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U.S. DEPARTMENT OF COMMERCE
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ABSTRACT

Physical environmental data from Auke Bay, Alaska, collected by staff of the National Marine Fisheries Service's Auke Bay Laboratory (ABL) during 1959-2004 near Auke Bay, Alaska, are summarized in tabular and graphic formats. Data for the 1959-1993 period were summarized in 1998 by ABL scientists Bruce L. Wing and Jerome J. Pella. This report updates the records and analyses through December 2004. Data include air temperatures, precipitation (rainfall and melted snowfall), water temperature for Auke Creek, annual dates of freeze-up and ice-out for Auke Lake, and Auke Bay sea surface temperature. Statistical time series methods, including spectral analysis for the 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.

Significant trends observed were an increase of average daily high, daily low and daily mid-range air temperatures, a decrease in annual snowfall, an increase of average daily sea surface temperature, and an increase in Auke Creek stream temperature. The observed trends of an increase in total precipitation and decrease in duration of ice cover on Auke Lake associated with earlier dates of ice-out on Auke Lake were not significant.

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INTRODUCTION

Auke Bay is a small (11 km^2) embayment in the fjord system of southeastern Alaska, located approximately 130 km inland from 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 1940, respectively (Lomire 1979). Auke Bay is subject to a northern maritime climate, having moderate temperatures, high precipitation, and predominantly 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). The 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 in comparing Auke Bay weather records to those of nearby Juneau, Mendenhall Glacier, and the Juneau International Airport. Auke Bay is protected by surrounding hills from the prevailing southeasterly winds year-round and in the winter from 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 both 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 and observational studies. Additionally, the U.S. Environmental Protection Agency, U.S. Army Corps of Engineers, and the Alaska Department of Environmental Conservation have studied the area for environmental impact assessments for the Alaska Marine Highway System ferry terminal, small boat harbor breakwater, fish processing plant, sewage outfall, and related shoreline developments.

This report presents tabular and graphic summaries and time series analyses of the physical data gathered by scientists from the National Marine Fisheries Service's Auke Bay Laboratory (ABL) since 1959. These summaries supplement and update previously published data from Auke Bay by Bruce et al. (1977), Coyle and Shirley (1990), and Wing and Pella (1998). In this report, we present new data for air temperatures and precipitation, Auke Creek stream temperature, and dates of Auke Lake freeze-up and ice-out, and Auke Bay sea surface temperature (SST).

METHODS

Meteorological Records

Weather observations have been taken daily since February 1963 at ABL (lat. 58°22.88'N, long. 134°38.67'W), as part of the National Weather Service Cooperative Observer Program. Daily air temperatures and precipitation were recorded at approximately 1630 hours local time 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 transcribed to computer-readable media. Extreme daily high and low temperatures were also 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 electric power outages. From October 1979 through June 1998, a battery-powered hygrothermograph served as a secondary backup to the standard system for periods when an observer was not available. For purposes of this report the monthly average temperatures have been converted to the Celsius scale.

Precipitation

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

Auke Bay Seawater 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 (10-20 m beyond the zero tide line) and on a less regular schedule according to specific project needs. In 1975, daily SST observations were reinstituted at the ABL float. To ensure continuity of the data, SSTs are taken at the end of the normal work day (1630 hours) and included as part of the daily weather observations. Sea surface temperatures were taken with a mercury thermometer until 2003 when it was replaced with an electronic YSI Model 30 Salinity, Conductivity, and Temperature System. A Vemco Minilog-T is used as a backup when an observer is not available. The temperature and salinity observations are taken at a standard 12 inch (30 cm) depth.

The large gaps in data records in the 1960s and 1970s resulted from changing priorities, personnel, and programs.

Auke Bay Monitor Station

The Auke Bay Monitor (ABM) oceanographic station (lat. 58°21.97'N, long. 134°40.00'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 are collected there on varying and irregular schedules according to the needs of specific projects.

Auke Lake Watershed 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 into Auke Bay.

Auke Creek

Auke Creek, the outflow from Auke Lake to Auke Bay, has a 10 km^2 (4.0 mi^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 20 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 in 1963 to increase salmon spawning area, but pink salmon do not consistently spawn in the modified area.

Auke Creek temperatures and stream flow were recorded continuously by a stream gauge at the upper end of the creek from October 1962 through September 1975; thereafter, the stream temperatures were recorded at the Auke Creek Hatchery weir at the lower end of the stream. Stream temperatures at the weir were monitored each morning with liquid-in-glass thermometers. Since 2000 the stream temperatures have been recorded every 4 hours by a Vemco Minilog-T.

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 ft) depth in the lake and flowed through an insulated 35-cm diameter pipe to the hatchery. Flow rate into the hatchery was approximately 0.06 m^3s^{-1} (0.5 cfs). Although some heat exchange occurred during the flow through the pipe, it was considered minimal. Auke Creek Hatchery temperatures were probably representative of Auke Lake temperatures at 6 m depth through the spring of 1990, when the ABL ceased using water from the same pipe for domestic and experimental use. The Auke Creek Hatchery continues to use water drawn from the lake, but temperatures in the hatchery are now monitored with liquid-in-glass thermometers once a day, depending on individual project requirements.

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 until 1992. 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 2005 were taken from field notes of ABL 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 December 2004 inclusive (42 years of nearly continuous monthly records for each variable with no series missing more than 5 of the 504 months), and SST from February 1975 to December 2004 inclusive (30 years of continuous monthly records). Over the span of observation (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 1 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 SST) 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 models; 2) estimation of parameters of the model(s) chosen; and 3) checking for adequacy of the model(s) by testing

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

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 re-estimated, and adequacy rechecked.

Statistics were computed up to a maximum lag of 120 months for precipitation and temperature series, up to a maximum lag of 70 months for snowfall (5 months, May through September, with no or very low snowfall were omitted from the series), and up to a maximum lag of 84 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 snowfall measurements (cm) were increased by 1 cm and monthly temperature measurements (°C) except for SST 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 fitted 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),

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

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

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

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 1-month-ahead forecast equations were included to clarify important temporal relationships within time series. Although these equations could be used in forecasting 1-month ahead and 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 U.S. National Weather Service, Western Regional Climate Center. 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 2004. 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 1), 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 less variation when superimposed on annual cycling. The annual cycles were discerned easily ($P < 0.001$) and accounted for more than 85% of the total variation in each temperature series (Table 4). January was the coldest month (-3.41°C) and July was the warmest month (14.30°C) by average MADMT (Table 3). Annual variation was evident from 1-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 1964 and 2004 (missing values were estimated by cubic spline interpolation) contained an irregular upward trend (Table 4; Fig. 4). Annual average MADHT ranged from a low of 7.43°C in 1972 to a high of 11.01°C in 1993 (Table 4; Fig. 4) with a series average of 9.11°C (SD = 0.79°C). Annual average MADLT ranged from a low of 0.33°C in 1972 to a high of 4.11°C in 2004 (Table 4; Fig. 4) with a series average of 2.34°C (SD = 0.98°C). Annual average

MADMT temperatures ranged from a low of 3.88°C in 1972 to a high of 7.57°C in 2004 (Table 4; Fig. 4) with a series average of 5.76°C (SD = 0.86°C). Slopes of the trend lines (Table 4; Fig. 4) for MADHT, MADLT, and MADMT showed that temperatures increased over the 41 years fitted (1964–2004) at rates of 0.037 °C yr^{-1} (SE = 0.009, $P < 0.001$), 0.058 °C yr^{-1} (SE = 0.009, $P < 0.001$), and 0.049°C yr^{-1} (SE = 0.009, $P < 0.001$), respectively. The Durbin-Watson statistics equaled 1.977, 1.728, and 1.917 for the three series, respectively, and provided no evidence of lag-1 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 ($r_{12} = -0.511$, SE = 0.049) 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 with significant spikes at lags of 12, 36, and 96 months: $r_{12} = -0.474$, SE = 0.049; $r_{36} = 0.125$, SE = 0.060; $r_{96} = -0.044$, SE = 0.064. 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 at lag of 12 months ($r_{12} = -0.495$, SE = 0.049) 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 a significant coefficient at lag of 1 month, and the SPACFs had significant coefficients at lag of 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 fitted to each temperature series and tested for adequacy. Generally, the SACF and SPACF of the residuals indicated the initial models that provided for interannual and intra-annual variation were adequate.

Statistics of the model fitted to the transformed high temperature series (MADHTs) (Table 5) showed all coefficients (excluding the constant) were significant and weakly correlated. The 1-month ahead forecast for transformed high temperature (MADHT) in January 2005 (Table 5) included linear terms of the transformed MADHT for the previous January (2004), the difference in transformed December MADHTs of the two previous years (2003 and 2004), and the residual for the previous January (2004). A general forecast equation for any month would show that events 1, 12, and 13 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 95 months) for residuals from this final high temperature model were statistically significant (six were expected by chance); and five partial autocorrelation coefficients (at lags of 26, 47, 95, 114, and 120 months) for the residuals were significant (six were expected by chance). The Ljung-Box test supported the conclusion that the residuals were indistinguishable from white noise for lags up to 120 months (Table 5).

For MADLTs, an interannual autoregressive term at a lag of 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 1-month ahead forecast for transformed low temperature (MADLT) in January 2005 (Table 6) included linear terms of the transformed MADLT for the previous January (2004), the difference in transformed December MADLTs of the two previous years (2003 and 2004), the difference in transformed January MADLTs of 3 and 4 years previous (2001 and 2002), and the residual for the previous January (2004). A general forecast equation for any month would show events 1, 12, 13, 36, and 48 months earlier than that month were of value in predicting MADLTs. Little or no additional information occurred in the residuals as evidenced by their SACF and SPACF (not shown). One autocorrelation coefficient (at lag of 95 months) for residuals from this final low temperatures model was statistically significant (six were expected by chance), and four partial autocorrelation coefficients (at lags of 60, 85, 95, and 120 months) for the residuals were significant (six were expected by chance). The Ljung-Box test supported the conclusion that the residuals were indistinguishable from white noise for lags up to 120 months (Table 6).

Statistics of the model fit to the transformed midrange temperature series (MADMTs) (Table 7) showed all coefficients (excluding the constant) were significant and all were weakly correlated. Just as was the case for the high temperature series (MADHTs), the 1-month ahead forecast for the transformed midrange temperature (MADMT) in January 2005 (Table 7) included linear terms of the transformed MADMT for the previous January (2004), the difference in transformed December MADMTs of the two previous years (2003 and 2004), and the residual for the previous January (2004). A general forecast equation for any month would show that events 1, 12, and 13 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 95 months) for residuals from this final midrange temperature model was statistically significant (six were expected by chance), and six partial autocorrelation coefficients (at lags of 10, 26, 60, 85, 95, and 120 months) for the residuals were significant (six were expected by chance). The Ljung-Box test supported the conclusion that the residuals were indistinguishable from white noise for lags up to 120 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 95 months, 95 months, and 95 months, respectively. Also, the corresponding SPACFs contained significant coefficients at the following lags: 26, 47, 95, 114, and 120 months; 60, 85, 95, and 120 months; and 10, 26, 60, 85, 95, and 120 months. All functions shared a significant coefficient at lag of 95 months (7 years and 11 months). When the final models were augmented by an autoregressive term with lag of 95 months, this fitted coefficient was statistically significant ($P < 0.01$) for all 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. In addition, the low temperature series had an autoregressive coefficient at lag of 36 months.

Test-year forecasts from the final models and simpler models supported certain of the simpler models. For MADHTs, mean square of forecast errors by the final 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 simpler model (parameterized by μ and θ_{12}) was smallest in three test years. 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}, and φ_1) was smallest in three test years as well as overall (5 years combined), and that of the simpler model (parameterized by μ and θ_{12}) was smallest in two test years. For high and midrange daily temperatures, the final model surpassed the simpler models in overall (5 years combined) forecast accuracy and was matched in certain years for best forecast accuracy by one of the simpler models. For low daily temperature, 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. 11a; 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 at the end of the passing summer. Mean monthly precipitation ranged from 7.33 cm in April to 22.44 cm in September (Fig. 12). The mean monthly extremes were 0.18 cm in February 1989 and 41.81 cm in September 1991 (Table 8). The annual cycle was discerned easily ($P < 0.001$) but accounted for only about 36% of the total variation (Table 4). Snowfall occurred from September through May (Fig. 12), although May, September, and October normally received only trace amounts; trace amounts of snowfall were treated as zeroes in analyses. Mean monthly snowfall for November through April was 37 cm. January had the highest average snowfall (mean of 68 cm with a range of 5 cm in 1987 to 180 cm in 1982) (Table 9). The annual cycle was evident ($P < 0.001$) but accounted for only about 42% of total variation.

Annual precipitation between 1964 and 2004 (Table 8) ranged from a low of 116.69 cm in 1995 to a high of 215.39 cm in 1991. Average annual precipitation was 159.19 cm (SD = 20.08 cm). The annual series contained an irregular upward trend, interrupted about the time of the 1982-1983 El Niño and in 1995 (Fig. 13). Slope of the trend line (Table 4) showed that precipitation increased over the 41 years (1964-2004) fitted but not at a significant rate (0.341 cm yr^{-1}, SE = 0.264, $P = 0.20$). The Durbin-Watson statistic was 1.957 and provided no evidence of lag-1 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 ($r_{12} = -0.453$, SE = 0.046) at lag equal to 12 months (and no further significant autocorrelation coefficients at higher lag multiples of 12 months), and the SPACF generally decayed toward zero at lag multiples of 12 months. The simple first-order annual moving-average model was fitted to the series of interannual month differences in annual precipitation. The SACF and SPACF of the residuals (not shown) 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 an autoregressive parameter of lag equal to 48 months was fitted. Both the annual moving-average parameter, θ_{12} ($P < 0.001$), and autoregressive parameter, φ_{48} ($P = 0.002$), were detected (Table 11), but the estimate for μ did not differ significantly from zero. The parameter estimates were weakly correlated. The one-month ahead forecast for transformed precipitation in January

2005 (Table 11) included linear terms of the transformed precipitation during the previous January (2004), the difference in transformed January precipitation 4 and 5 years earlier (2000 and 2001), and the residual for the previous January (2004). 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). Two autocorrelation coefficients (at lags of 90 and 96 months) for residuals from this final precipitation model were statistically significant (six were expected by chance), and four partial autocorrelation coefficients (at lags of 8, 90, 101, and 119) for the residuals were significant (six were expected by chance). The Ljung-Box test supported the conclusion that the residuals were indistinguishable from white noise for lags up to 120 months (Table 11).

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

Annual snowfall (calendar year) between 1964 and 2004 (Table 9) ranged from a low of 36.59 cm (2000) to a high of 442.47 cm (1994), with an average of 219.24 cm (SD = 103.69 cm). The series contained an irregular downward trend until the late 1980s, whereafter snowfall rose above the long-term mean in 1989, 1990, 1991, and 1994 (Fig. 16). The series fell below the long-term mean for 2 years preceding 1994 and thereafter, except in 1999 when the snowfall was slightly above the long-term mean (Fig. 16). Slope of the trend line (Table 4; Fig. 16) indicated that snowfall decreased over the 41 years fitted (1964-2004) at a rate of 3.582 cm yr^{-1} (SE = 1.263, $P < 0.01$). The Durbin-Watson statistic was 1.726 and provided no evidence of lag-1 autocorrelation in residuals from the fitted line. Differences in annual snowfall in successive years reached more than 250 cm three times (1970-71, 1993-94, and 1994-95) and more than 100 cm fifteen times (Table 9). Snowfall during the snow year (July through June, but essentially late September through early May) ranged from a low of 51.57 cm (2000-01) to a high of 421.64 cm (1975-76), with an average of 222.05 cm (SD = 95.00 cm) (Table 10).

No snow fell during June, July, and August, and average snowfall for May and September was less than 0.1 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 ($r_7 = -0.494$, SE = 0.062), and the SPACF decayed regularly at lag multiples of 7 months. Intra-annual variation for the snowfall series included a first-order autoregressive process. The SACF and SPACF spikes at lag of 2 months ($r_2 = 0.182$, SE = 0.060; $\hat{\phi}_{22} = 0.180$, SE = 0.059) exceeded three standard errors, and were further remarkable for absence of adjoining significant values. 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 at lag of 2 months, φ_2. The estimates of the intra-annual autoregressive parameter, φ_2, ($P = 0.03$) and the constant, μ, ($P < 0.05$) were also significant. 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. 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 of 70 months (10 years) was significant at $\alpha = 0.05$. The Ljung-Box test confirmed that the residuals were indistinguishable from white noise for lags up to 66 months (> 9 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) were inconclusive: the mean square of forecast errors for the simpler model was smallest in 3 of the 5 test years and overall (5 years combined) and that of the final model was smallest in 2 test years. The SACF of the simpler model's residuals, however, had a significant spike ($r_2 = 0.127$, SE = 0.060) at lag equal to 2 months, and the SPACF had a nearly significant spike ($\hat{\phi}_{22} = 0.117$, SE = 0.060) at the same lag. The final model that included an autoregressive parameter, φ_2, showed no additional information in the residuals as evidenced by their SACF and SPACF (not shown).

Auke Bay Saltwater Temperatures

Auke Bay Monitor Station

Although the records for SST extend back to 1959, the observations were not taken on a regular schedule nor were the methods of observation constant (Wing and Pella 1998; 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 Auke Bay Monitor Station were presented. This irregular schedule of observations has continued and currently monthly observations are made only from May through August.

Auke Bay Laboratory

Sea surface temperatures in 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 ABL is located in the northeastern corner of Auke Bay and is well protected from the prevailing southeasterly winds, surface waters at the ABL 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 ABL 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 above) 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. Sea surface temperatures for 1959-69 are reported in Wing and Pella (1998) and are not mentioned further here.

According to Hagen[2], oscillations in the daily recorded Auke Bay SSTs and in a 4-day running average of these values did not appear to be related to tidal cycles. The oscillations of

[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.

the averaged data could be artifacts of smoothing called the Slutzky-Yule effect (Kendall and Stuart 1966).

Monthly averages of daily sea surface temperatures (MADSSTs) fluctuated very regularly (Fig. 19), with 92.5% 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 August (Table 13). Annual average of MADSSTs between 1976 and 2004 ranged from a low of 7.0°C in 1976 to a high of 8.9°C in 1993 (Fig. 20). Average annual MADSSTs was 8.2°C (SD = 0.43°C). The annual series began with lowest annual temperature in 1976 and thereafter fluctuated with increasing variation (Fig. 20). The slope of the trend line suggested SST increased over the 29 years fitted at a rate of 0.024°C year^{-1} (SE = 0.009, $P = 0.01$). The Durbin-Watson statistic was 1.754 and provided no evidence of lag-1 autocorrelation in residuals from the fitted line.

Interannual month differences in logarithm-transformed MADSST produced simple SACF and SPACF (Figs. 21, 22). The annual component of the transformed MADSST series was a first-order moving-average process: the SACF had a highly significant spike ($r_{12} = -0.386$, SE = 0.077) 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 35 months. The intra-annual component was a first-order autoregressive process; the SACF appeared to decay exponentially from lags of 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 [$\hat{\phi}_{11} = 0.584$, SE = 0.055]. In addition, the SACF had two additional significant coefficients at lags equal to 11 and 13 months, and the SPACF had seven additional significant coefficients at lags of 11, 13, 23, 25, 37, 49, and 52 months; roughly four 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 14) indicated that all coefficients excluding the constant were highly significant ($P < 0.001$). All parameter estimates were weakly correlated. The 1-month-ahead forecast for transformed SST in January 2005 (Table 14) included linear terms of transformed SST during the previous January (2004), the difference in transformed December SST of the two previous years (2003 and 2004), and the residual for the previous January (2004). A general forecast equation for any month would show that events 1, 12, and 13 months prior were of value in predicting SST. Apparently, little or no additional information occurred in the residuals, as evidenced by their SACF and SPACF (not shown). Two autocorrelation coefficients (at lags of 10 and 39 months) for residuals from this final model were statistically significant (four were expected by chance), and two partial autocorrelation coefficients for residuals at the same lags were significant. The Ljung-Box test (Table 14) supported the conclusion that the residuals were indistinguishable from white noise for lags up to 84 months.

Mean square of forecast errors for the final model (parameterized by μ, θ_{12}, and φ_1) was smallest in three of the five test years as well as overall (5 years combined), and that of the simpler model (parameterized by μ and θ_{12}) was smallest in two test years.

The trend of increase in SST at Auke Bay (+0.024ºC yr^{-1}) is comparable to the +0.03ºC yr^{-1} increase observed for the integrated 0-100 m by Royer and Grosch (in press) at GAK-1 in the northern Gulf of Alaska but lower than the +0.04ºC yr^{-1} observed by Nixon et al. (2004) for Woods Hole, MA. Auke Bay is 130 km inland from the open ocean and influenced by local terrestrial climate conditions. The GAK-1 station is exposed to the open ocean circulation of the Gulf of Alaska with less terrestrial effect than Auke Bay. Woods Hole, although in a well protected harbor, is close to the open coast and influenced by both terrestrial climate and oceanic conditions. Although each of the three studies uses different methods, the close similarity of results suggest the warming trends have been hemispheric for the last 40 years and are not localized phenomena.

