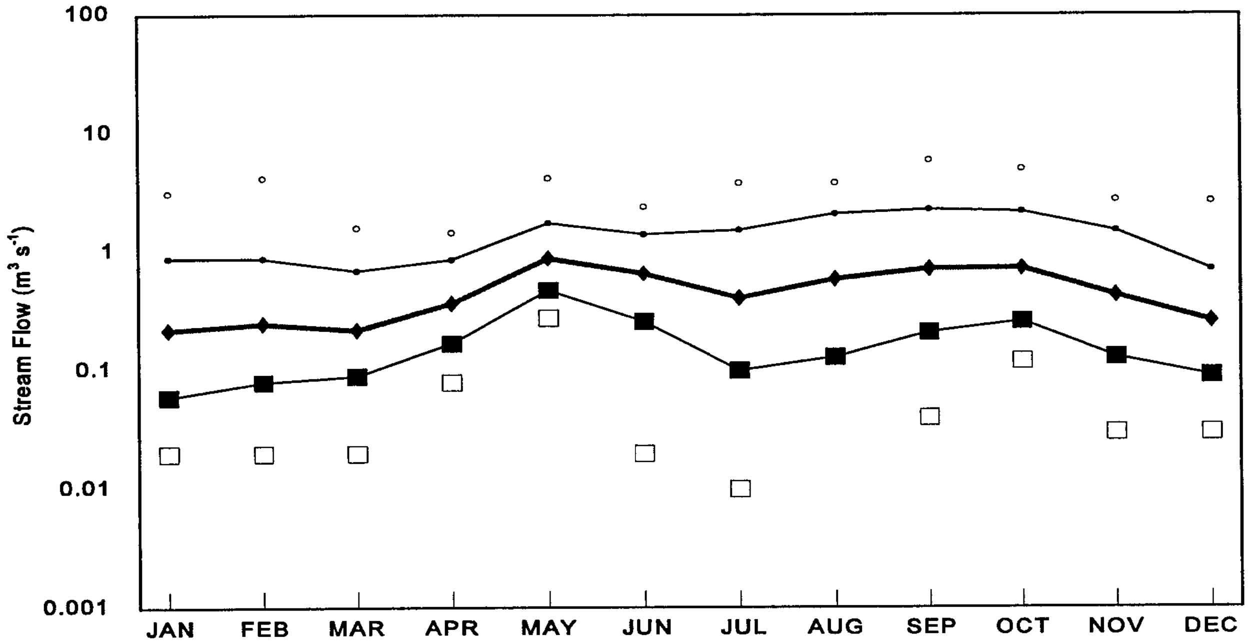

Figure 27.--Statistics of annual Auke Creek stream flow cycle (1962-75), including extreme days (maximum [◦] and minimum [□]) and monthly averages (high [•], low [■], and series average [♦]). Minima of no surface flow are not shown.

