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MICROCLIMATOLOGY
of
OGOTORUK VALLEY,
ALASKA

Final Report

P. W. Allen and R. O. Weedfall

U. S. Weather Bureau

April 1962

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Prepared for the U. S. Atomic Energy Commission as
part of Project Chariot Environmental Study Program

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WEATHER and CLIMATE

Abstract

The unique topographic features of Ogotoruk Valley result in cold-air channeling from the northeast, around the western end of the Brooks Range. Depressed precipitation totals and lower temperatures result. The frequent northerly winter gales also prevent heavy snow accumulation. The cool waters of the Arctic have an important climatic effect and depress summer warming of the air and soil and thus help keep the level of permafrost at shallow depths, especially in the lower parts of the Valley, away from the rocky hill-tops.

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I. Introduction and Operational Procedure

This final report has continued the micrometeorological study of the Ogotoruk Valley from May 1961 through December 1961 and summarized the conclusions reached from this study which started in September 1959.

The study of Ogotoruk Valley and its variable weather has been approached by measuring selected meteorological parameters and comparing them with the same parameters at nearby locations that have relatively long periods of observational records. Thus, it has been possible to arrive at approximate normals for Ogotoruk. With this picture of what is "normal" in Ogotoruk Valley, it has been possible to proceed with a microclimatological study by observing the variations of many of these same parameters in different locations within the Valley itself, and also broadening the scope of the study by measuring soil temperatures and comparing these differences within the Valley and also with other soil studies and observations.

II. Operations and Instrumentation

In general, complete readings from the micro-scale network were obtained throughout the summer months from April 1 through September 1961. The operational plan and instrumentation was similar to that of 1960, with certain differences. Each station in the network was equipped with Palmer thermometers at six levels. These were of the hydrocarbon-in-steel type and permitted daily reading of the maximum and minimum temperature since the preceding observation. They were clamped between radiation shields for measuring air temperatures at 5 and 50 cm. above the ground. Soil temperature measurements were obtained at 5, 10, 20, and 50 cm. below the surface. The wind instruments were placed on 15 foot towers at stations A34.7, A34.9, A34.12, and A34.14. The new station, A34.15, was in operation by the end of May.

III. Wind

Little change in the expected wind pattern of Ogotoruk Valley has been noted. Table 1 shows that the average wind speeds have continued greater than Kotzebue's since observations began in September 1959. In the fall and early winter months of 1961, the northerly "Ogotoruk Wind" again asserted its dominance, often with sustained gale force. These high wind speeds out of the north and north-northeast are accounted for mainly by the extreme pressure gradients and circulation patterns mentioned in previous report (11). Although brief periods of weaker winds occur ahead of them, in the wake of eastward-moving storms, strong easterly, northeasterly, or northerly winds occur as air flows in a spiral fashion from an area of high pressure to one of low pressure. The exact direction depends on location and terrain.

This flow is further influenced by the temperature inversion which exists most of the year up to at least 3000 feet and is strongest in the winter months. This stable stratification of the air, as Dickey (3) notes, acts as a lid in resisting flow over the mountains to the east, and thus assists in channeling it around the western end of the Brooks Range.

The contours on a topographic map of northwestern Alaska show the Ogotoruk Valley as the mouth of a low topographic channel extending to the northeast. Even the 500 foot contours in the Valley itself, as seen in Figure 1, extend to the north-northeast. This Valley is part of the first broad channel extending through the western end of the Brooks Range, accounting for Ogotoruk Valley having stronger northerly winds than nearby areas as daily comparisons for the past two years have shown. Thus, the appellation "Ogotoruk Wind" should take its place among other famous local winds.