Auke Lake Watershed Temperatures

Auke Creek Temperatures

Auke Creek stream temperatures are strongly influenced by seasonal snow melt and runoff. Observed stream temperatures have ranged from a minimum -0.2ºC (multiple records) to a maximum 21.8ºC (21 August 1977). Temperatures are at the annual minimums from late December through March when stream flows are low and Auke Lake is typically ice covered (Table 15; Fig. 23). Annual average Auke Creek stream temperatures between 1971 and 2005, including 1968 (intervening years with missing monthly temperatures were excluded), contained an upward trend (Fig. 24, Table 4) due to the increasing trend of summer temperatures (Taylor 2006). Annual average stream temperatures ranged from a low of 7.3ºC in 1972 to a high of 8.9ºC in 1998 (Table 4). The slope of the trend line (Table 4) showed that stream temperatures increased over the 36 years fitted (1968, 1971-2005) at a rate of 0.055ºC yr^{-1} (SE = 0.009, $P < 0.001$). The Durbin-Watson statistic equaled 1.713 and provided no evidence of lag-1 autocorrelation in residuals for the fitted line. Maximum stream temperatures occur from June through August during periods of low runoff and when the surface waters of Auke Lake are warmed by incident sunlight. During exceptionally low runoff conditions, surface flows from Auke Lake may cease and a minimum flow is maintained in the creek by groundwater seepage from the surrounding hill side. Under these conditions the stream temperatures at the weir near the mouth of the creek are lower than the surface temperatures of Auke Lake.

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 when surface waters cool to 0°C. Frequently, ice forms intermittently around the lake margins for several days to 2 weeks before the lake ices over completely. November 25 was the average last day of float plane operation in Auke Lake and was usually 2 weeks before the lake froze over completely.[1] Freeze-up appears to have occurred earlier in the past decades than in the 1990s and 2000s.

The duration of Auke Lake ice cover between the 1992-1993 winter and the 2004-2005 winter contained a downward trend (Fig. 25). The slope of the trend line (Table 4) showed that the duration of ice cover declined over the 13 winters but not at a significant rate (-3.615 days yr^{-1}, SE = 1.947, P = 0.09). The Durbin-Watson statistic was 2.481 and provided no evidence of lag-1 autocorrelation in residuals from the fitted line.

The ice-out-date between 1967 and 2005, including 1960 and 1963, contained a trend toward earlier dates (Fig. 26). The slope of the trend line (Table 4) showed that the ice-out date was earlier over the 41 years but not at a significant rate (-0.385 days yr^{-1}, SE = 0.242, P = 0.12). The Durbin-Watson statistic was 2.326 and provided no evidence of lag-1 autocorrelation in residuals from the fitted line.

Freeze-up occurred as early as 15 November in 1963 to as late as 4 January in 2005 (Table 17). Several years the freeze-up has not happened in the fall but was delayed until early winter shortly after the winter solstice (Table 17), resulting in shorter duration of the ice cover (Fig. 25).

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 16) on Auke Lake normally occurred in late April or early May: 18 April was the average date of ice out for the years of available data. Earliest date of ice-out was 1 February 1977 and latest ice-out date was 20 May 1972. On several occasions the ice cover on Auke Lake disappeared in early January or February and then re-froze over again until April.

SUMMARY

Time series analyses of the physical environmental records available for Auke Bay reveal six significant trends. Air temperatures (daily high, midrange and low temperatures), SSTs, and annual stream temperatures have increased, and snowfall has decreased. These significant trends are all related to the rise of mean air temperatures. The non-significant trends for increased total precipitation, decreased duration of ice cover on Auke Lake, and earlier date of ice-out on Auke Lake may or may not be related to the rising air temperatures.

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TABLES

Table 1.-- Monthly averages of daily high air temperature (°C) (MADHTs) at Auke Bay, Alaska, 1963-2004.

	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	-5.25	0.28	-0.34		-2.80	4.14	-2.35	-1.18	-1.40	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	9.90
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	13.28
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.-- Cont.

	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Jan	-0.96	-1.99	-1.68	3.33	-1.15	-0.94	0.13	-5.46	-1.01	-2.08	-0.76
Feb	1.01	-1.06	3.68	2.96	2.96	-4.38	1.80	1.66	3.28	5.78	1.58
Mar	3.43	5.92	4.03	5.96	5.58	5.24	3.09	4.89	3.04	6.23	4.72
Apr	12.25	11.41	9.69	9.59	12.47	11.46	12.36	11.22	10.53	10.26	8.57
May	14.02	14.77	13.97	12.72	17.74	13.97	15.92	16.00	16.78	15.53	11.89
Jun	18.55	17.38	17.43	19.45	19.21	18.14	18.05	16.76	19.48	19.19	18.22
Jul	21.35	20.19	15.93	18.10	21.31	19.49	18.82	20.57	18.80	19.19	19.24
Aug	19.84	19.47	16.86	18.07	20.01	21.22	17.68	16.46	19.58	17.05	17.99
Sep	15.08	13.54	12.61	11.31	15.64	14.11	16.45	13.74	16.28	13.90	12.17
Oct	8.51	7.62	7.99	6.85	10.26	8.46	8.98	6.85	8.40	9.28	8.02
Nov	1.72	-1.10	3.63	4.72	4.61	0.62	2.59	1.85	4.78	3.51	3.86
Dec	3.92	-2.46	2.02	-1.55	3.42	-0.22	-1.71	-1.10	3.95	-0.34	3.83

	2000	2001	2002	2003	2004		Min.[1]	Mean[1]	Max.[1]	Extreme[1]	
Jan	-0.92	4.45	1.34	2.18	-1.25		-8.40	-1.04	5.49	12.88	
Feb	3.30	2.06	1.96	2.94	5.02		-5.82	1.97	6.38	14.56	
Mar	5.49	4.32	3.02	3.77	5.33		1.34	4.67	7.56	12.88	
Apr	8.79	10.25	8.94	12.00	10.30		5.94	9.59	12.47	21.67	
May	14.38	12.08	13.44	14.97	17.60		10.64	13.95	17.74	25.56	
Jun	17.36	18.03	17.58	17.30	21.34		14.73	17.50	21.34	29.68	
Jul	17.27	16.86	16.77	19.20	20.14		15.93	18.59	21.35	31.36	
Aug	17.23	18.86	16.11	18.10	21.59		14.06	18.03	21.59	28.34	
Sep	13.18	13.59	13.82	12.66	13.20		11.31	13.83	16.45	22.78	
Oct	8.29	7.91	9.41	10.11	8.71		6.50	8.51	10.64	17.22	
Nov	4.78	2.84	6.54	2.35	4.76		-2.07	2.92	6.55	12.32	
Dec	1.48	0.07	2.39	2.04	2.59		-5.25	0.47	4.14	9.52	

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

Table 2.--Monthly averages of daily low air temperature (°C) (MADLTs) at Auke Bay, Alaska, 1963-2004.

	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975
Jan		-3.64	-7.84	-13.38	-7.78	-8.62	-16.30	-7.39	-11.82	-11.98	-8.51	-10.58	-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	4.20	2.13	2.24	3.92	3.19	3.58
Jun	6.78	8.55	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	-12.04	-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	-12.32	-3.42	-1.90	0.50	-0.45	-1.32	-4.59
Feb	-6.10	2.97	-2.91	-13.66	-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	8.98	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.-- Cont.

	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Jan	-4.72	-5.44	-6.56	0.03	-6.47	-4.33	-4.33	-11.17	-6.13	-6.22	-4.97
Feb	-7.84	-6.82	-0.38	-2.24	-4.14	-11.06	-4.60	-4.17	0.30	0.12	-3.92
Mar	-5.45	-0.65	-2.51	-0.27	-1.39	0.00	-3.86	-3.04	-3.34	-1.70	-1.97
Apr	0.62	2.00	0.77	1.89	2.17	2.24	1.75	0.35	1.10	2.90	1.08
May	5.32	6.53	4.68	4.35	6.78	5.57	6.36	4.41	5.96	6.72	3.92
Jun	9.11	9.65	8.57	8.44	9.74	9.30	8.29	8.85	9.48	9.45	8.16
Jul	11.83	11.20	8.38	10.73	11.47	10.53	10.82	10.24	11.17	10.67	10.37
Aug	10.79	10.91	10.01	9.54	10.37	11.54	9.46	9.93	11.44	9.25	9.45
Sep	8.44	8.70	7.65	5.25	8.23	7.50	9.28	6.33	8.16	6.78	7.95
Oct	3.29	2.69	2.22	1.70	5.87	4.14	4.50	2.49	2.86	4.03	4.68
Nov	-1.66	-5.54	0.25	1.23	0.43	-3.19	-2.50	-2.82	0.97	-0.67	1.12
Dec	0.11	-7.36	-0.96	-6.03	0.31	-4.54	-5.67	-5.19	0.47	-3.99	0.31

	2000	2001	2002	2003	2004	Min.[1]	Mean[1]	Max.[1]	Extreme[1]
Jan	-4.95	0.74	-2.39	-3.00	-6.14	-16.30	-5.78	1.06	-24.60
Feb	-2.22	-3.98	-2.08	-2.00	0.17	-13.66	-3.76	2.97	-26.30
Mar	0.27	-1.61	-5.60	-3.47	-0.56	-7.34	-2.17	1.62	-19.60
Apr	1.40	1.34	-2.06	1.01	2.39	-2.41	0.68	2.90	-11.20
May	4.64	4.14	4.88	4.86	7.08	2.13	4.60	7.08	-2.80
Jun	8.57	9.11	9.30	9.00	11.18	5.77	8.31	11.18	0.00
Jul	10.26	10.15	9.92	11.65	11.98	5.43	10.00	11.98	-1.12
Aug	9.81	10.95	10.24	10.06	11.69	7.28	9.70	11.69	2.80
Sep	7.07	8.05	8.34	7.43	7.38	5.15	7.23	9.28	-2.80
Oct	3.86	3.65	5.54	4.72	3.83	1.70	3.76	5.87	-10.60
Nov	1.85	2.27	3.01	-2.06	1.25	-7.78	-1.19	3.01	-20.20
Dec	-1.83	-3.61	-1.10	-1.71	-0.93	-12.04	-3.63	0.73	-25.80

[1] Min. is the lowest MADLT, Mean is the average of the MADLTs, Max. is the highest MADLT, and Extreme is the lowest daily low temperature observed.

Table 3.--Monthly averages of daily midrange air temperature (°C) (MADMTs) at Auke Bay, Alaska, 1963-2004.

	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975
Jan		-1.40	-4.84	-10.11	-4.84	-5.35	-12.35	-4.68	-8.96	-8.23	-5.63	-7.53	-3.92
Feb	0.34	2.03	-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	-1.90	1.93	0.50	-2.46	2.41	0.95	3.19	-0.25	-1.93	1.71	-1.96	0.64
Apr	3.72	4.09	4.28	4.03	4.26	3.84	5.12	4.65	3.95	1.76	4.87	4.23	3.98
May	10.11	7.72	6.75	6.92	9.24	10.11	10.30	8.46	6.58	7.03	8.23	8.54	8.37
Jun	10.75	13.13	10.98		14.42	12.71	15.37	11.54	12.99	10.64	11.34	10.75	10.86
Jul	13.80	13.29	14.84	15.57	13.58	14.81	12.74	12.60	15.60	15.48	12.74	12.74	13.89
Aug	14.62	12.67	14.78		13.47	14.62	10.67	11.98	13.97	13.47	11.68	13.38	12.94
Sep	11.73	10.31	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	6.61	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	0.26	-0.08	-1.76		2.16	1.23	-0.28	0.36	1.76	-4.45	2.63	-1.20
Dec	0.25	-8.67	-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	7.95	9.35	8.85	9.02	10.39	11.40	7.31	10.30	10.28	7.76	8.79	9.38	9.55
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	14.00	14.76	13.36	14.53	13.47	14.06	14.81	14.90	13.58	11.93	14.14	15.08	12.94
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	9.96
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	0.34	-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.-- Cont.

	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Jan	-2.84	-3.71	-4.12	1.68	-3.81	-2.64	-2.11	-8.31	-3.57	-4.14	-2.86	-2.93	2.59
Feb	-3.41	-3.94	1.65	0.36	-0.59	-7.72	-1.37	-1.25	1.79	2.68	-1.17	0.45	-0.96
Mar	-1.01	2.64	0.76	2.85	2.09	2.62	-0.39	0.93	-0.15	2.27	1.37	2.88	1.36
Apr	6.43	6.70	5.23	5.74	7.32	6.85	7.06	5.78	5.81	6.58	4.83	5.10	5.80
May	9.67	10.65	9.32	8.53	12.26	9.77	11.70	10.21	11.37	11.13	7.92	9.51	8.11
Jun	13.83	13.52	13.00	13.94	14.48	13.72	13.17	12.81	14.48	14.32	13.19	13.12	12.63
Jul	16.59	15.70	12.16	14.41	16.39	15.01	14.82	15.41	14.99	14.93	14.88	13.76	13.50
Aug	15.31	15.19	13.48	13.80	15.19	16.39	13.57	13.19	15.75	13.15	13.72	13.52	14.90
Sep	11.76	11.12	10.13	8.28	11.94	10.78	12.86	10.04	12.14	10.34	10.06	9.18	10.82
Oct	5.90	5.16	5.10	4.27	8.06	6.29	7.24	4.67	5.63	6.66	6.35	6.10	5.78
Nov	0.03	-3.32	1.94	2.98	2.52	-1.85	0.04	-0.49	2.87	1.42	2.49	3.31	0.85
Dec	2.01	-4.91	0.53	-3.79	1.86	-2.41	-3.70	-3.14	2.21	-2.17	2.04	-0.17	-1.38

	2002	2003	2004	Min.[1]	Mean[1]	Max.[1]
Jan	-0.53	-0.41	-3.70	-12.35	-3.41	3.28
Feb	-0.06	0.47	2.60	-9.74	-0.90	4.68
Mar	1.01	0.15	3.29	-2.46	1.31	4.28
Apr	6.68	6.50	6.35	1.76	5.21	7.32
May	11.05	9.92	12.34	6.58	9.34	12.34
Jun	13.44	13.15	16.26	10.64	12.89	16.26
Jul	13.34	15.43	16.06	11.93	14.30	16.59
Aug	13.18	14.08	16.64	10.67	13.88	16.64
Sep	11.08	10.04	11.50	8.28	10.54	12.86
Oct	7.48	7.41	6.27	4.27	6.15	8.20
Nov	4.77	0.15	2.42	-4.93	0.80	4.77
Dec	0.69	0.17	0.83	-8.67	-1.57	2.21

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

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) air temperatures, precipitation, snowfall, and average daily sea surface temperature (MADSST). Annual mean and extremes of Auke Creek stream temperature, Auke Lake ice-out date, and Auke Lake ice cover duration. Slope of long-term trend and its statistical significance (P) for annual Auke Creek stream temperature, Auke Lake ice cover duration, and the Auke Lake break up date.

				Variation due to annual cycle		Trend	
Variable	Mean annual	Minimum annual	Maximum annual	%	P	slope	P
MADHT	9.11°C	7.43°C	11.01°C	92.5	< 0.001	0.037°C yr^{-1}	< 0.001
MADLT	2.34°C	0.33°C	4.11°C	85.4	< 0.001	0.058°C yr^{-1}	< 0.001
MADMT	5.76°C	3.88°C	7.57°C	90.2	< 0.001	0.049°C yr^{-1}	< 0.001
Precipitation	159.19 cm	116.69 cm	215.39 cm	35.8	< 0.001	0.341 cm yr^{-1}	0.20
Snowfall	219.24 cm	36.59 cm	442.47 cm	41.5	< 0.001	-3.582 cm yr^{-1}	< 0.01
MADSST	8.2°C	7.0°C	8.9°C	92.5	< 0.001	0.024°C yr^{-1}	0.01
Auke Creek Temperature	7.3ºC	5.5ºC	8.9ºC			0.055ºC yr^{-1}	< 0.001
Auke Lake Ice Out Date	10 Apr	01 Feb	05 May			-0.385 da yr^{-1}	0.12
Auke Lake Ice Cover Duration	108.6 days	78 days	157 days			-3.615 da yr^{-1}	0.09

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

Model: $\left(1-B^{12}\right) z_t = \mu + \dfrac{1-\theta_{12} B^{12}}{1-\phi_1 B^1} a_t$, where $z_t = \ln\left(\text{MADHT}_t + 20°\text{C}\right)$, $t = 1, 2, \ldots, 492$.

Parameter	Estimate	SE	*t* statistic	Probability	Lag
μ	0.0015387	0.0010763	1.43	0.15	0
θ_{12}	0.78760	0.02848	27.65	< 0.001	12
ϕ_1	0.12777	0.04557	2.80	< 0.01	1

	Correlations of Estimates		
Parameter	μ	θ_{12}	ϕ_1
μ	1	-0.021	-0.002
θ_{12}	-0.021	1	-0.080
ϕ_1	-0.002	-0.080	1

Ljung-Box autocorrelation check of residuals			
To Lag	Chi Square	Degrees of Freedom	Probability
6	4.83	4	0.305
12	9.68	10	0.469
18	13.87	16	0.609
24	16.21	22	0.805
30	22.43	28	0.761
36	26.89	34	0.802
42	31.67	40	0.824
48	41.46	46	0.663
54	43.58	52	0.791
60	47.23	58	0.843
66	48.91	64	0.919
72	50.28	70	0.964
78	54.00	76	0.974
84	56.24	82	0.987
90	59.60	88	0.991
96	70.88	94	0.964
102	72.29	100	0.983
108	73.45	106	0.993
114	76.06	112	0.996
120	80.50	118	0.997

One-month-ahead forecast equation for transformed temperature of January 2005 from December 2004 ($T = 492$):

$$\tilde{z} = 0.001342 + z_{T-11} + 0.12777\left(z_T - z_{T-12}\right) - 0.78760\hat{a}_{T-11}.$$

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

$$\text{Model}: \quad \left(1-B^{12}\right)z_t = \mu + \frac{1-\theta_{12}B^{12}}{1-\phi_1 B^1 - \phi_{36}B^{36}}\, a_t, \quad \text{where } z_t = \ln\left(\text{MADLT}_t + 20°\text{C}\right), t = 1, 2, \ldots, 492.$$

Parameter	Estimate	SE	*t* statistic	Probability	Lag
μ	0.0031713	0.0023058	1.38	0.17	0
θ_{12}	0.77006	0.03211	23.98	< 0.001	12
ϕ_1	0.10420	0.04574	2.28	0.02	1
ϕ_{36}	0.14894	0.05019	2.97	< 0.01	36

Parameter	Correlations of Estimates			
	μ	θ_{12}	ϕ_1	ϕ_{36}
μ	1	-0.018	-0.003	-0.002
θ_{12}	-0.018	1	-0.070	0.407
ϕ_1	-0.003	-0.070	1	-0.064
ϕ_{36}	-0.002	0.407	-0.064	1

Ljung-Box autocorrelation check of residuals			
To Lag	Chi Square	Degrees of Freedom	Probability
6	1.84	3	0.606
12	6.62	9	0.677
18	11.12	15	0.744
24	15.46	21	0.799
30	19.53	27	0.850
36	22.74	33	0.910
42	26.82	39	0.930
48	32.41	45	0.920
54	33.77	51	0.970
60	40.12	57	0.956
66	41.46	63	0.984
72	43.10	69	0.994
78	48.14	75	0.993
84	52.48	81	0.994
90	58.40	87	0.992
96	70.36	93	0.962
102	72.00	99	0.981
108	73.99	105	0.991
114	75.50	111	0.996
120	82.90	117	0.993

One-month-ahead forecast equation for transformed temperature of January 2005 from December 2004 ($T = 492$):

$$\tilde{z} = 0.002369 + z_{T-11} + 0.10420\left(z_T - z_{T-12}\right) + 0.14894\left(z_{T-35} - z_{T-47}\right) - 0.77006\hat{a}_{T-11}.$$

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

$$\text{Model}: \quad \left(1 - B^{12}\right) z_t = \mu + \frac{1 - \theta_{12} B^{12}}{1 - \phi_1 B^1} a_t, \quad \text{where } z_t = \ln\left(\text{MADMT}_t + 20°\text{C}\right), t = 1, 2, \ldots, 492.$$

Parameter	Estimate	SE	t statistic	Probability	Lag
μ	0.0023811	0.0015702	1.52	0.13	0
θ_{12}	0.75144	0.03035	24.76	< 0.001	12
ϕ_1	0.12007	0.04557	2.63	< 0.01	1

	Correlations of Estimates		
Parameter	μ	θ_{12}	ϕ_1
μ	1	-0.024	-0.002
θ_{12}	-0.024	1	-0.069
ϕ_1	-0.002	-0.069	1

Ljung-Box autocorrelation check of residuals			
To Lag	Chi Square	Degrees of Freedom	Probability
6	3.16	4	0.531
12	10.97	10	0.360
18	14.17	16	0.586
24	16.85	22	0.772
30	22.38	28	0.763
36	29.03	34	0.710
42	33.47	40	0.758
48	41.85	46	0.647
54	42.74	52	0.817
60	49.07	58	0.792
66	50.07	64	0.899
72	50.81	70	0.959
78	53.65	76	0.976
84	55.76	82	0.988
90	61.47	88	0.986
96	74.21	94	0.935
102	76.22	100	0.963
108	78.07	106	0.981
114	79.46	112	0.991
120	84.28	118	0.992

One-month-ahead forecast equation for transformed temperature of January 2005 from December 2004 ($T = 492$):

$$\tilde{z} = 0.002095 + z_{T-11} + 0.12007\left(z_T - z_{T-12}\right) - 0.75144\hat{a}_{T-11}.$$

Table 8.--Monthly precipitation (cm) at Auke Bay, Alaska, 1963-2004.