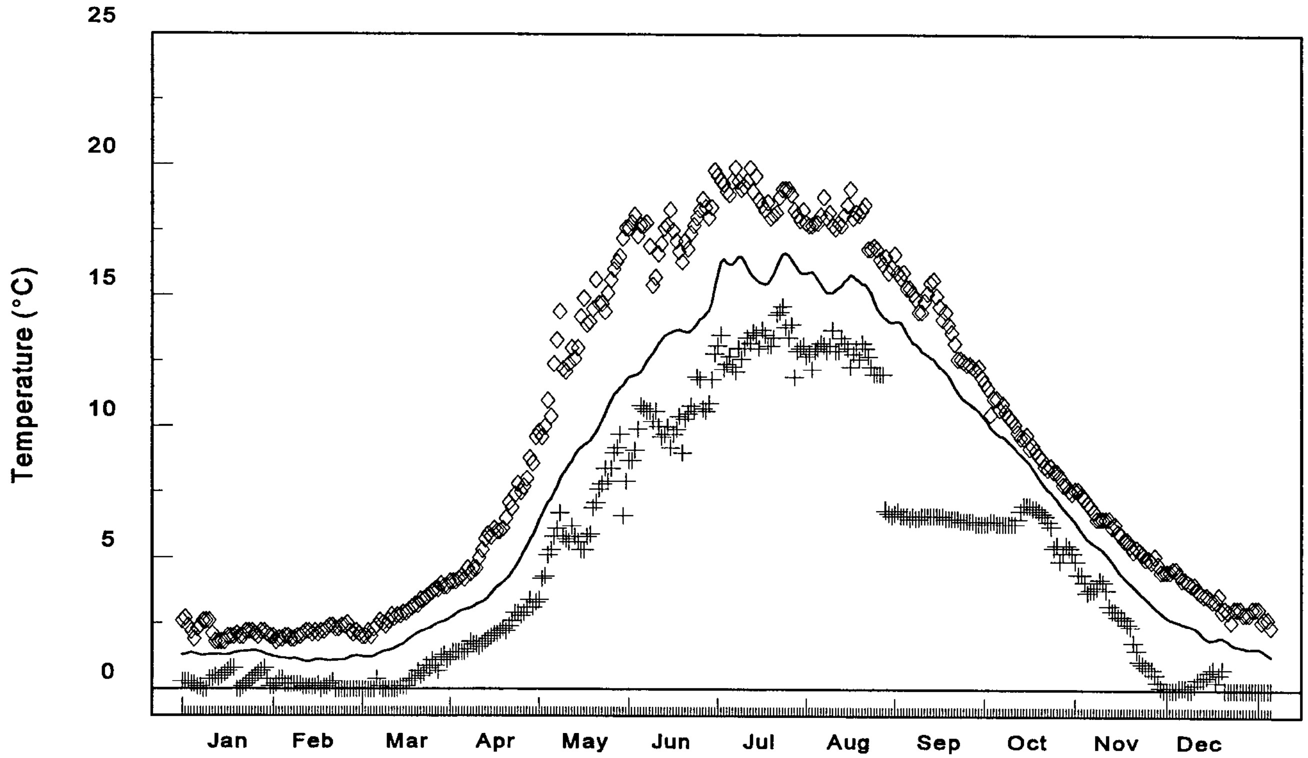

Figure 28.--Statistics of annual Auke Creek temperature cycle (1963-93), including 4-day moving average (-) and extreme days (maximum [0] and minimum [+]). August-October minima appear to be instrumental errors.

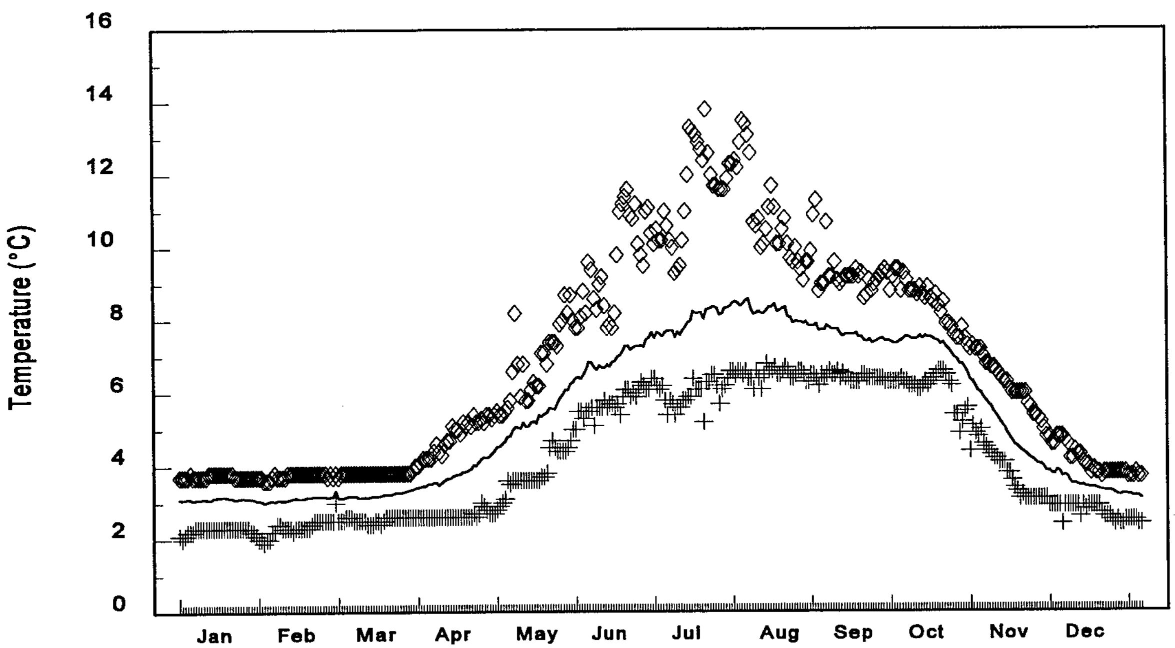

Figure 29.--Statistics of annual Auke Creek hatchery temperature cycle (1971-92), including 4-day moving average (–) and extreme days (maximum [◊] and minimum [+]).

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