Although Ogotoruk Valley is considered to be a good hunting ground by the Eskimos, few of their villages exist nearby, and with good reason. These high winds, coupled with low winter temperatures, make this area one of the most uncomfortable in the world. As the U. S. Air Force (8) has noted, at low temperatures the wind speed has a decided effect on the rate at which the body cools, and the "windchill" factor, which is a parameter dependent on both wind speed and temperature, is more important to survival than the actual temperature reading. Thus, Verkhoyansk in eastern Siberia with its mean winter temperature of minus 52° F. is more comfortable than Kotzebue, as Verkhoyansk experiences calms 88% of the time during the winter months; and the average monthly winds at Kotzebue seem light in comparison with the averages from Ogotoruk, as Table 1 shows.

Table 2 shows that this northerly flow has been predominant in the colder months of the year and that its percentage frequency decreases only slightly in favor of southerly flow from May through August.

This southerly flow is not only greater percentage-wise in the summer, but a reference to Table 1 shows that the average speeds are greatly decreased and closer to Kotzebue's. This weaker southerly flow is associated with the weaker summer circulation patterns.

In the summer of 1960, several recording wind instruments were placed at several stations at tussock level. The directions were in general agreement with those observed at the base camp wind tower at an elevation of 20 feet, but were considerably less in speed because of the effect of ground friction. In the summer of 1961, the recording instruments were placed on 15 foot towers and placed in other locations in the Valley at A34.7, A34.9, A34.12, and A34.14 as mentioned previously. No significant difference in direction or speed was evident in the readings from these stations from May through September.

One interesting, but not unusual, pattern noticed during the summer months of 1961 was the day and night reversal of directions, especially when light winds or little pressure gradient were over the region. From April through August, 450 observations were made from the four wind towers. At 0100 BST, 58% of the wind directions were from northwest through northeast and 29% from southeast through southwest. At 1600 BST, only 32% were from the northerly directions and 45% were from the southerly directions. This is sometimes called the land-sea breeze effect, or the drainage wind in hilly or mountainous areas. During the day, the land heats up more than the water and the colder denser air over the water pushes inland. At night, the land loses heat by radiation faster than the water and the overlying air becomes colder and thus heavier than that over the water and this colder air flow moves down the Valley and toward the sea. This effect was not noticed at the base camp station A34.0 during the colder months of the year because the large scale pressure gradients and wind fields were so much stronger than the land-sea breeze effect.

V. Precipitation

Northwestern Alaska is considered to have a semi-maritime climate. Excessive amounts of precipitation typical of a maritime climate do not occur when the Arctic Ocean is frozen because of the low amount of precipitable water vapor possible in extremely cold air, slower evaporation into the air over ice, and the paths of the storms are close to this part of the state only in the summer months. Thus, as Figure 2 shows, the maximum precipitation has been noted in July and August at Kotzebue and a much greater maximum in August and September at Cape Lisburne. The greatest annual total is considered to be at Cape Lisburne and the present average is 15.68 inches. Eastward from Cape Lisburne, totals of 4 to 10 inches of liquid precipitation are considered normal. Southward, the totals decrease to Kotzebue's thirty year normal of 8.02 inches. A seven year record from Point Hope averages out to 10.21 inches. Kotzebue's average for the same period was 9.77 inches, indicating little difference in annual totals along this part of the coast. Thus, an annual total very near or just slightly above Kotzebue's 8.02 inches should be "normal" for Ogotoruk Valley over the long run, with a statistical range from 4 to 16 inches.

The variability of liquid precipitation makes it difficult to estimate mean monthly amounts. For instance, Ogotoruk had .50 inches in September 1959, 1.58 inches in September 1960, and 4.80 inches in September 1961. Cape Lisburne had .12 inches in July 1960, and 3.51 inches in August 1960. However, certain seasonal differences are explainable when the causes of the variability are considered.

This variability in liquid precipitation is related to the variability of the circulation patterns; northwestern Alaska is on the outer fringe of the main storm tracks to the south during the colder months of the year and in between the main tracks in the summer months. The station which is nearest to a storm's precipitation center as it passes will usually have the greatest totals. This occurs mainly during the summer months from June through September, as the larger totals from Kotzebue and Cape Lisburne demonstrate.