	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	7.59	8.71	10.74	6.15	12.50	8.59	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	7.32	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	6.05	3.61	10.24	6.53	7.65	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	17.15	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	6.99	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.-- Cont.

	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Jan	16.00	10.36	11.61	15.14	14.91	20.37	3.66	5.13	4.17	5.11	19.00	5.56	12.90
Feb	0.18	10.49	18.54	12.27	14.22	6.10	5.18	16.66	19.00	2.51	6.05	3.15	9.60
Mar	5.92	11.68	7.67	10.24	6.40	13.23	5.36	8.23	4.88	8.46	5.54	11.63	8.66
Apr	4.75	4.55	8.36	7.11	5.18	7.32	5.51	5.54	9.55	8.86	14.02	14.10	6.15
May	14.20	5.79	11.33	18.90	5.05	10.95	10.01	4.57	8.08	5.56	14.83	10.06	12.83
Jun	6.45	11.53	8.53	8.99	9.40	6.43	9.47	17.78	11.15	6.50	7.95	16.84	6.17
Jul	11.61	13.61	13.94	13.97	5.54	14.25	12.95	9.45	24.59	17.40	13.46	16.99	16.56
Aug	9.12	17.25	25.32	15.06	8.43	7.54	13.21	21.87	10.77	19.46	21.77	16.59	10.85
Sep	20.70	35.41	41.81	23.98	27.10	30.91	20.73	30.07	22.15	19.66	29.90	24.71	22.23
Oct	20.47	20.40	22.94	14.50	21.69	26.64	13.59	14.73	18.47	27.69	26.37	20.57	20.27
Nov	22.40	15.65	21.11	16.69	26.29	19.41	7.09	7.75	11.23	5.69	12.83	14.02	8.36
Dec	20.90	18.62	24.23	13.11	15.04	9.93	9.93	5.82	26.42	11.76	27.10	8.10	9.60
Annual	152.70	175.34	215.39	169.95	159.26	173.08	116.69	147.60	170.43	138.66	198.81	162.33	144.17

	2002	2003	2004	Min.[1]	Mean[1]	Max.[1]
Jan	8.03	14.17	15.65	3.66	11.96	23.83
Feb	12.50	5.51	11.00	0.18	9.79	19.53
Mar	4.47	9.98	10.62	1.80	8.57	17.35
Apr	2.29	1.96	7.14	1.96	7.33	14.10
May	8.41	6.81	3.68	3.68	9.84	18.90
Jun	14.53	12.62	3.53	3.53	10.50	20.57
Jul	15.52	11.40	10.52	4.78	13.60	30.30
Aug	28.88	13.51	7.77	3.45	16.40	28.88
Sep	16.94	33.38	24.31	8.46	22.44	41.81
Oct	29.95	12.67	15.82	10.87	21.64	39.75
Nov	21.56	14.38	18.06	3.89	13.61	26.29
Dec	14.33	11.79	22.02	3.61	12.94	27.10
Annual	177.39	148.18	150.11	116.69	159.19	215.39

[1]Min. is the lowest monthly precipitation, Mean is the average of the monthly precipitation, and Max. is the highest monthly precipitation.

Table 9.--Monthly snowfall (cm) at Auke Bay, Alaska, 1963-2004.

	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	trace	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		223.27	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	100.58	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	4.57	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	19.05	22.61	29.72	66.55	14.22	4.83	14.73	28.70
Annual	287.78	161.29	90.68	257.30	254.00	94.23	285.50	186.69	201.68	164.34	194.56	50.55	83.06

Table 9.-- Cont.

	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Jan	118.62	90.68	69.09	37.85	48.01	160.27	17.78	47.24	33.27	39.62	104.65	26.67	5.08
Feb	0.51	91.19	38.61	18.54	65.53	72.14	25.15	75.95	41.40	0.76	67.56	3.56	38.61
Mar	56.64	4.57	23.11	2.03	7.87	43.69	54.36	12.70	45.72	7.87	4.32	0.00	1.52
Apr	trace	0.00	0.76	trace	0.00	0.51	0.00	0.00	0.00	0.00	3.05	0.00	0.00
May	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
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	trace	trace	16.76	5.08	0.00	0.00	0.00	1.27	2.29	0.00	0.00	2.54	10.16
Nov	85.09	112.27	25.91	10.92	3.81	111.00	7.87	6.35	2.54	12.45	16.76	0.01	7.11
Dec	22.86	95.00	151.64	59.94	23.88	54.86	61.47	7.37	32.26	40.13	43.18	3.81	66.55
Annual	283.72	393.70	325.88	134.37	149.10	442.47	166.62	150.88	157.48	100.84	239.52	36.59	129.03

	2002	2003	2004	Min.[1]	Mean[1]	Max.[1]
Jan	51.82	47.75	71.63	5.08	68.21	180.34
Feb	69.60	44.45	7.62	0.00	43.89	137.41
Mar	4.32	42.67	40.64	0.00	27.70	132.59
Apr	0.25	0.25	0.51	0.00	4.42	82.55
May	0.00	0.00	0.00	0.00	0.09	3.81
Jun	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
Aug	0.00	0.00	0.00	0.00	0.00	0.00
Sep	0.00	0.00	0.00	0.00	0.03	1.27
Oct	0.00	0.00	0.01	0.00	1.49	16.76
Nov	0.00	51.56	1.52	0.00	27.54	112.27
Dec	41.40	27.43	21.08	3.81	49.49	151.64
Annual	167.39	214.12	143.01	36.59	219.24	442.47

[1]Min. is the lowest monthly snowfall, Mean is the average of the monthly snowfall, and Max. is the highest monthly snowfall.

Table 10.-- Seasonal snowfall (cm) at Auke Bay, Alaska, 1963-2004.

	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
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
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
Oct		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	132.59	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	trace	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	410.46	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	88.90	30.99	8.13	Trace	10.67	4.57	17.27	13.97	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	66.55	14.22	4.83	14.73
Jan	92.71	5.08	20.32	46.99	100.58	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	4.57	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
Total	421.64	84.58	172.72	198.63	235.20	202.18	284.48	170.43	168.15	210.31	161.04	94.23	65.79

Table 10.-- Cont.

	88-89	89-90	90-91	91-92	92-93	93-94	94-95	95-96	96-97	97-98	98-99	99-00	00-01
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	trace	trace	16.76	5.08	0.00	0.00	0.00	1.27	2.29	0.00	0.00	2.54
Nov	12.95	85.09	112.27	25.91	10.92	3.81	111.00	7.87	6.35	2.54	12.45	16.76	0.01
Dec	28.70	22.86	95.00	151.64	59.94	23.88	54.86	61.47	7.37	32.26	40.13	43.18	3.81
Jan	118.62	90.68	69.09	37.85	48.01	160.27	17.78	47.24	33.27	39.62	104.65	26.67	5.08
Feb	0.51	91.19	38.61	18.54	65.53	72.14	25.15	75.95	41.40	0.76	67.56	3.56	38.61
Mar	56.64	4.57	23.11	2.03	7.87	43.69	54.36	12.70	45.72	7.87	4.32	0.00	1.52
Apr	trace	0.00	0.76	trace	0.00	0.51	0.00	0.00	0.00	0.00	3.05	0.00	Trace
May	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	Trace
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	217.42	294.39	338.84	252.73	197.36	304.29	263.14	205.23	135.38	85.34	232.16	90.17	51.57

	01-02	02-03	03-04	04-05	Min.[1]	Mean[1]	Max.[1]
Jul	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
Sep	0.00	0.00	0.00	0.00	0.00	0.03	1.27
Oct	10.16	0.00	0.00	0.01	0.00	1.49	16.76
Nov	7.11	0.00	51.56	1.52	0.00	27.54	112.27
Dec	66.55	41.40	27.43	21.08	3.81	49.49	151.64
Jan	51.82	47.75	71.63		5.08	68.21	180.34
Feb	69.60	44.45	7.62		0.00	43.89	137.41
Mar	4.32	42.67	40.64		0.00	27.70	132.59
Apr	0.25	0.25	0.51		0.00	4.42	82.55
May	0.00	0.00	0.00		0.00	0.09	3.81
Jun	0.00	0.00	0.00		0.00	0.00	0.00
Total	209.80	176.53	199.39		51.57	222.05	421.64

[1]Min. is the lowest seasonal monthly snowfall, Mean is the average of the seasonal monthly snowfall, and Max. is the highest seasonal monthly snowfall.

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 $z_t = \ln(\text{precipitation}_t)$, $t = 1, 2, \ldots, 492$.

Parameter	Estimate	SE	t statistic	Probability	Lag
μ	-0.0010378	0.0034992	-0.30	0.77	0
θ_{12}	0.84543	0.02590	32.64	< 0.001	12
ϕ_{48}	-0.15140	0.04968	-3.05	0.002	48

	Correlations of Estimates		
Parameter	μ	θ_{12}	ϕ_{48}
μ	1	-0.032	-0.007
θ_{12}	-0.032	1	0.292
ϕ_{48}	-0.007	0.292	1

Ljung-Box autocorrelation check of residuals			
To Lag	Chi Square	Degrees of Freedom	Probability
6	5.18	4	0.270
12	10.54	10	0.394
18	14.98	16	0.526
24	20.61	22	0.545
30	22.70	28	0.748
36	27.89	34	0.761
42	29.86	40	0.879
48	32.35	46	0.936
54	34.89	52	0.967
60	35.63	58	0.991
66	36.89	64	0.997
72	42.26	70	0.997
78	44.42	76	0.999
84	59.22	82	0.973
90	67.80	88	0.946
96	75.90	94	0.914
102	89.42	100	0.767
108	92.52	106	0.822
114	97.69	112	0.830
120	106.63	118	0.765

One-month-ahead forecast equation for transformed precipitation of January 2005 from December 2004 ($T = 492$):

$$\tilde{z} = -0.001195 + z_{T-11} - 0.15140(z_{T-47} - z_{T-59}) - 0.84543\hat{a}_{T-11}.$$

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: $\left(1-B^{7}\right)z_{t} = \mu + \dfrac{1-\theta_{7}B^{7}}{1-\phi_{2}B^{2}}\,a_{t}$, where $z_{t} = \ln\left(\text{snowfall}_{t} + 1\text{ cm}\right)$, $t = 1, 2, \ldots, 287$.

Parameter	Estimate	SE	t statistic	Probability	Lag
μ	-0.01804	0.0090068	-2.00	< 0.05	0
θ_7	0.90300	0.02664	33.89	< 0.001	7
ϕ_2	0.13033	0.06000	2.17	0.03	2

	Correlations of Estimates		
Parameter	μ	θ_7	ϕ_2
μ	1	-0.018	0.014
θ_7	-0.018	1	-0.082
ϕ_2	0.014	-0.082	1

Ljung-Box autocorrelation check of residuals			
To Lag	Chi Square	Degrees of Freedom	Probability
6	3.23	4	0.520
12	7.88	10	0.641
18	12.33	16	0.721
24	16.77	22	0.776
30	18.93	28	0.900
36	27.22	34	0.789
42	36.18	40	0.643
48	38.35	46	0.781
54	41.38	52	0.854
60	48.08	58	0.820
66	56.27	64	0.743

One-month-ahead forecast equation for transformed snowfall of January 2005 from December 2004 ($T = 287$):

$$\tilde{z} = -0.015689 + z_{T-6} + 0.13033\left(z_{T-1} - z_{T-8}\right) - 0.90300\hat{a}_{T-6}.$$

[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 afternoon observations of sea surface temperature (°C) (MADSSTs) at Auke Bay Laboratory, 1975-2004.

	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	1994	1995	1996	1997	1998	1999	2000
Jan	4.56	3.73	3.03	2.58	3.96	3.74	4.20	3.30	3.00	2.90	4.10	4.10	3.90
Feb	4.47	3.24	3.05	2.80	4.29	2.68	3.30	3.49	2.40	2.90	4.30	2.50	3.43
Mar	4.59	3.80	3.60	3.40	4.77	3.82	3.80	3.50	2.80	3.00	5.10	4.00	3.67
Apr	6.46	7.64	6.83	6.27	6.78	7.93	6.80	7.00	5.70	6.30	7.30	6.00	6.30
May	10.67	10.41	10.98	10.83	9.65	12.85	8.90	12.60	10.80	12.00	11.40	9.10	10.35
Jun	12.81	14.33	13.88	13.86	14.35	15.00	13.60	13.70	13.80	13.90	15.20	13.70	13.27
Jul	13.66	16.03	15.20	14.46	14.93	15.74	15.20	15.10	15.08	14.70	15.80	14.90	14.25
Aug	13.05	15.62	14.77	13.07	13.65	15.15	16.30	13.70	13.20	15.00	13.90	15.00	13.07
Sep	10.72	12.28	11.23	10.16	10.07	11.53	11.30	11.54	10.80	12.10	10.90	10.30	10.52
Oct	8.03	8.28	7.54	7.68	6.75	8.40	7.90	8.60	7.50	7.70	8.20	7.90	7.72
Nov	6.30	4.93	5.12	5.41	5.47	5.96	5.50	5.20	5.20	5.70	5.90	5.70	5.79
Dec	4.42	4.16	3.27	3.89	4.43	4.38	4.10	3.70	3.80	4.40	5.00	4.60	4.81

Table 13.-- Cont.

	2001	2002	2003	2004	Min.[1]	Mean[1]	Max.[1]
Jan	4.56	3.53	4.25	3.72	2.56	3.64	4.56
Feb	4.21	4.08	4.68	3.61	2.09	3.32	4.78
Mar	4.60	3.76	5.07	3.87	2.32	3.84	5.10
Apr	6.96	7.40	7.25	6.24	4.34	6.27	7.93
May	8.90	8.72	10.55	12.50	6.86	10.02	12.85
Jun	13.80	13.57	13.64	15.50	11.28	13.49	15.50
Jul	13.73	11.66	14.20	16.10	11.66	14.51	16.10
Aug	15.03	11.57	13.88	15.94	11.57	14.02	16.30
Sep	9.96	9.65	10.93	11.11	9.65	10.90	12.28
Oct	7.40	7.61	8.50	7.58	6.75	7.74	8.60
Nov	5.50	6.83	5.67	5.14	4.32	5.55	6.83
Dec	4.03	4.55	4.40	4.69	3.27	4.32	5.09

[1]Min. is the lowest MADSST, Mean is the average of the MADSSTs, and Max. is the highest MADSST.

Table 14.--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.

$$\text{Model}: \left(1-B^{12}\right)z_t = \mu + \frac{1-\theta_{12}B^{12}}{1-\phi_1 B^1}a_t, \quad \text{where } z_t = \ln\left(\text{MADSST}_t\right), t = 1, 2, \ldots, 348.$$

Parameter	Estimate	SE	t statistic	Probability	Lag
μ	0.0076577	0.0044221	1.73	0.08	0
θ_{12}	0.74448	0.03722	20.00	< 0.001	12
ϕ_1	0.61631	0.04319	14.27	< 0.001	1

	Correlations of Estimates		
Parameter	μ	θ_{12}	ϕ_1
μ	1	0.050	0.024
θ_{12}	0.050	1	0.031
ϕ_1	0.024	0.031	1

Ljung-Box autocorrelation check of residuals			
To Lag	Chi Square	Degrees of Freedom	Probability
6	3.07	4	0.546
12	8.58	10	0.573
18	10.41	16	0.844
24	12.52	22	0.946
30	16.07	28	0.965
36	17.91	34	0.989
42	27.03	40	0.942
48	31.17	46	0.954
54	37.87	52	0.929
60	40.89	58	0.957
66	52.11	64	0.856
72	57.11	70	0.866
78	60.60	76	0.902
84	67.13	82	0.882

One-month-ahead forecast equation for transformed temperature of January 2005 from December 2004 ($T = 348$):

$$\tilde{z} = 0.002938 + z_{T-11} + 0.61631\left(z_T - z_{T-12}\right) - 0.74448\hat{a}_{T-11}.$$

Table 15.--Average monthly Auke Creek temperatures (ºC), 1962- 2005.

	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977
Jan.		0.8	1.1	0.8	0.8	0.9	1.0			1.1	1.1	0.5	0.3	1.2	0.8	1.7
Feb.			1.0	1.0		0.2	1.7			0.3	0.9	0.4	1.0	0.6	0.6	2.7
Mar.				1.1	0.9		1.0		3.6	1.2	0.7	0.9	0.4	1.1	0.8	2.8
Apr.			3.9	3.5	1.8	2.3	3.8		5.5	1.7	1.1	3.1	2.3	2.3	2.5	4.7
May			6.7	6.1	4.5	5.3	8.9		9.0	4.6	3.4	7.2	5.9	6.8	6.6	10.0
Jun.			12.1		12.1	13.3	15.9	17.2	10.8	12.7	9.2	12.8	11.9	12.1	11.5	13.8
Jul.				16.4	17.2	15.4	17.1	13.6	11.7	16.6	16.5	15.0	15.2	15.9	14.2	18.0
Aug.				15.9	14.9	13.7	13.7	12.5		16.8	13.5	13.1	14.9	13.9	15.3	17.4
Sep.			11.9	10.8	11.0		11.1	12.0		12.9	9.9	10.8	12.9	11.4	11.9	12.2
Oct.	8.1	8.0	7.3	8.4	7.5		7.7			7.0	5.1	7.3	7.0	7.9	8.2	7.7
Nov.	5.7	3.9		3.9	3.7	3.5	5.1			3.3	3.2	2.1	5.1	2.6	5.3	3.4
Dec.	3.0	1.8	1.3	1.7	1.7	1.4	1.6			1.1	0.9	1.1	2.8	0.8	2.8	0.7
average				6.4			7.5			6.5	5.5	6.2	6.5	6.4	6.2	6.3

	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993
Jan.	0.8	0.3	0.8	1.7	0.5	1.1	1.2	1.7	1.3	1.9	1.4	1.1	1.1	0.8	1.7	0.9
Feb.	1.4	0.0	1.1	1.8	0.5	0.6	1.4	0.6	1.5	2.1	1.1	0.5	0.6	1.3	1.5	1.0
Mar.	2.2	1.1	1.7	2.7	1.1	2.3	2.9	1.0	1.9	2.2	2.8	0.4	1.8	1.3	2.6	1.2
Apr.	4.9	3.6	4.1	4.9	2.4	4.9	6.0	2.4	3.0	4.6	5.1	3.0	4.9	2.2	5.4	3.6
May	7.6	9.3	9.6	12.6	5.4	10.3	11.9	7.0	8.7	9.5	9.2	9.3	11.0	8.4	9.3	12.2
Jun.	12.6	14.1	16.6	15.0	13.7	15.2	13.6	10.9	13.2	12.4	13.2	15.0	15.1	13.5	15.0	16.7
Jul.	13.9	15.0	15.1	15.0	16.2	16.3	14.6	14.9	15.7	16.5	13.7	18.2	17.5	16.3	16.4	16.7
Aug.	15.3	16.6	14.6	14.9	15.2	14.0	14.8	14.5	13.8	16.2	13.5	16.7	16.5	14.4	15.1	16.5
Sep.	12.2	12.9	11.5	11.2	12.1	10.8	12.0	11.3	11.9	11.4	11.4	13.6	12.6	11.0	11.2	12.6

Table 15.-- Cont.