The normal for Kotzebue from June through September is 4.91 inches and the average for Cape Lisburne, based on only about five recent years of record, is 10.71 inches, as shown in Table 3. These totals would seem to indicate that Cape Lisburne's probability of being nearer a storm's center is greater than Kotzebue's. A favored summer storm track of the low-pressure areas is along the northern shoreline of Siberia and Alaska. Another storm track originates north of Japan, follows the southeastern shoreline of Siberia through the Bering Straits

and then crosses over into Alaska. Several storms following this latter track were observed in both September 1960 and 1961 and penetrated inland in the vicinity of Ogotoruk and Cape Lisburne and then followed the northern coastline north of the Brooks Range. These storms dumped over an inch of rain each on both Ogotoruk and Cape Lisburne. However, it is questionable whether this is a frequent source of heavy precipitation as the average for Kotzebue from 1945-52 for these months was 6.33 inches compared to 4.54 inches for Point Hope. In 1960, Cape Lisburne had the highest summer totals with 7.68 inches, then Kotzebue with 7.57 inches and then Ogotoruk with 6.34 inches. The summer totals for 1961 indicated that Ogotoruk had a very wet season with 11.04 inches, Cape Lisburne had 11.24 inches, and Kotzebue only 4.49 inches.

Differences in the summer precipitation totals in Ogotoruk Valley itself for 1960 and 1961 have been analyzed on maps (Figures 3 and 4). Lines of equal rainfall (Isohyets) were drawn and both seasons were quite similar in pattern and show that the greater amounts of precipitation have been recorded inland away from the sea and close to the hilltops. Two main factors contribute toward this: orographic lifting of the air and the wind-shadow effect. Orographic effect is more noticeable over large mountain ranges, such as the Sierras in the western United States which have unusually large amounts of precipitation on the windward or western side and desert conditions just east of the mountains. As air is lifted over a mountain barrier, it is cooled adiabatically and can hold less water vapor. The excess water is precipitated out. Although the sides of Ogotoruk Valley cannot be considered mountains as such, they are high enough to give to a strong horizontal flow of moist air enough orographic lift to increase its precipitation on the windward side. A southeasterly flow in a typical rain situation would increase totals orographically on the western side of Ogotoruk Valley. The same flow would increase totals on the eastern side of the Valley due to the "wind-shadow" effect. Geiger (5) describes this effect as increasing totals on the lee side of hills. Precipitation is carried by stronger winds over the top of the hill and dumped in the wind-shadow, which is an area behind the hill having weak irregular air movements.

Isohyets of precipitation totals covering individual storms of one, two, or four day duration gave varying patterns which seemed to depend on the dominant direction and speed of the wind during the time of precipitation. Precipitation has occurred most frequently with a flow from the southeast. Hence, over a three months summer period, it is felt that there is enough regularity or similarity of summer storm situations that the precipitation pattern should resemble those shown in Figures 3 and 4.

The bar graph in Figure 2 shows a secondary maximum for Cape Lisburne in November. This minor secondary maximum is noted all along the northern Alaskan coast during the fall months. The additional snowfall results from the passage of cold winds over relatively warm open water, thus increasing the instability of the air. This phenomenon is referred to as "lee-shore" snowfall and is common downwind from the Great Lakes in the fall also. Point Hope evidently gets more of this lee-shore snowfall as its seven year average from October through December is almost double that of Kotzebue's. This effect is hardly noticeable in Kotzebue's normal figures for these months and does not seem to have affected Ogotoruk's small totals in 1960 and 1961.

Ogotoruk and Kotzebue may not share in this lee-shore snowfall because of the stabilizing influence of the cold air channeled from the northeastern land areas around the western end of the Brooks Range creating the "Ogotoruk Wind." The average totals for Cape Lisburne and Point Hope from January through May were not quite as much higher than Ogotoruk's and Kotzebue's as from October through December, and the monthly amounts were very small.

Meaningful precipitation totals in winter are difficult to obtain in this part of the world because a certain amount of fallen snow is always drifted into the measuring gauge. Also some stations are unable to melt the collected snow and they estimate one-tenth the amount of the measured snow depth in the gauge as the liquid equivalent. This introduces an error because snow density varies. More meaningful winter data are accumulated snow depths.

A large deviation from any monthly normal snowfall is the usual occurrence, as shown in Figure 5. The two seasonal totals for Ogotoruk Valley have been less than half of the normals for Kotzebue and Cape Lisburne. The sporadic five year average from Point Hope was just a little over half of Cape Lisburne's somewhat longer mean. These figures indicate more clearly than the liquid precipitation values how these snowfall totals have been depressed in the area between Cape Lisburne and Kotzebue by the "Ogotoruk Wind."

Two and one-half years of monthly maximum snow depths are shown in Table 4. The striking feature is the small accumulation at the main weather station A34.0 in Ogotoruk Valley and attests to the strength of the "Ogotoruk Wind," which blows considerable amounts of snow out to sea. The maximum depths reached were 8 inches in April 1960 and 6 inches in April 1961. The lee-shore snowfall accumulations in Ogotoruk Valley decreased from 4 inches in October 1960 to 2 inches in December, and from 7 inches in November 1961 to 3.5 inches in December. This lesser accumulation of snow in the main part of the Valley outside of depressions is felt to be a normal condition and is attributed to the strong northerly winds.

However, depths up-valley along the creek bed and its tributaries were near six feet and in some depressions the snow was deeper.

In summary, the highest precipitation totals occur from June through September and may be expected at Cape Lisburne because the station benefits from nearby high ground and because it is more frequently near the precipitation centers for the northern storm track; Kotzebue normally should have more precipitation than Ogotoruk -- however, unusual years such as 1961 would raise Ogotoruk's average somewhat. The stabilizing influence brought from the northeast by the "Ogotoruk Wind" depresses precipitation totals in Ogotoruk Valley from October through May. These monthly totals are much smaller than those during the summer months. Kotzebue should have greater precipitation than Ogotoruk during this period. The greatest total of all should still be at Cape Lisburne however.

VI. Humidity

Relative humidity measurements have been made at the base camp station A34.0 throughout the year 1961 and the monthly mean from the daily average of the three or seven airway observations computed. This monthly mean humidity has been over 80% for all months of the year except February and April 1961 when 76% for both months was computed. These were daytime observations when the humidity is normally somewhat lower than at night. The high humidity is attributed mainly to the nearness of the ocean although the swamp-like characteristics of the Valleys when not frozen, and the snow and ice surfaces at other times, contribute water vapor. The other coastal stations of Kotzebue and Barrow show similar high readings, especially during the summer months, with Barrow's normal readings being the highest. The highest readings at Barrow may be more of an indication of the latitudinal temperature gradient existing, as relative humidity decreases as temperature increases, and we may assume the absolute humidity tends to be uniform over the Arctic Ocean in this region.

Readings of the daily maximum and minimum relative humidities were obtained both summers of 1960 and 1961 at stations A34.0 and A34.12, and also at A34.7 in 1961. From June through September 1961, the maximum reading every day at all three stations was 100%. Except for a few instances, the same statement could be made for the summer of 1960, which was a less rainy and cloudy season. A comparison of the monthly mean of the minimum daily relative humidities in Table 6 shows that lower readings occur further inland. The same amount of moisture probably prevails in the air so this gradient is related to the fact that the air becomes warmer inland during the day.

VII. Cloudiness

Most of Alaska is very cloudy all times of the year, but more so in the summer and fall months. Coastal areas are generally more cloudy and foggy than inland areas.