	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993
Oct.	8.2	8.7	8.2	7.9	7.6	7.5	8.2	7.0	8.6	7.9	8.7	8.4	8.1	7.4	7.0	8.6
Nov.	3.7	5.1	5.8	5.0	3.8	3.7	2.9	2.1	3.7	5.0	5.3	4.1	3.5	3.5	4.5	5.3
Dec.	1.4	2.2	1.5	1.8	1.8	0.5	1.0	1.0	2.3	3.1	2.6	2.3	1.2	2.1	1.6	2.4
average	6.6	7.2	7.4	7.9	6.7	7.3	7.6	6.2	7.2	7.8	7.3	7.8	7.9	6.9	7.6	8.2

	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	Average
Jan.	1.8	1.0	1.2	1.1	2.1	1.6	1.8	2.0	1.5	2.0	1.2	1.4	1.2
Feb.	1.1	1.4	1.2	2.0	2.9	1.0	2.0	1.4	1.1	1.8	1.5	1.5	1.2
Mar.	1.4	1.0	1.6	1.6	3.8	1.1	3.2	2.4	1.6	2.5	2.5	2.4	1.8
Apr.	4.2	3.2	3.9	4.2	6.6	2.5	4.9	5.4	3.3	5.5	5.0	6.5	3.8
May	9.9	12.5	10.1	11.6	12.9	7.1	10.2	8.7	8.0	11.6	13.5	14.5	8.9
Jun.	14.8	15.1	13.6	16.4	17.4	13.5	15.1	14.8	13.9	15.1	16.7	17.4	14.0
Jul.	15.9	17.1	15.1	17.0	17.7	15.9	15.9	15.4	15.0	15.9	17.6	17.1	15.8
Aug.	16.5	14.9	14.2	16.9	15.4	16.0	15.0	16.3	13.8	15.5	18.4	16.6	15.1
Sep.	11.7	13.4	11.6	13.9	11.6	11.3	11.5	11.7	11.7	11.1	12.8	12.3	11.8
Oct.	8.3	8.7	7.5	8.5	8.7	8.0	8.1	8.1	8.7	8.4	8.2	8.0	7.9
Nov.	4.0	3.6	4.1	5.6	4.6	5.1	5.3	4.2	6.2	3.8	4.4	4.5	4.2
Dec.	1.2	1.2	2.1	3.7	2.3	2.7	2.5	1.4	3.7	1.4	2.4	2.0	1.9
average	7.6	7.8	7.2	8.6	8.9	7.2	8.0	7.7	7.4	7.9	8.7	8.7	7.3

Table 16.--Auke Lake ice-out dates, 1960-2005.

1960s	1970s	1980s	1990s	2000s
1960 Apr 26	1970 Mar 24	1980 Apr 19	1990 Apr 08	2000 Apr 3
1961	1971 May 13	1981 Mar 26	1991 Apr 29	2001 Apr 6
1962 Apr late	1972 May 20	1982 May 14	1992 Mar 18	2002 Apr 28
1963 Apr 29	1973 Apr 30	1983 Apr 18	1993 Apr 23	2003 Apr 13
1964	1974 May 07	1984 Mar 29	1994 Apr 11	2004 Apr 6
1965	1975 May 08	1985 Apr 26	1995 Apr 25	2005 Apr 10
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 Apr 20	1988 Apr 15	1998 Mar 31	
1969 Apr 30	1979 Apr 24	1989 Apr 28	1999 May 5	

Table 17.--Duration of Auke Lake ice cover, 1992-2006.

Winter	Ice over	Ice out	Duration (days)
1992-1993	18 Dec	23 Apr	127
1993-1994	02 Jan	11 Apr	99
1994-1995	23 Nov	25 Apr	154
1995-1996	20 Nov	21 Apr	153
1996-1997	20 Nov	25 Apr	156
1997-1998	01 Jan	31 Mar	89
1998-1999	17 Dec	05 May	157
1999-2000	17 Dec	06 Jan	13
1999-2000	08 Jan	03 Apr	85
2000-2001	14 Dec	23 Jan	40
2000-2001	15 Feb	06 Apr	50
2001-2002	27 Nov	20 Apr	113
2002-2003	29 Dec	06 Jan	8
2002-2003	10 Jan	13 Apr	70
2003-2004	26 Dec	06 Apr	102
2004-2005	27 Dec	10 Apr	106
2005-2006	04 Jan	14 Apr	101

Note: An early January breakup was followed by refreezing in 2000, 2001 and 2003.

FIGURES

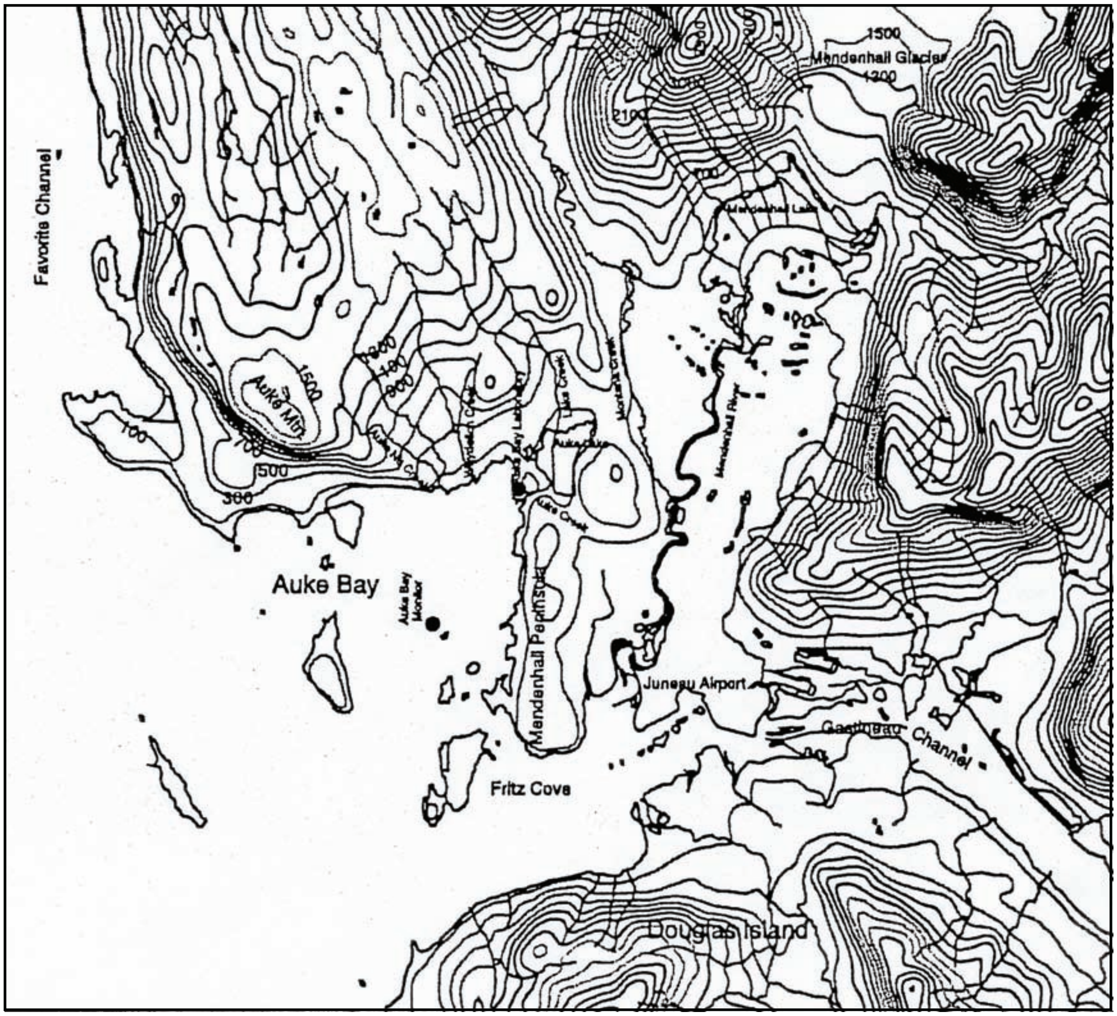

Figure 1. -- Auke Bay, Alaska, and vicinity.

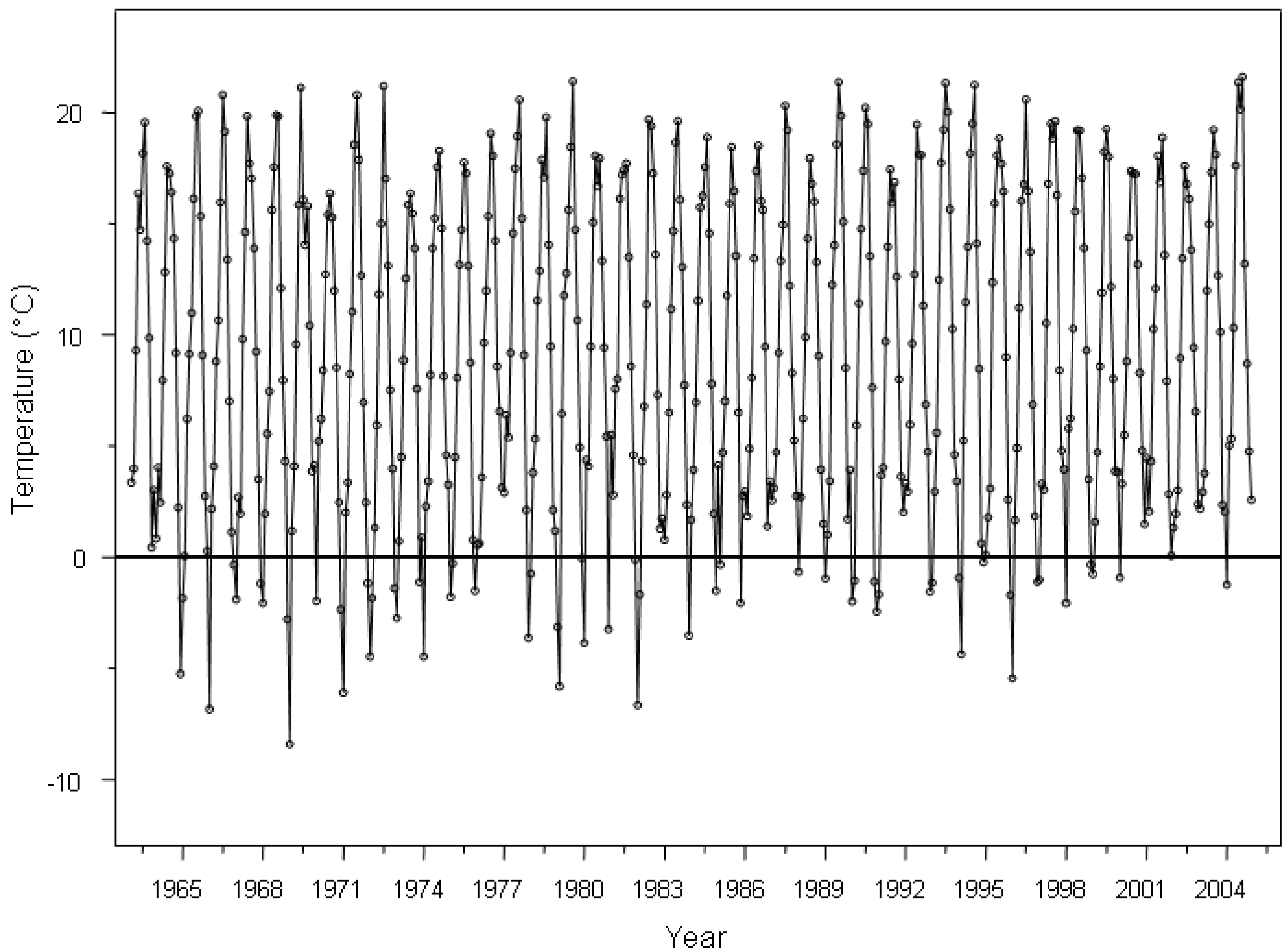

Figure 2a.-- Monthly averages of daily high temperature (MADHTs) at Auke Bay Laboratory, February 1963 through December 2004.

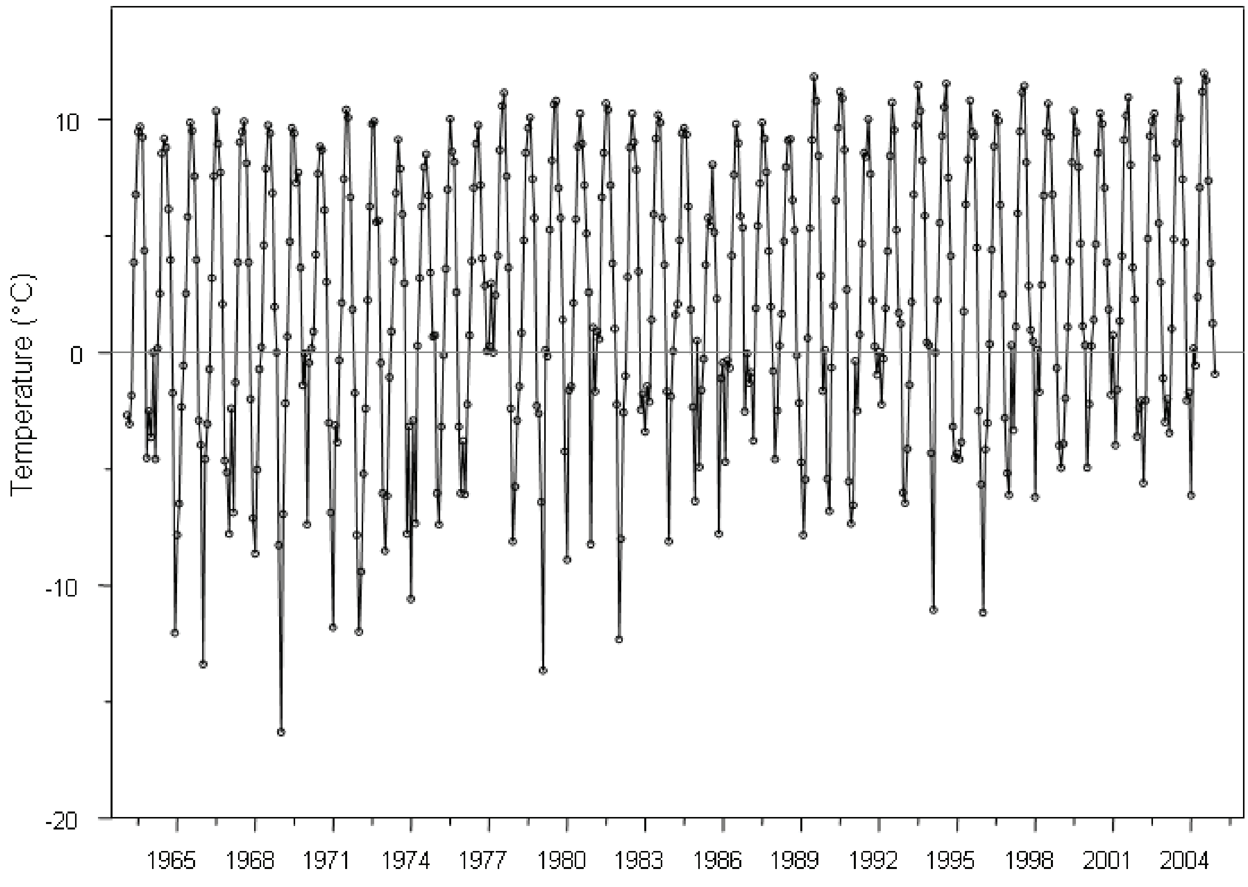

Figure 2b.-- Monthly averages of daily low temperature (MADLTs) at Auke Bay Laboratory, February 1963 through December 2004.

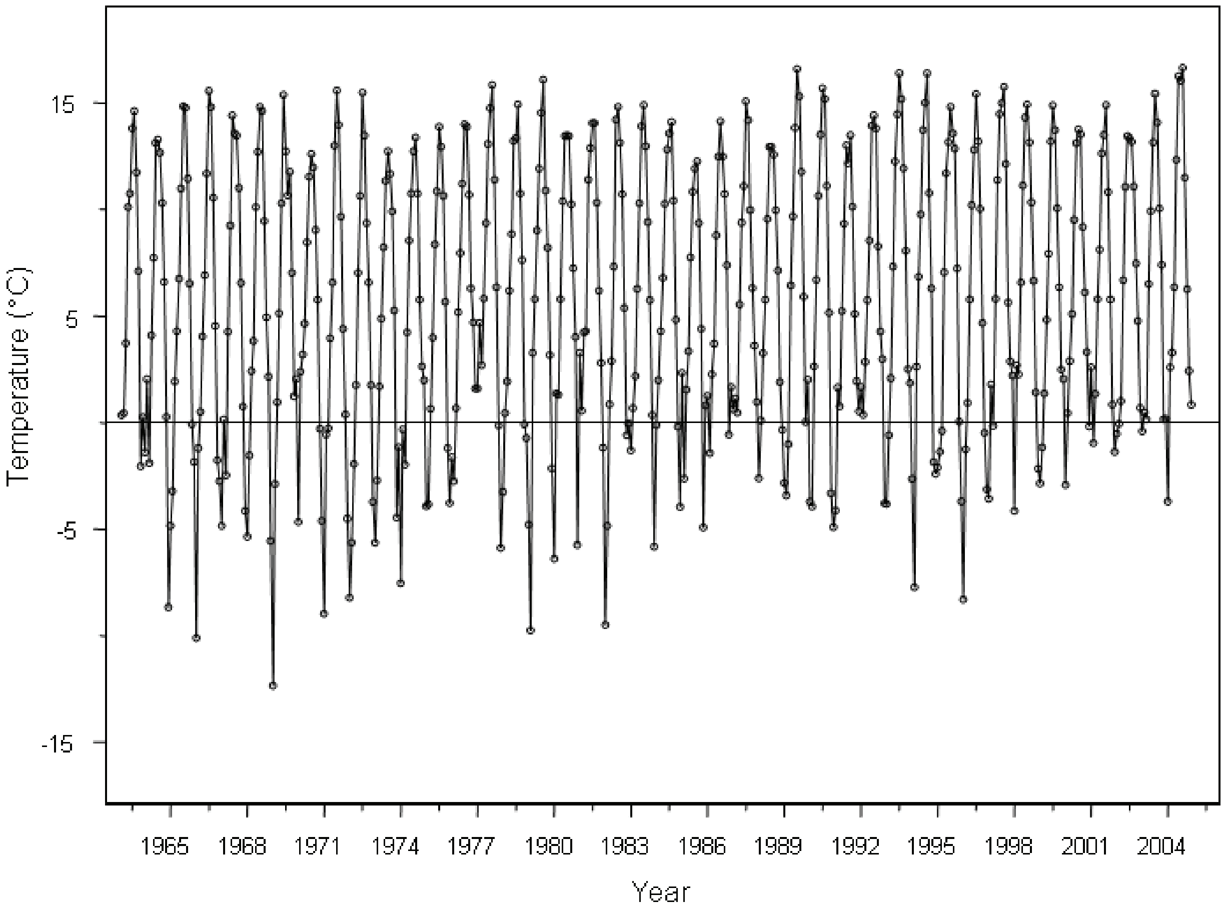

Figure 2c.-- Monthly averages of daily midrange temperature (MADMTs) at Auke Bay Laboratory, February 1963 through December 2004.

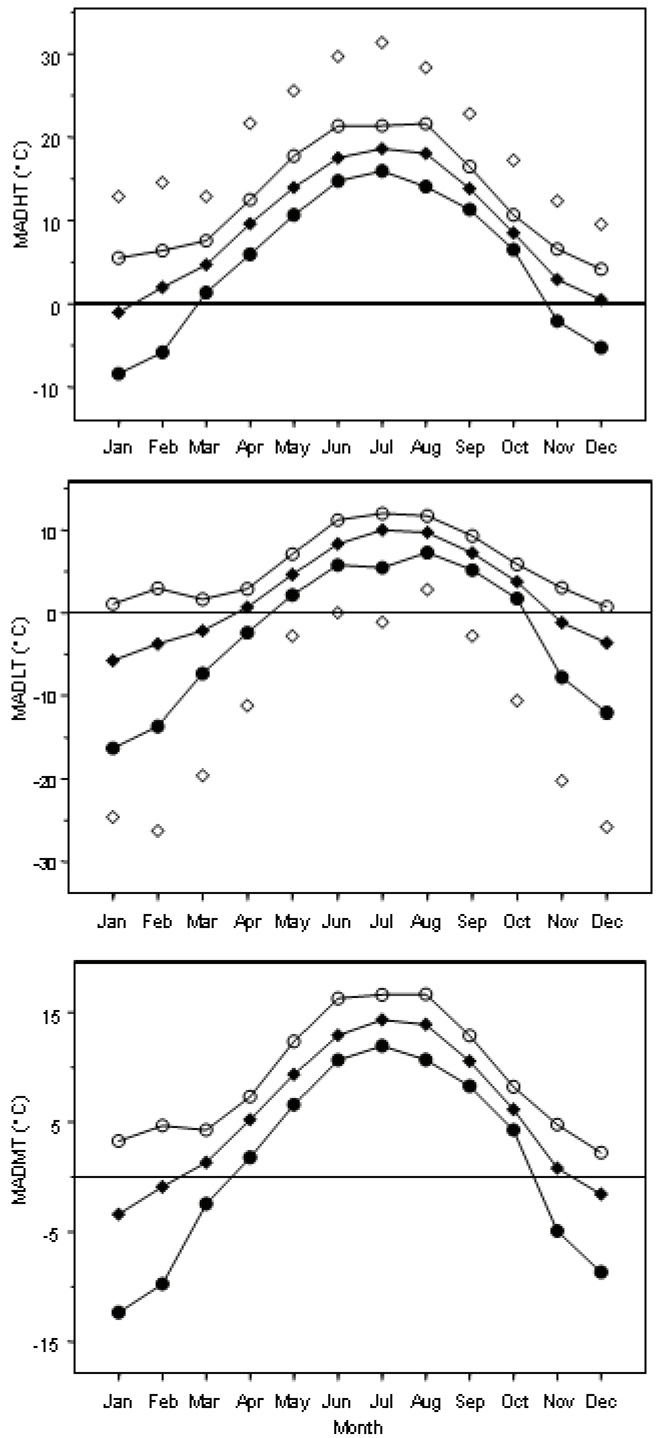

Figure 3.-- Statistics of annual temperature cycle at the Auke Bay Laboratory (1963-2004) including daily extremes (lowest low and highest high [◊]) and monthly extrema (high [○], low [●] and series averages [♦]) for monthly average daily high (MADHT), low (MADLT), and midrange (MADMT) air temperature series.

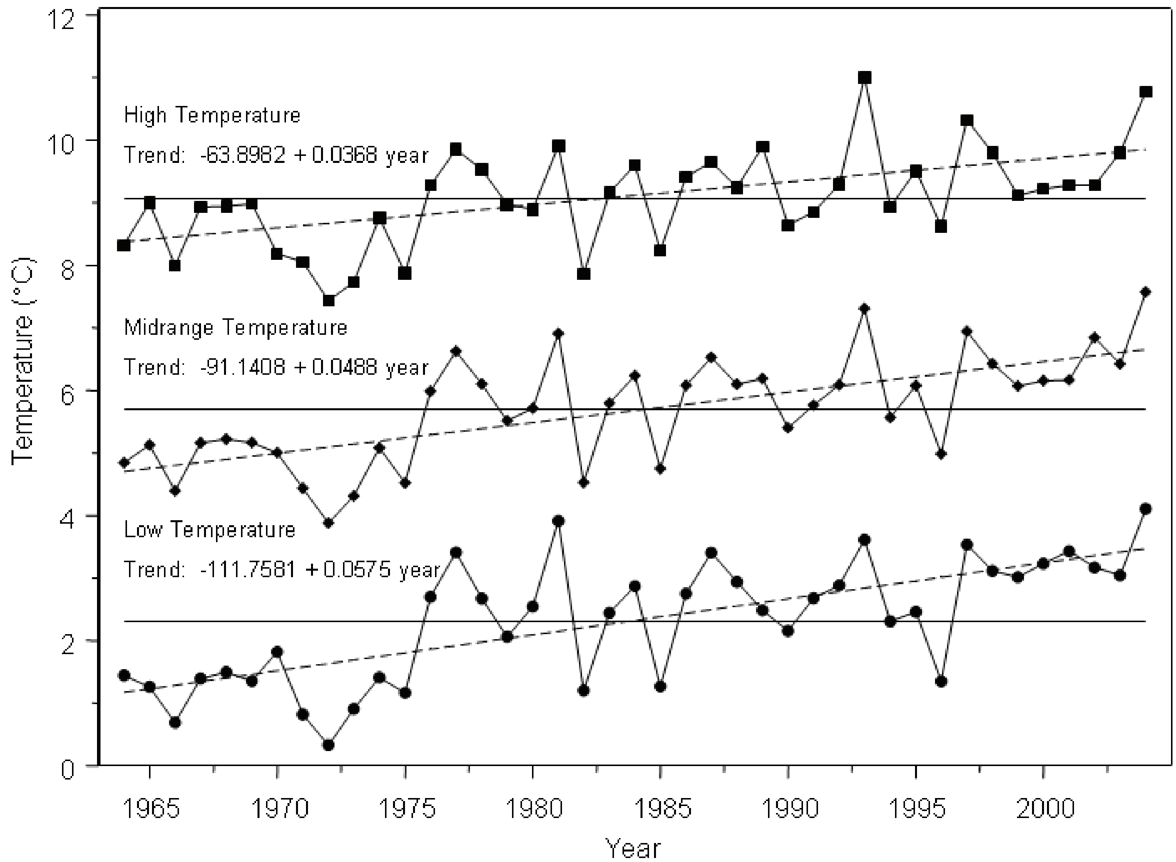

Figure 4.-- Annual average of monthly average high (MADHTs[■]), midrange (MADMTs[♦]), and low (MADLTs[●]) daily air temperatures at Auke Bay Laboratory, 1963-2004. Missing monthly values were estimated by cubic spline interpolation. Solid horizontal lines are the overall annual means. Dashed lines are the trends.

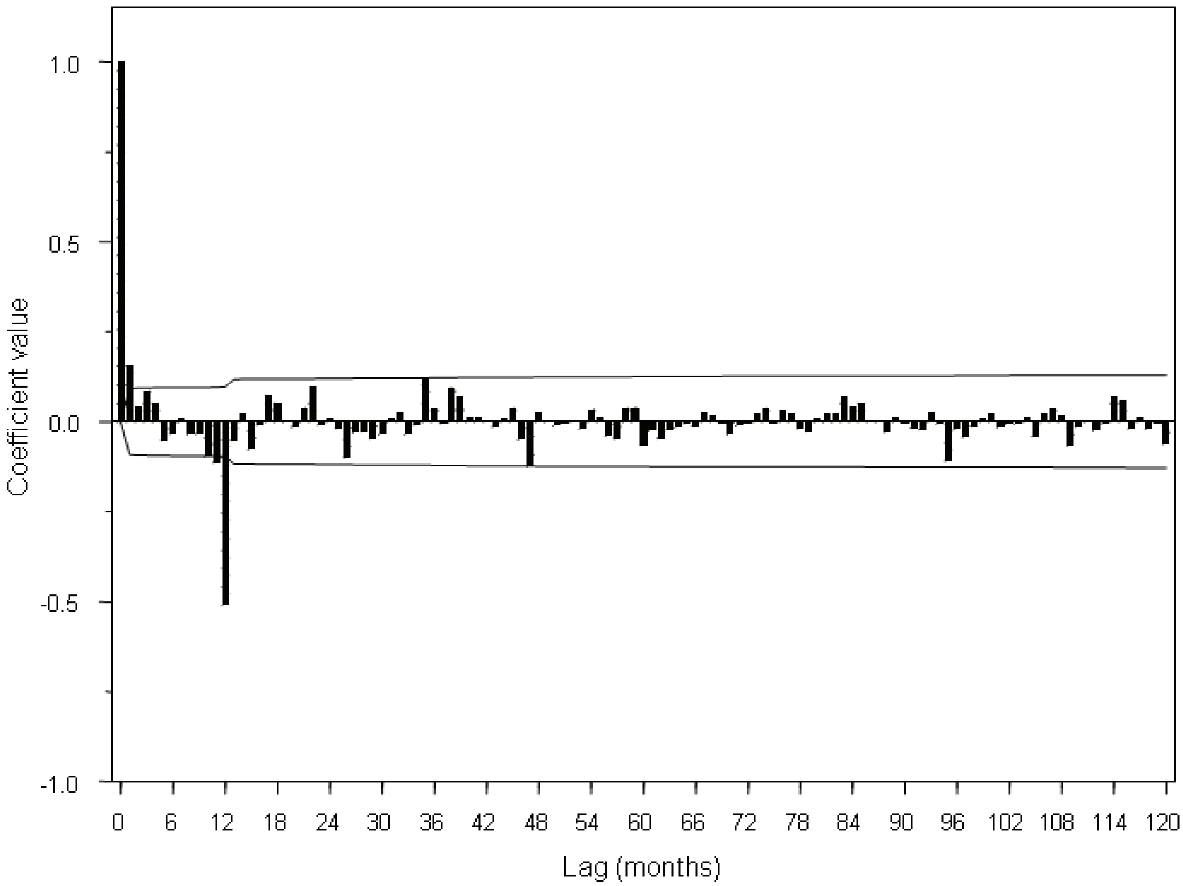

Figure 5.-- Sample autocorrelation function (SACF) of interannual month differences in logarithm-transformed monthly average daily high air temperatures (MADHTs) at Auke Bay. The interval covering two standard errors is indicated.

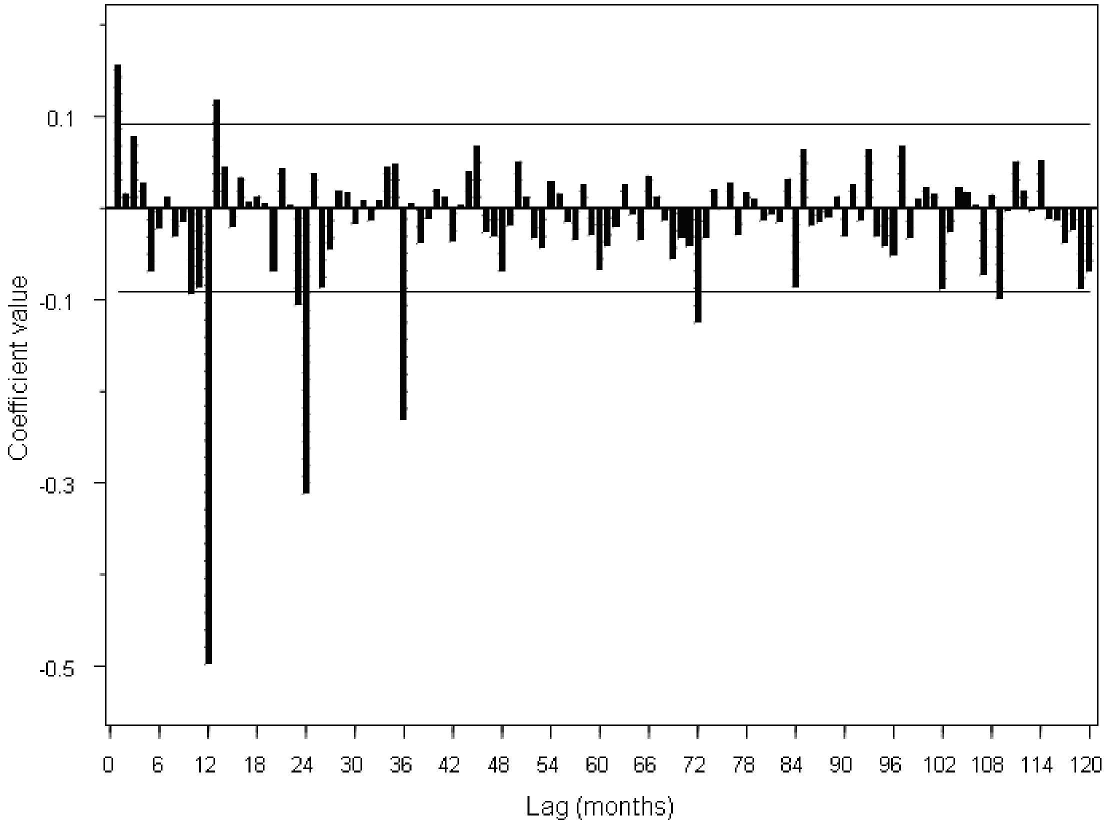

Figure 6.-- Sample partial autocorrelation function (SPACF) of interannual month differences in logarithm-transformed monthly average daily high air temperatures (MADHTs) at Auke Bay. The interval covering two standard errors is indicated.

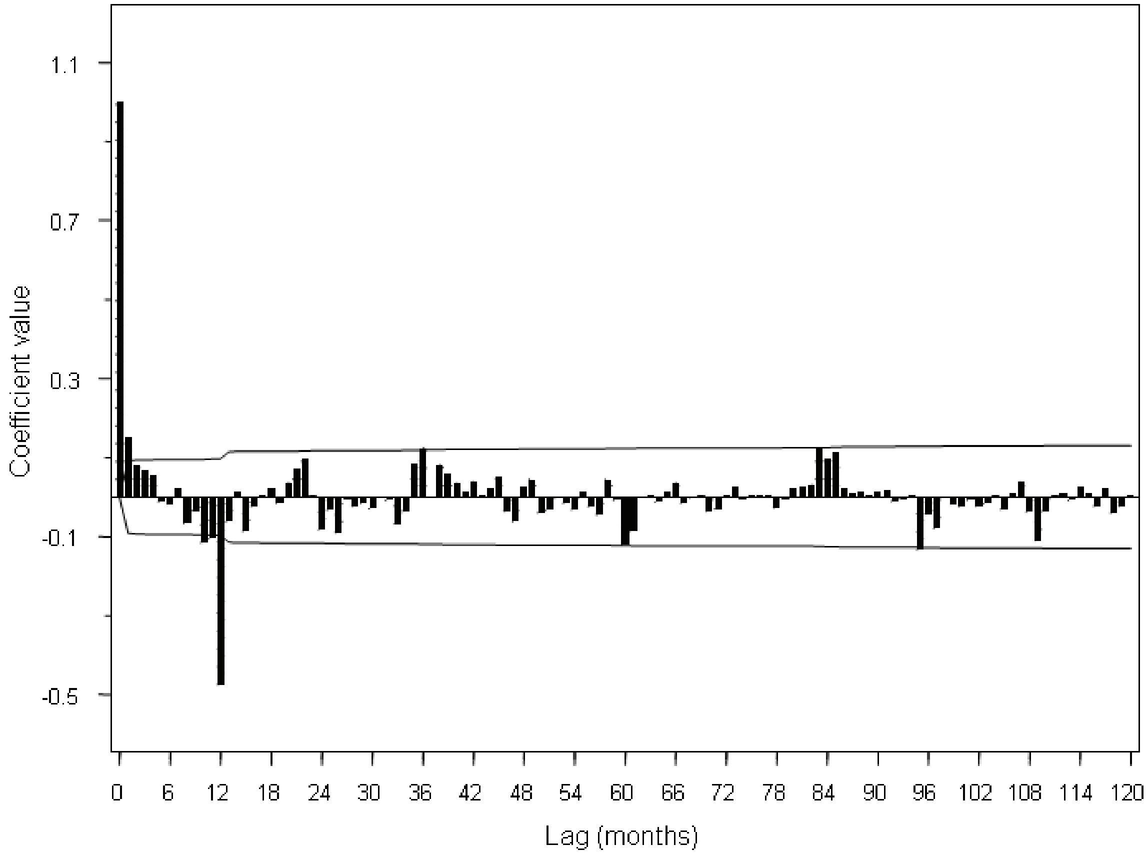

Figure 7.-- Sample autocorrelation function (SACF) of interannual month differences in logarithm-transformed monthly average daily low air temperatures (MADLTs) at Auke Bay. The interval covering two standard errors is indicated.

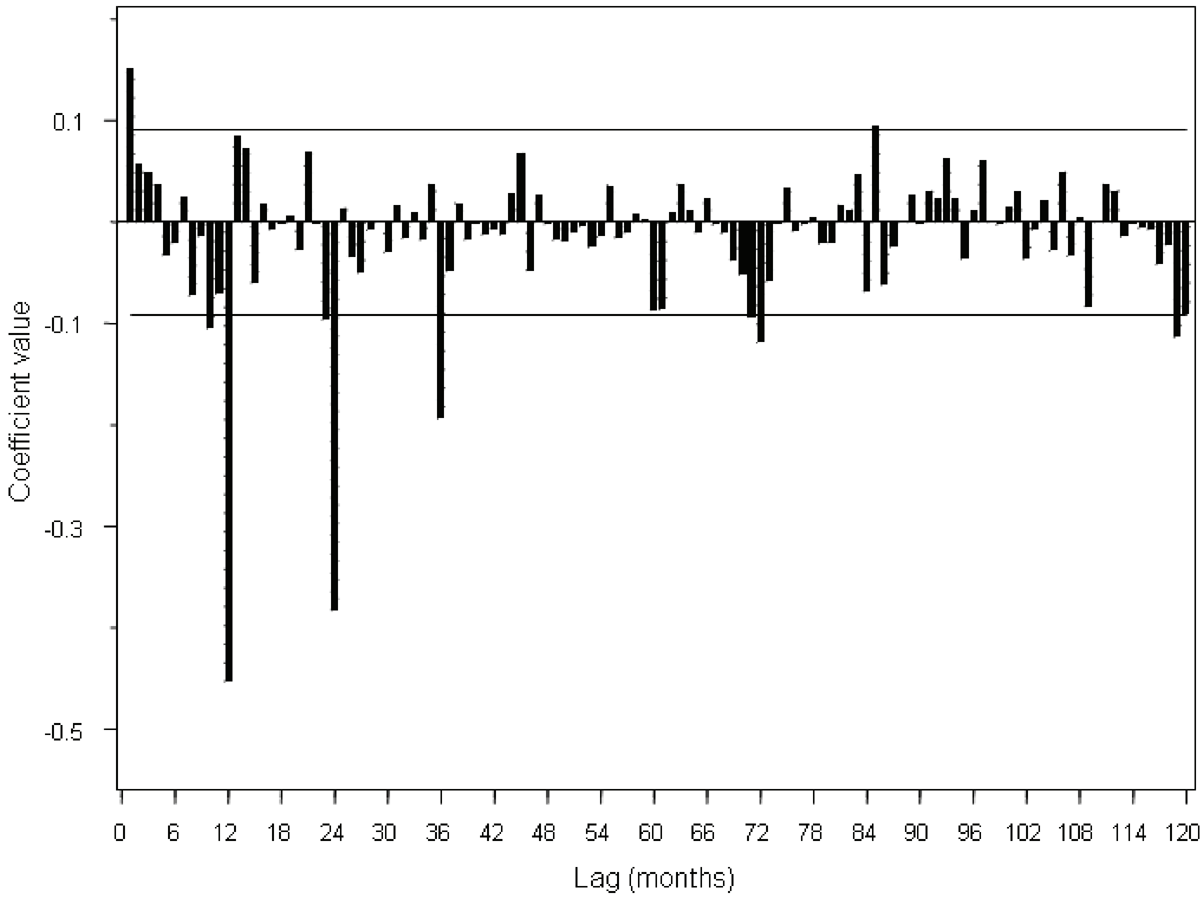

Figure 8.-- Sample partial autocorrelation function (SPACF) of interannual month differences in logarithm-transformed monthly average of daily low air temperatures (MADLTs) at Auke Bay. The interval covering two standard errors is indicated.

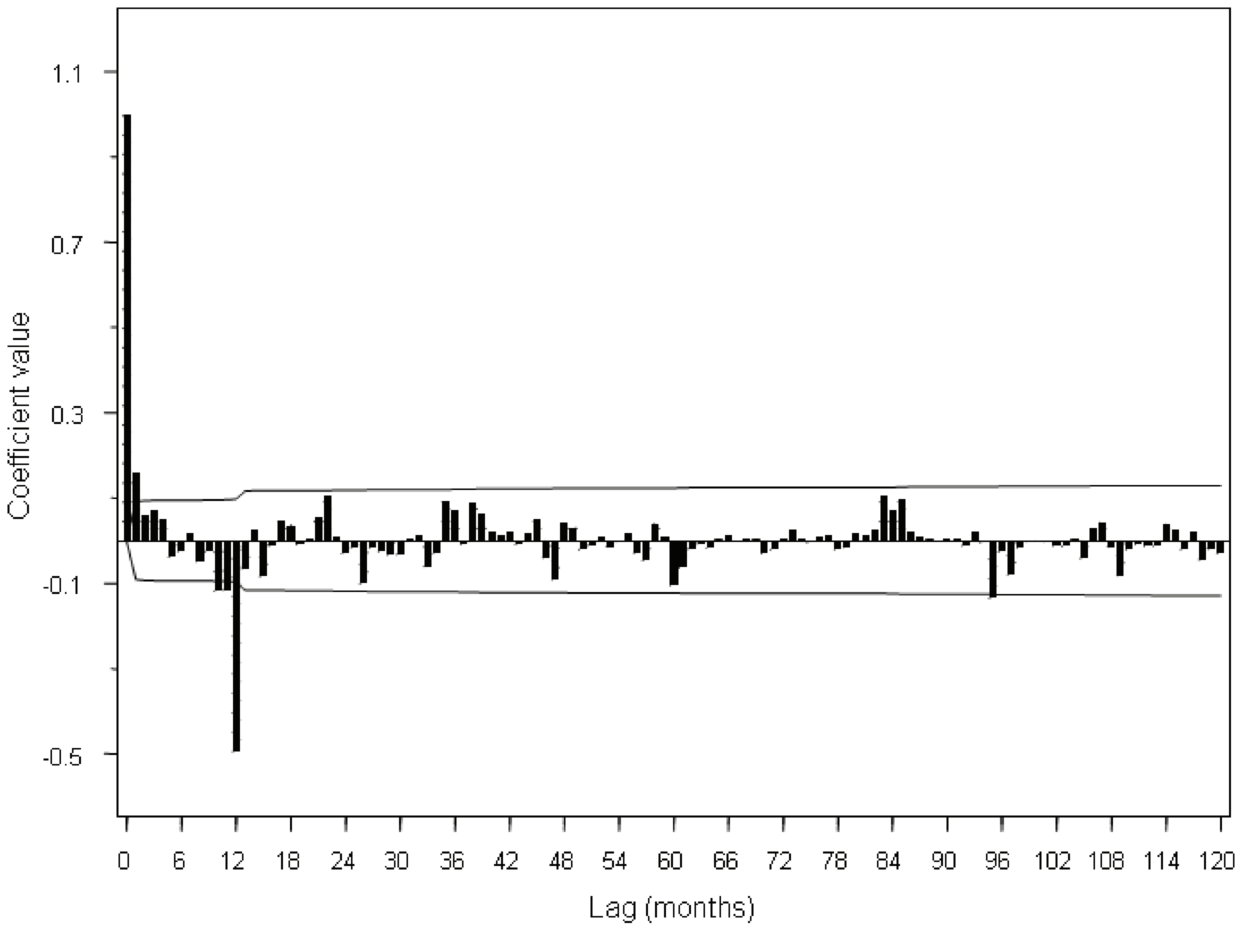

Figure 9.-- Sample autocorrelation function (SACF) of interannual month differences in logarithm-transformed monthly average daily midrange air temperatures (MADMTs) at Auke Bay. The interval covering two standard errors is indicated.

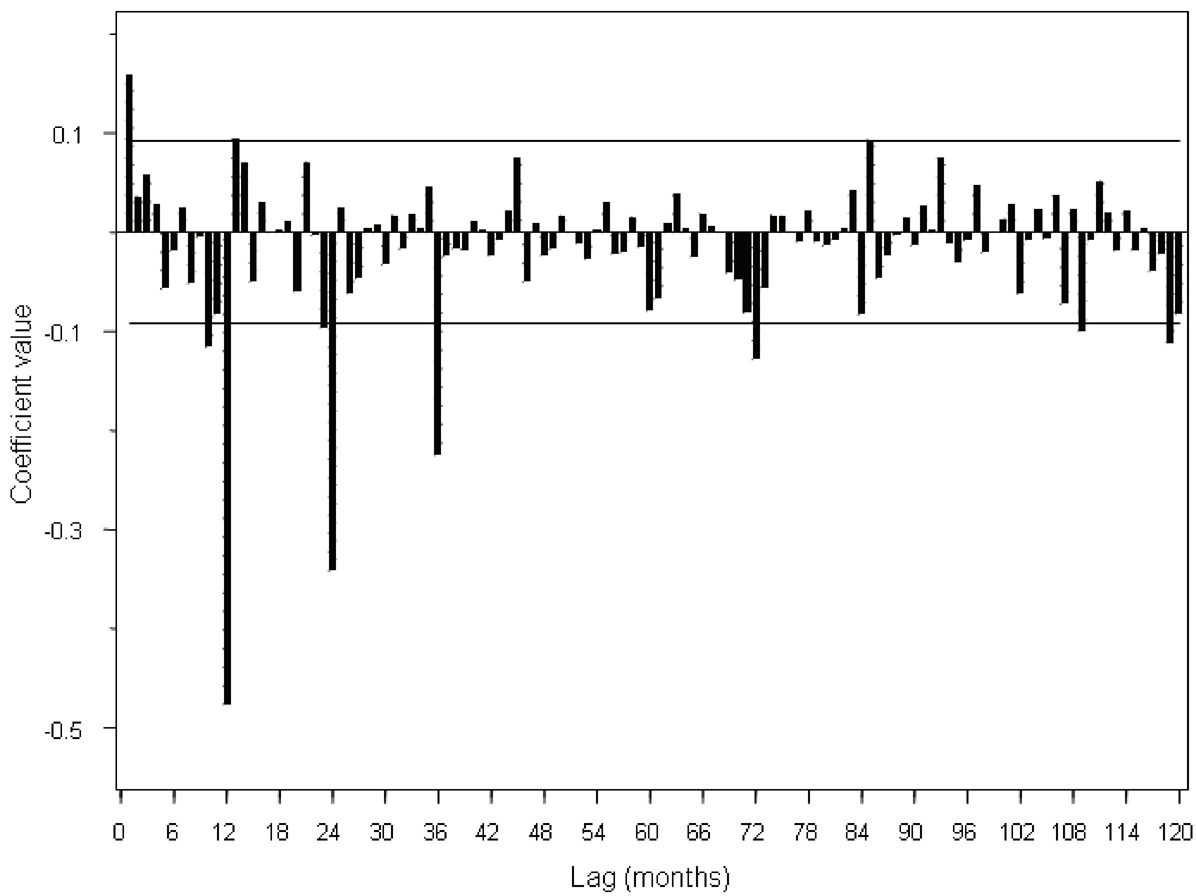

Figure 10.-- Sample partial autocorrelation function (SPACF) of interannual month differences in logarithm-transformed monthly average daily midrange air temperatures (MADMTs) at Auke Bay. The interval covering two standard errors is indicated.

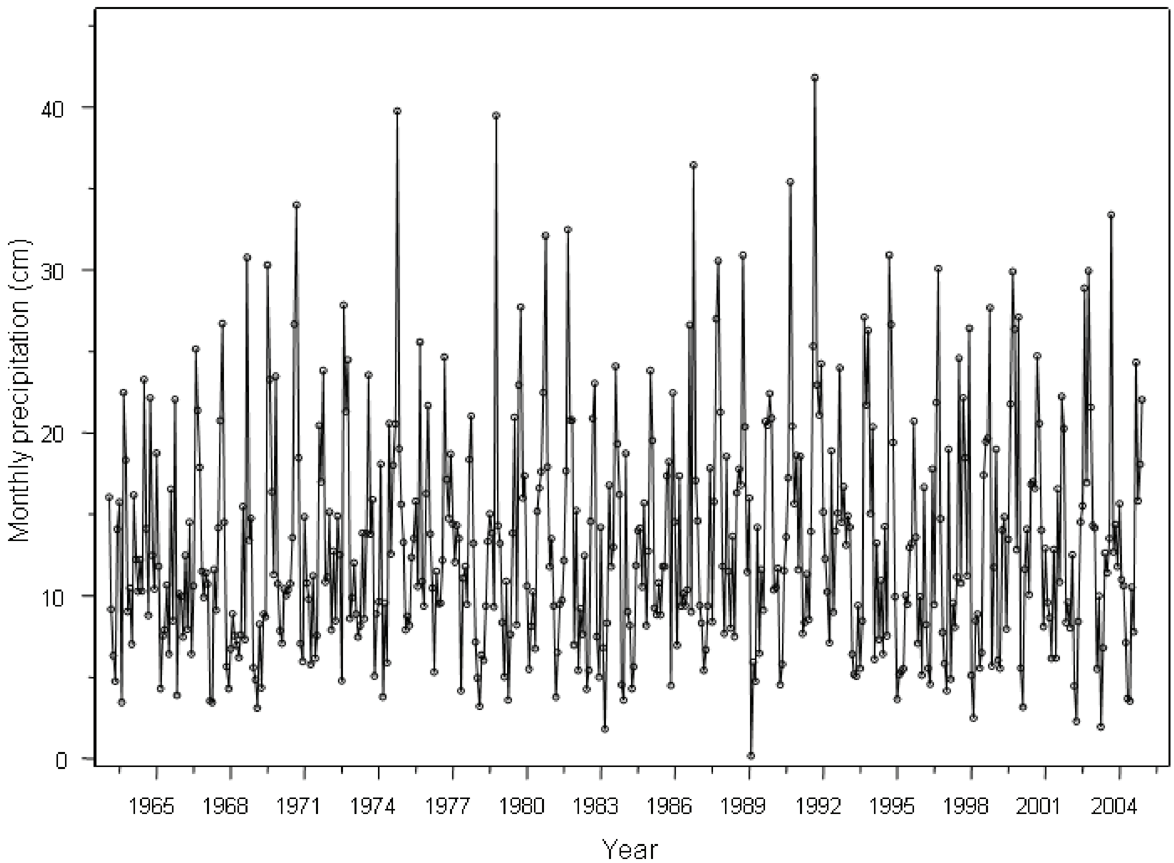

Figure 11a.--Total monthly precipitation at the Auke Bay Laboratory, February 1963 through December 2004.

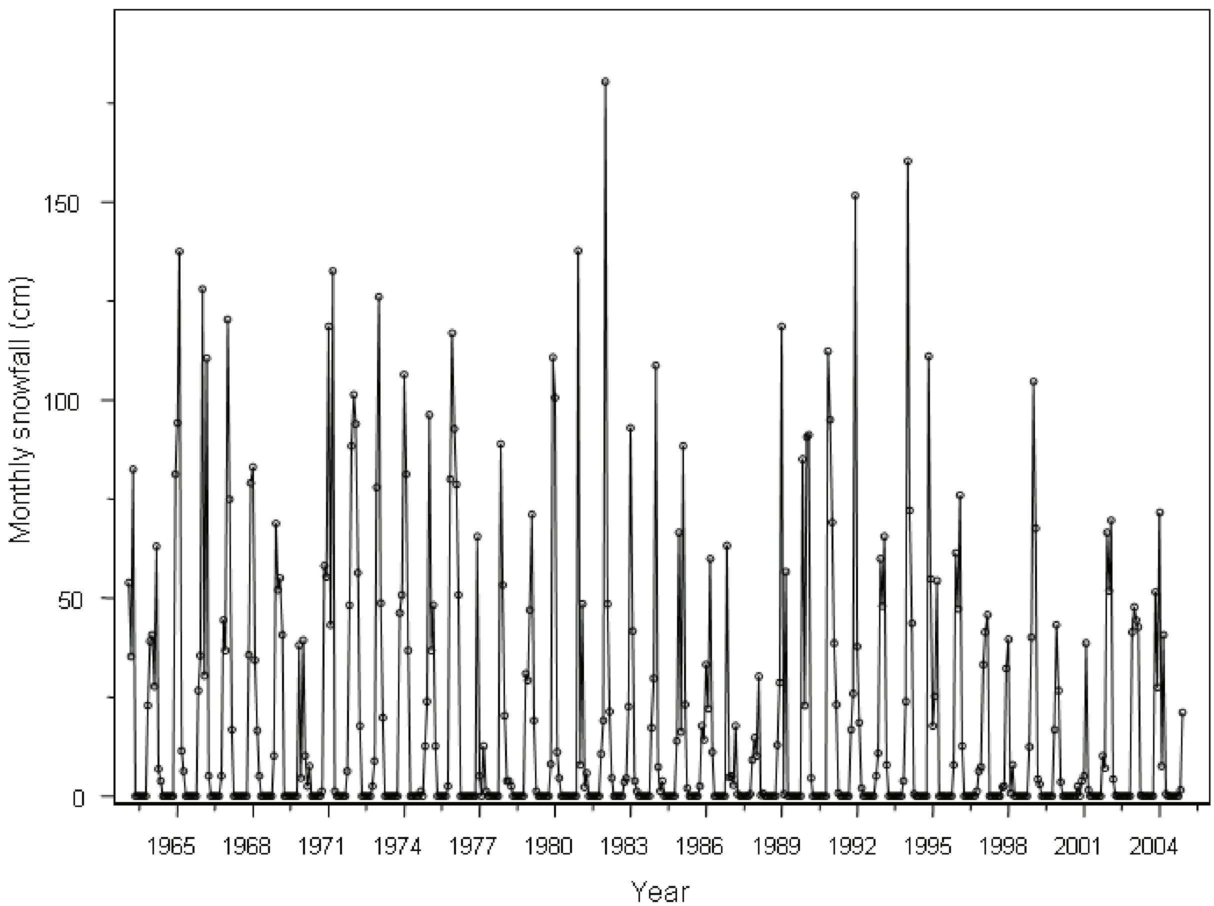

Figure 11b.--Monthly snowfall at the Auke Bay Laboratory, February 1963 through December 2004.

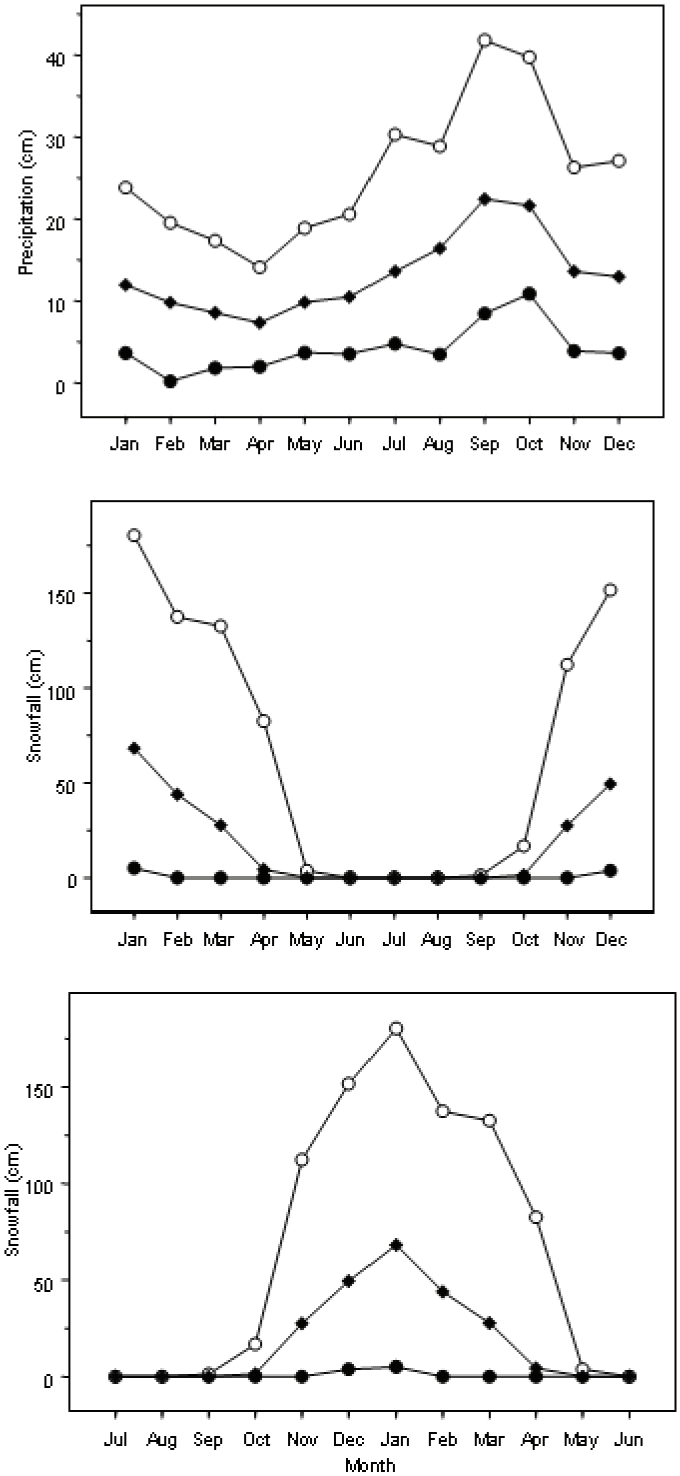

Figure 12.-- Statistics of annual precipitation cycle at Auke Bay Laboratory (1963-2004) from monthly precipitation (cm) (maximum[○], mean [♦], and minimum [●]) for total precipitation, calendar-year snowfall (January-December), and seasonal snowfall (July-June).

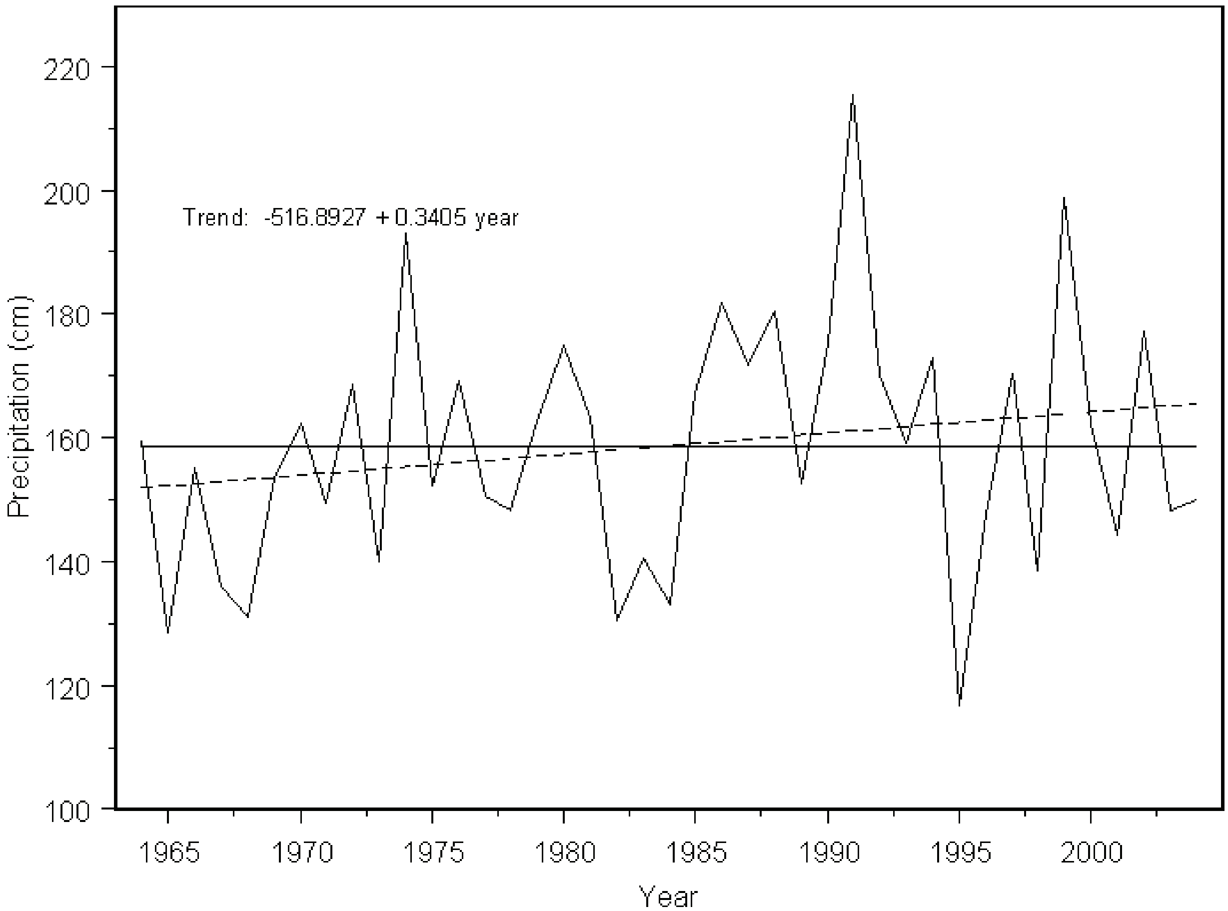

Figure 13.-- Annual total precipitation (cm) at Auke Bay, 1964-2004. Missing monthly values were estimated by cubic spline interpolation. Slope of the trend line was not significant (P = 0.20). Solid horizontal line is the overall mean, and the dashed line is the trend.

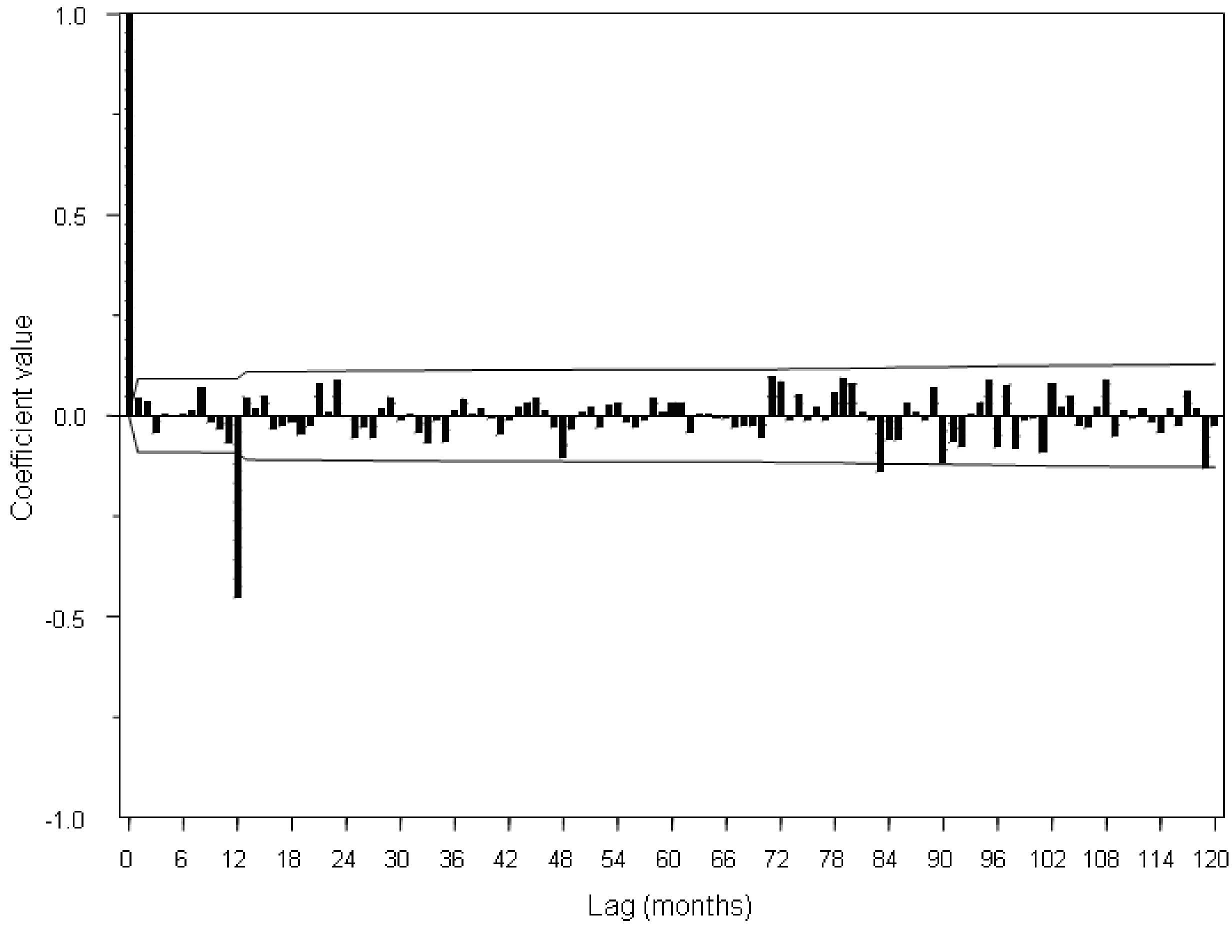

Figure 14.-- Sample autocorrelation function (SACF) of interannual month differences in logarithm-transformed precipitation at Auke Bay. The interval covering two standard errors is indicated.

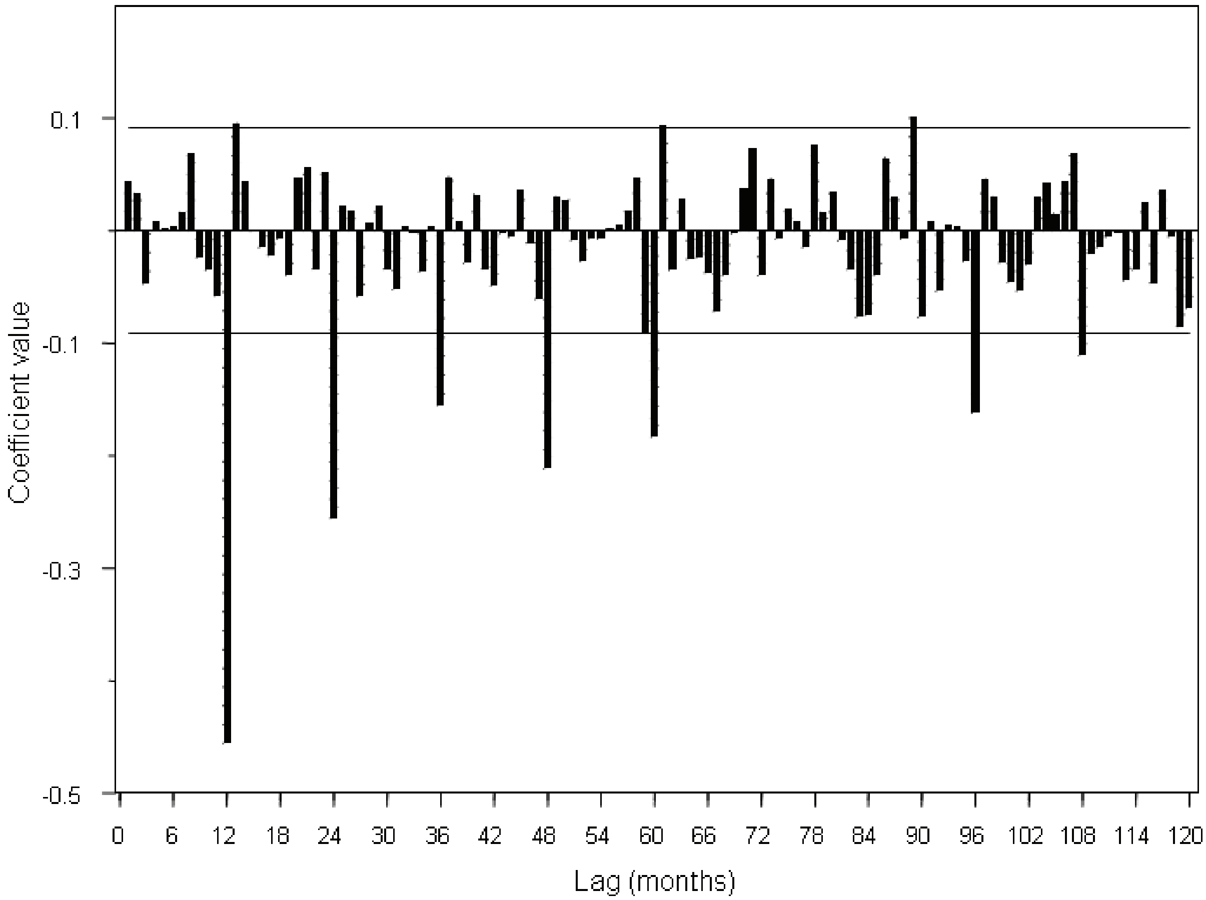

Figure 15.-- Sample partial autocorrelation function (SPACF) of interannual month differences in logarithm-transformed precipitation at Auke Bay. The interval covering two standard errors is indicated.

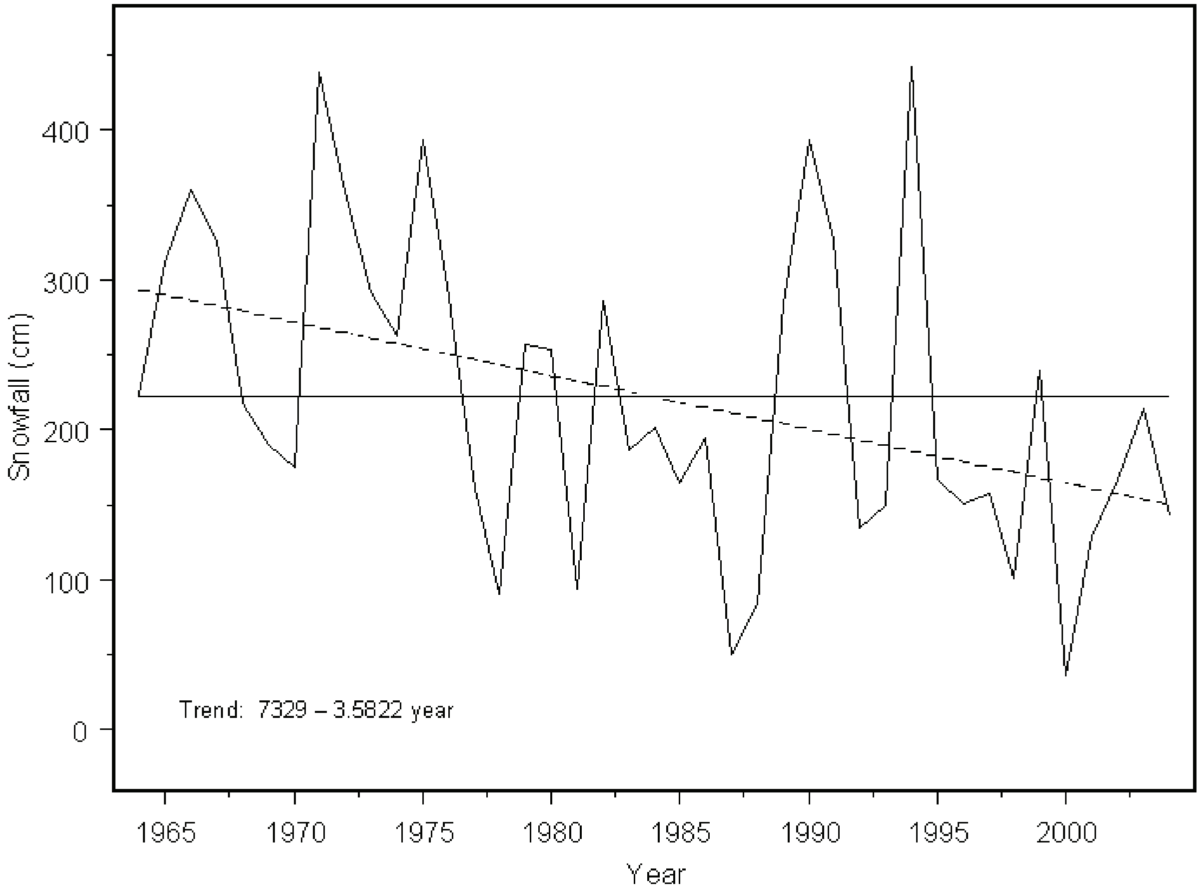

Figure 16.-- Annual total snowfall (cm) at Auke Bay, 1964-2004. Missing monthly values were estimated by cubic spline interpolation. Solid line is the overall annual mean, and the dashed line is the trend.

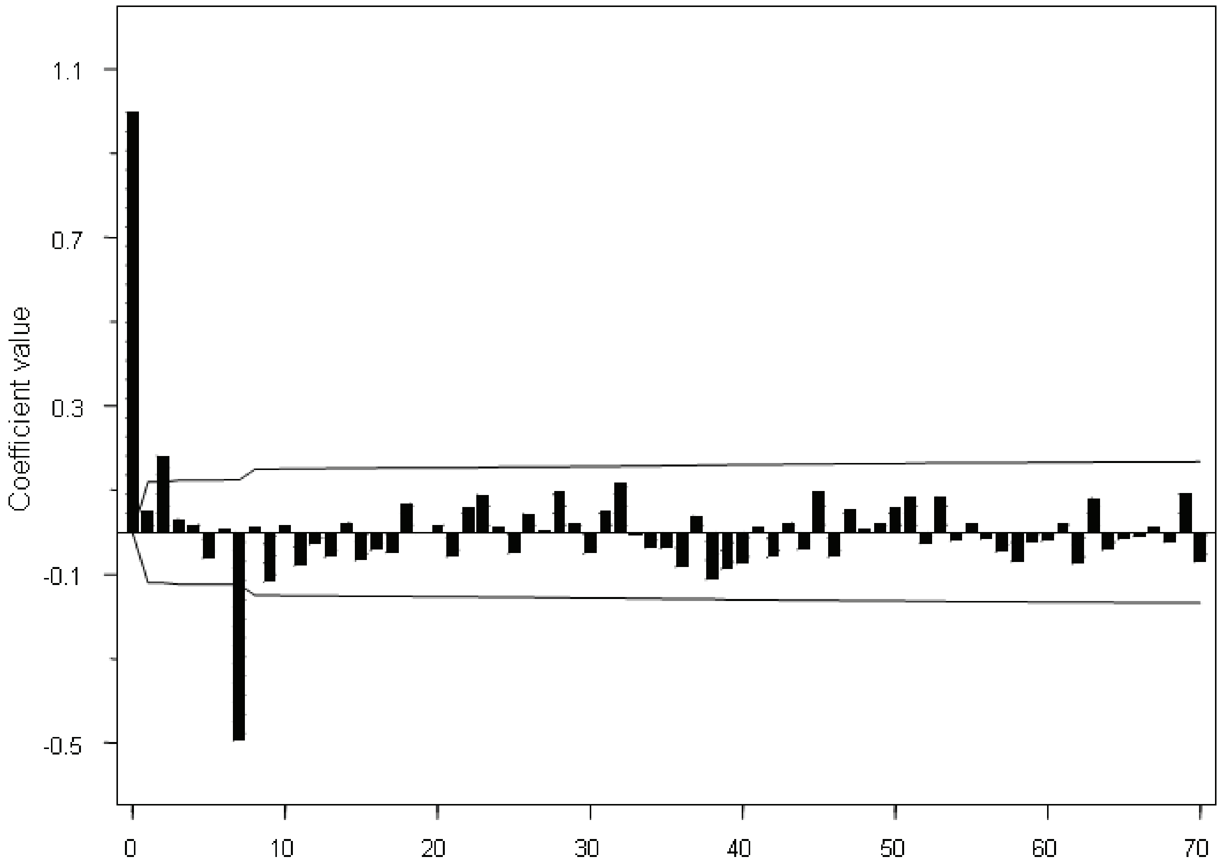

Figure 17.-- Sample autocorrelation function (SACF) of interannual month differences in logarithm-transformed snowfall at Auke Bay. The interval covering two standard errors is indicated.

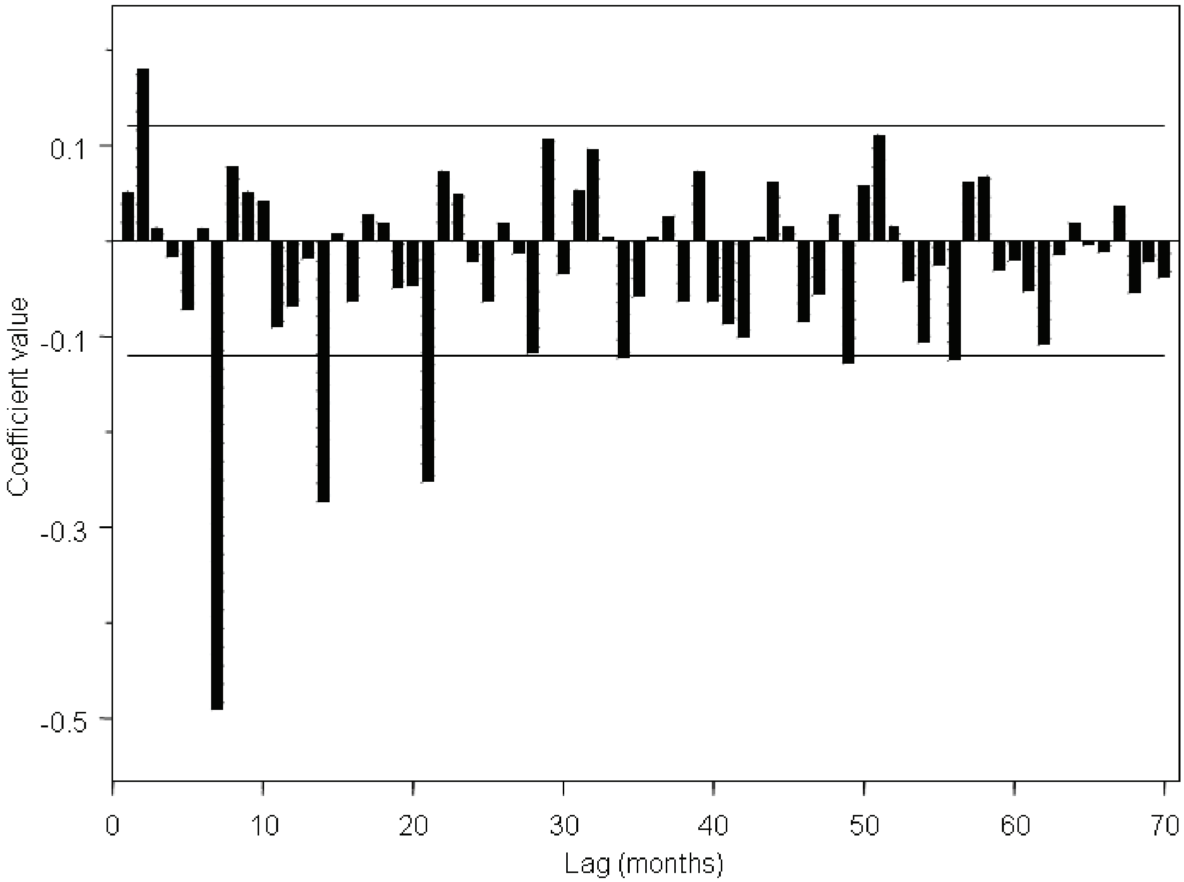

Figure 18.-- Sample partial autocorrelation function (SPACF) of interannual month differences in logarithm-transformed snowfall at Auke Bay. The interval covering two standard errors is indicated.

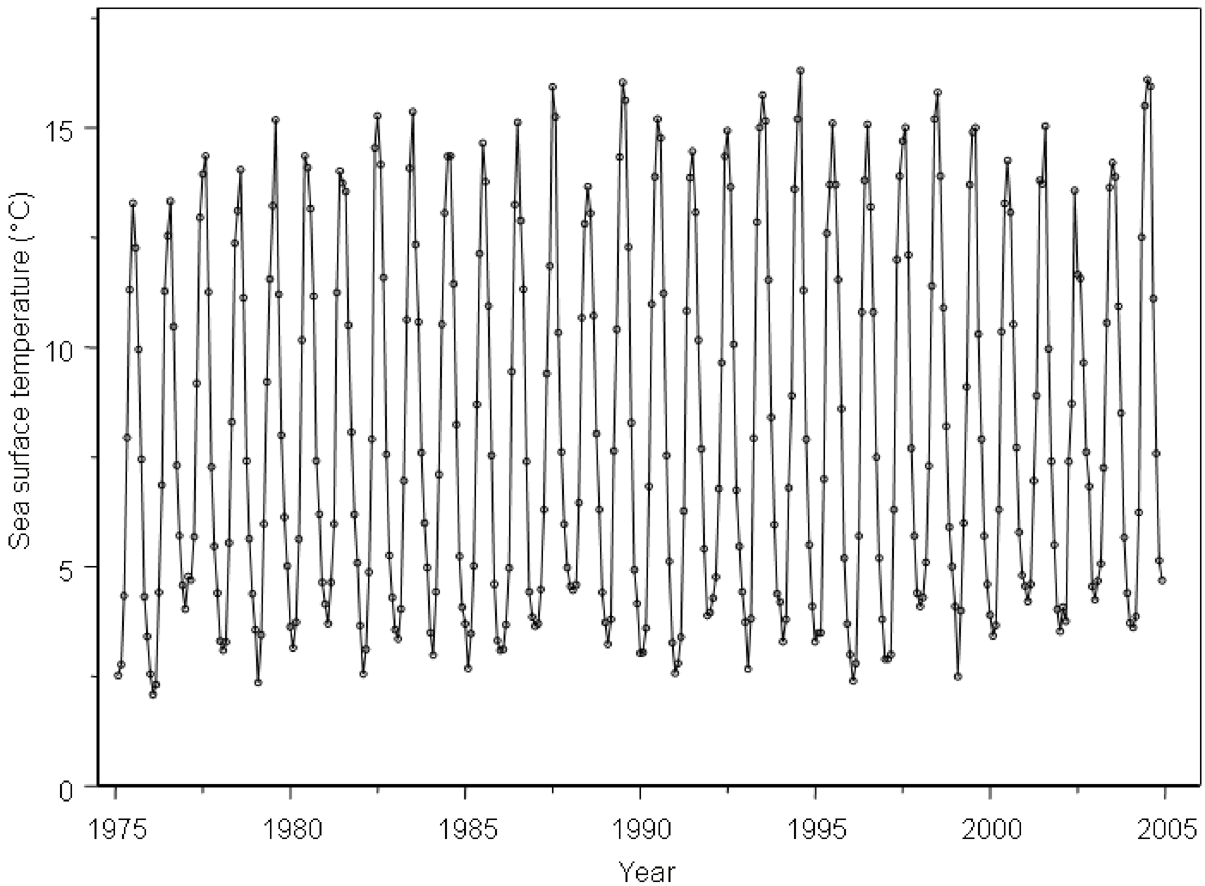

Figure 19.-- Monthly averages of daily sea surface temperatures (MADSSTs) at Auke Bay Laboratory, February 1975 through December 2004.

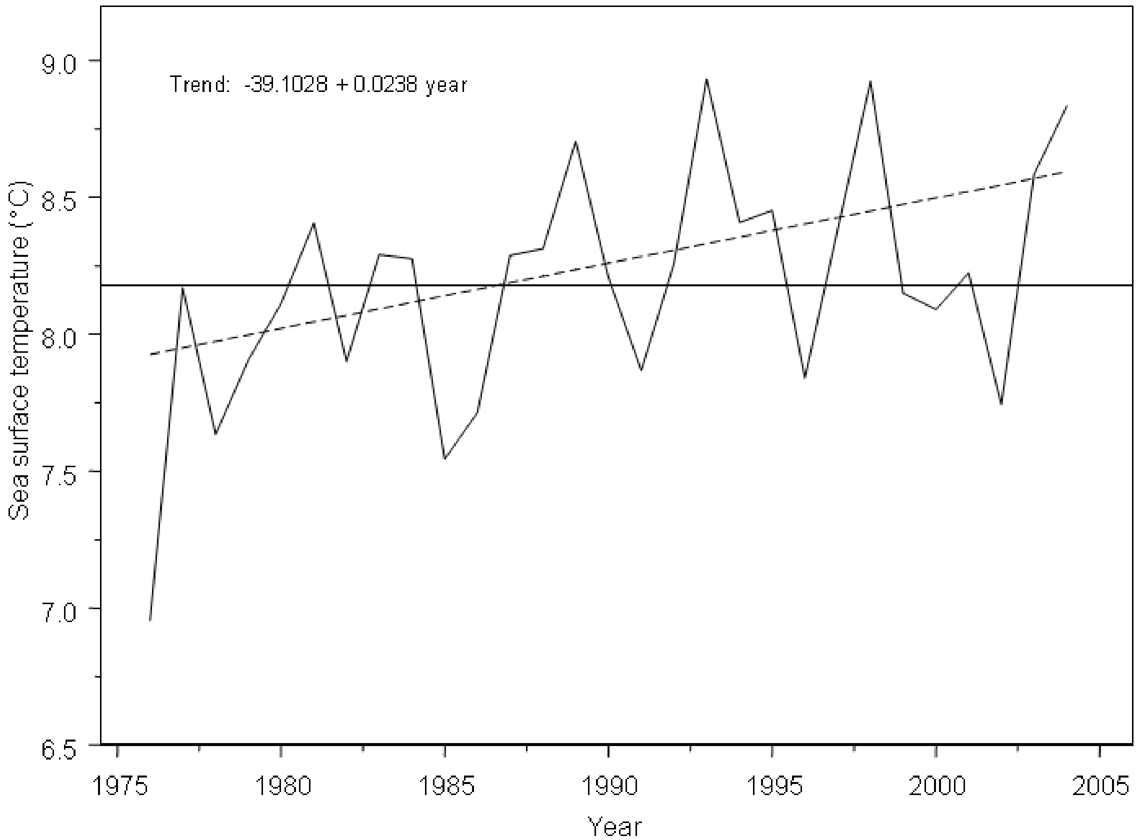

Figure 20.-- Annual average of monthly average daily sea surface temperatures (MADSSTs) at Auke Bay, Alaska, 1976-2004. The solid line is the overall annual mean, and the dashed line is the trend.

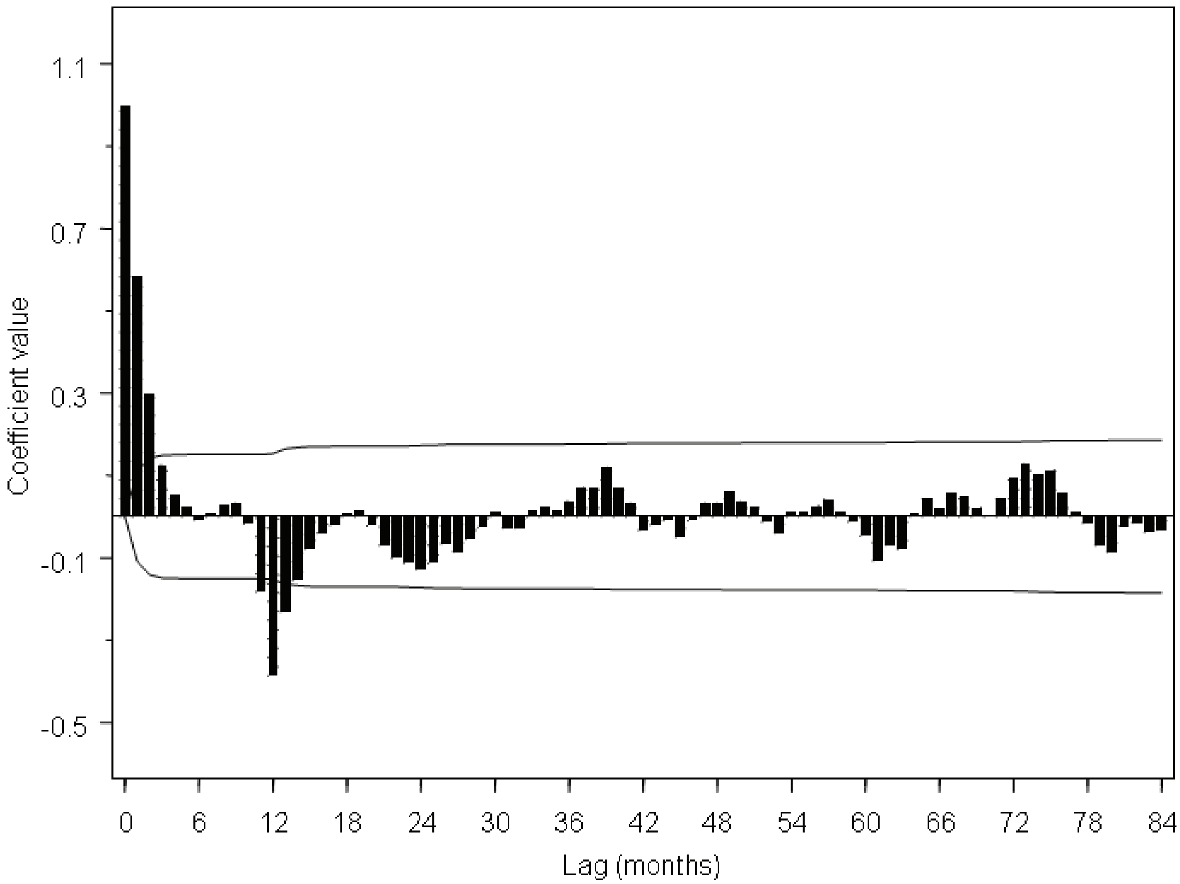

Figure 21.-- Sample autocorrelation function (SACF) of interannual month differences in logarithm-transformed monthly average daily sea surface temperatures (MADSSTs) at Auke Bay. The interval covering two standard errors is indicated.

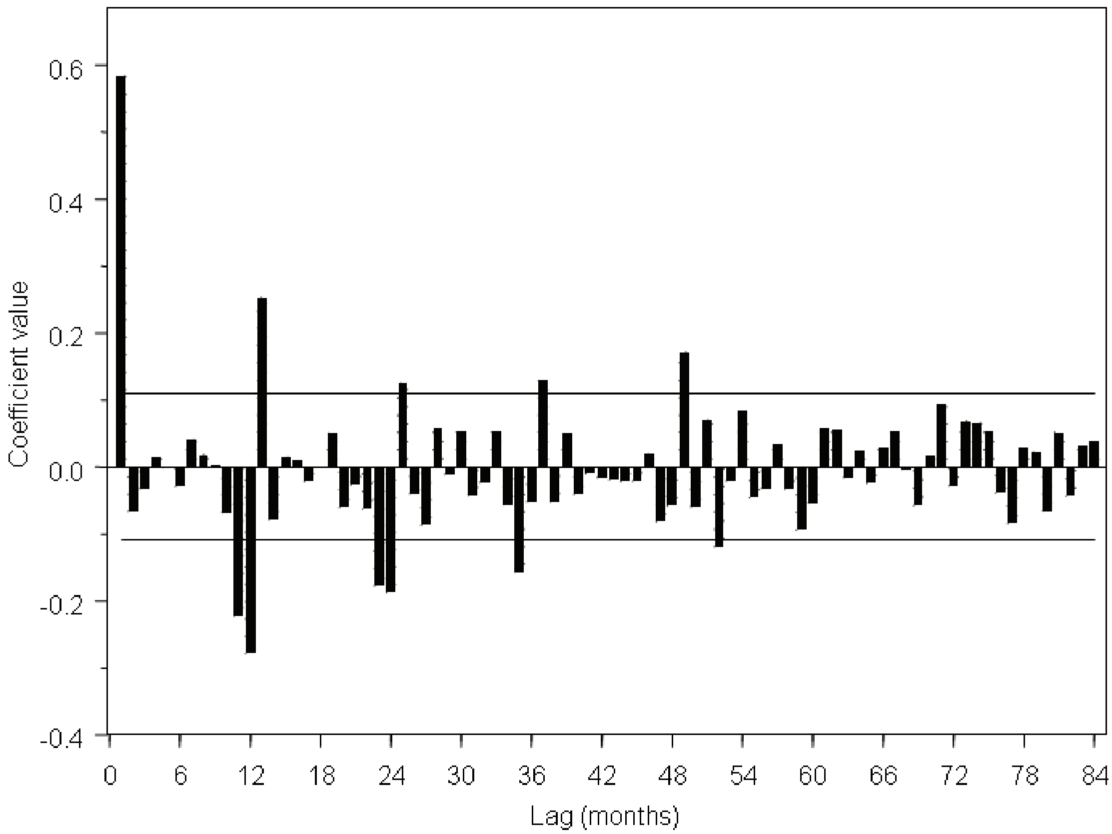

Figure 22.-- Sample partial autocorrelation function (SPACF) of interannual month differences in logarithm-transformed monthly average daily sea surface temperatures (MADSSTs) at Auke Bay. The interval covering two standard errors is indicated.

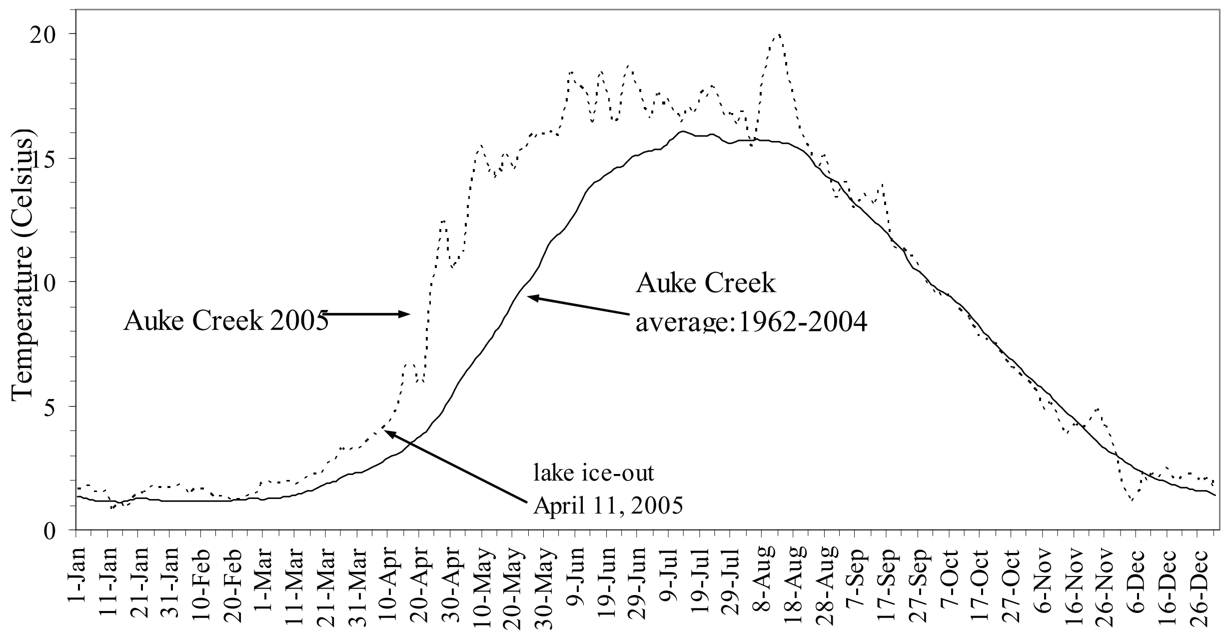

Figure 23.--Average of daily Auke Creek stream temperatures (ºC), 1962-2005 (Taylor 2006).

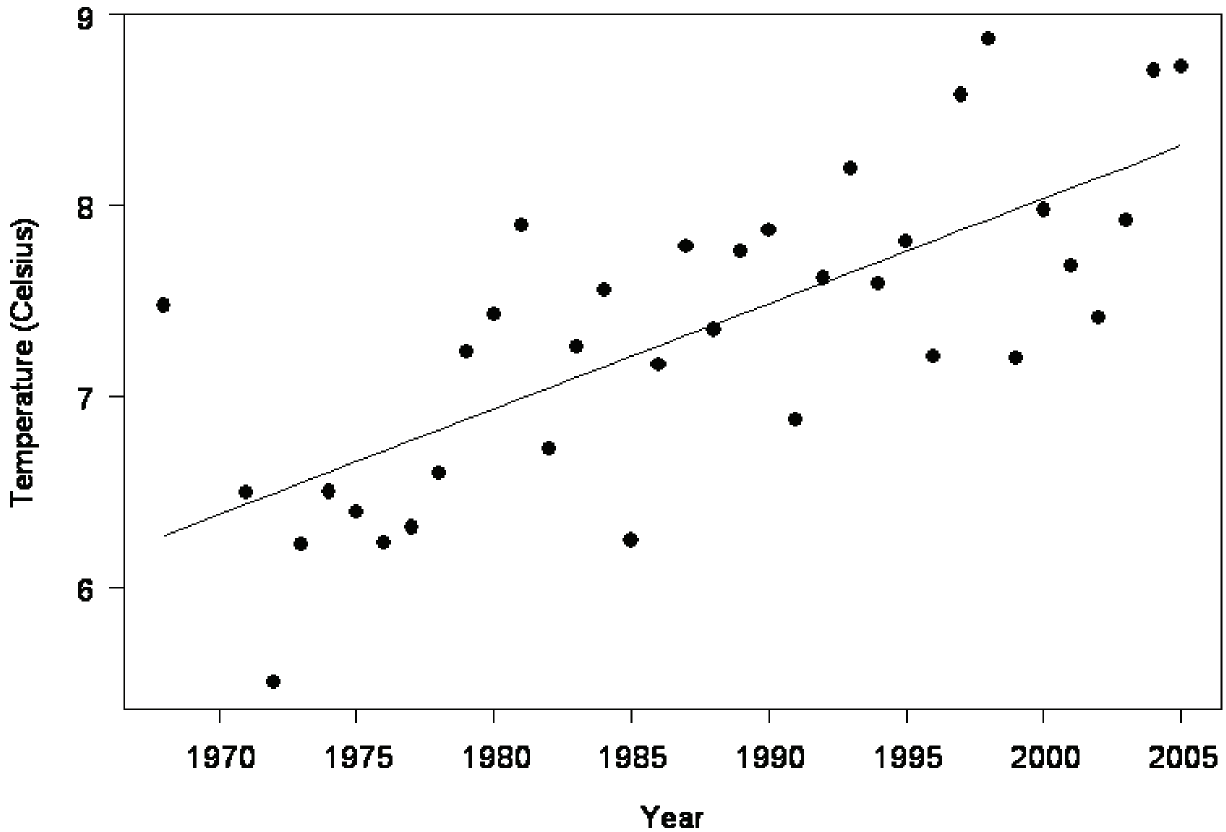

Figure 24.--Average annual temperature of Auke Creek and the trend line over all years.

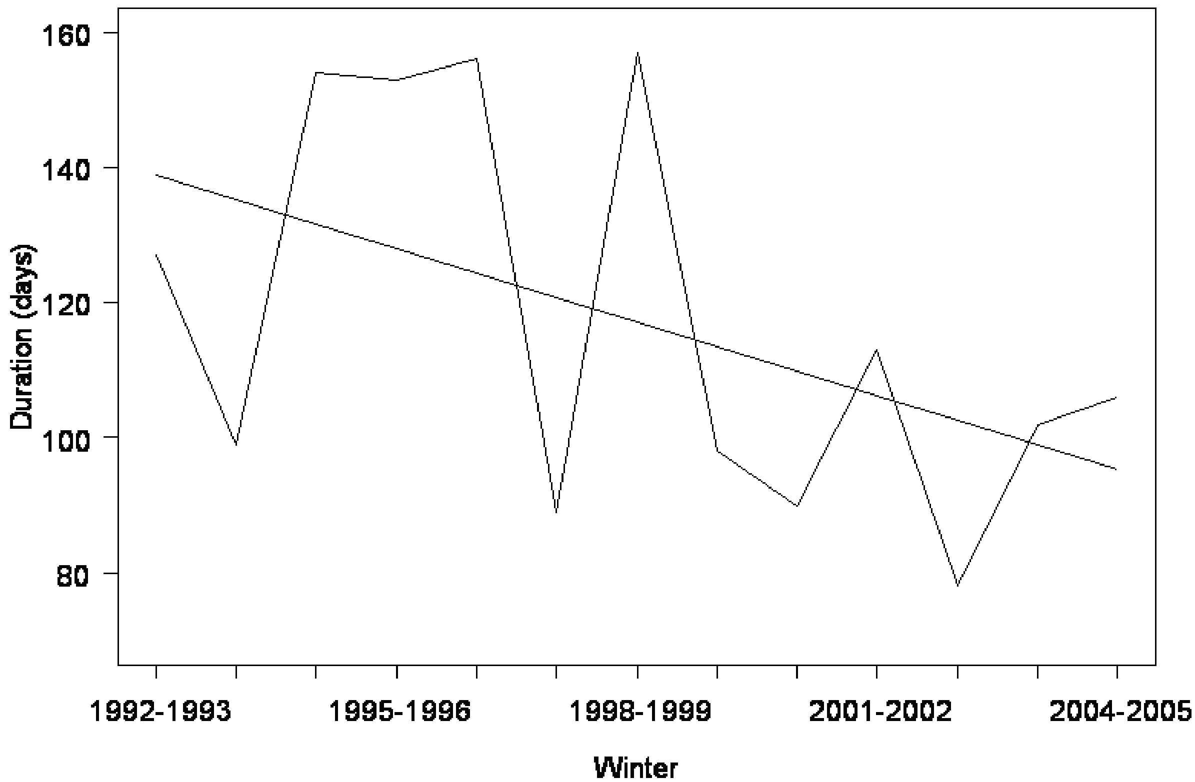

Figure 25.-- Winter ice cover duration for Auke Lake and the trend line for 1992-2005.

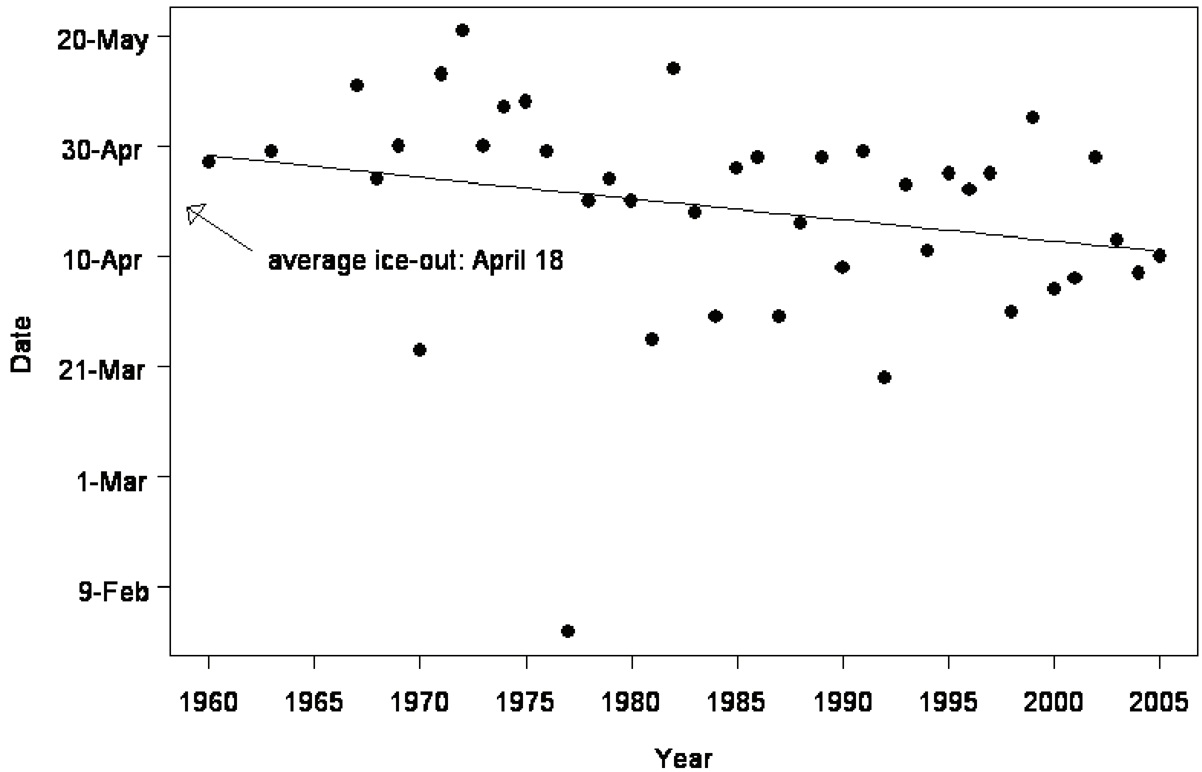

Figure 26.-- Ice breakup dates of Auke Lake and the trend line for 1960-2005.

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