Table 7 shows the mean monthly sky cover percentages for Ogotoruk Valley for the years 1960 and 1961 from sunrise to sunset averaged from three to seven observations a day. Also shown are the normal monthly values (averaged hourly) for Kotzebue and Barrow, which are coastal stations; Umiat, which is 75 miles inland; and Fairbanks, which is in the interior of Alaska. Comparing these normals, it is seen that Barrow and Umiat are less cloudy in the winter and more cloudy in the summer than Kotzebue, and that Kotzebue is just slightly cloudier than inland Fairbanks in the summer. It must be remembered that sky cover includes obscuration of sky in official Weather Bureau terminology, and this includes blowing snow and fog. Furthermore, it is based on an individual's subjective estimate of the sky cover. The type of sky cover is not broken down into height or type of cloud. However, in a general way, it suggests that it is a little less cloudy away from the coastal areas in the summer months and does show that there is an abundance of cloud cover in northwestern Alaska during the months when the Arctic Ocean is not frozen.

In Ogotoruk Valley, summer differences in fog and low stratus amounts would be discernible if simultaneous observations were made throughout the day in various locations in the Valley. The weather observer on his daily morning tour of the station network always radioed in to the base camp when the fog lifted upvalley. This would enable the pilot to take off in fog in the base camp and assure him that he would have landmarks when flying back to Kotzebue. It is the observer's subjective opinion that on most mornings when the fog was in the base camp, it extended inland just up to station A34.8 in general. The fact that the mean relative humidity was less and the mean maximum temperature greater at A34.12 than at A34.0 would seem to bear this out.

VIII. Solar Radiation

Figure 6 compares an average of the pyrliograph readings taken in Ogotoruk Valley during the year 1961 with a three year average from Barrow and a fifteen year mean from Fairbanks. From October until the end of May, it seems that the curve for Ogotoruk should fall between that of Fairbanks and Barrow and be more dependent on total possible amount of sunshine, which is a function of latitude, since all three stations have roughly the same kind of snow and ice climate during this time of year. The high figures in April, May, and June are apparent rather than real and are a result of what Geiger (5, page 164) calls the "light climate" effect. Snow cover has a very high "albedo" and reflects most of the incoming solar radiation. The pyrliograph measures this reflected radiation again as it is scattered back to earth a second time.

However, after the ice break-up and thaw, greater cloudiness prevails along the coastal areas, and thus Barrow's and Ogotoruk's solar radiation would be expected to be less than inland Fairbanks'. Since the ice break-up occurs about two to four weeks earlier in the Ogotoruk Valley area, its peak readings would drop off sooner than Barrow's. The summer readings appear to correlate closely with the average monthly cloudiness, as expected.

The amount of radiation received from the "midnight" sun during its 54-day reign is very low between the hours of 2000 and 0400 and is not recorded on the pyrliographs used on this project. The effective amount of solar radiation received anywhere on the earth's surface depends on the angle of elevation of the sun with the horizon. At lower angles, the sun's rays are spread over a greater area and have to penetrate over twice as much of the earth's atmosphere and hence more of its radiation is absorbed before reaching the earth's surface.

According to Geiger (5) "the amount of radiation received from the sun depends on the time of day, the season, the degree of cloudiness, the direction of the slope, and the angle of the slope." Geiger further states that in the far north, differences in the direction of the slope have little effect on a plant's exposure since practically all of the solar radiation during the summer growing season is diffuse rather than direct because of the heavy cloud cover. Thus, microclimatic differences in northern or southern-facing slopes would be very small and, in the case of Ogotoruk Valley, too small to be measured.

Table 8 shows the differences in the average monthly totals at the four locations in Ogotoruk Valley that were instrumented with pyrhelio-graphs. Two of the stations with comparable readings the previous year averaged 234 and 246 Langleys per day for the month of August 1961 compared to 330 and 302, respectively, for the month of August 1960. The monthly cloud cover for August 1961 was 82% compared to 68% in August 1960, showing how sensitive radiation received at the surface is to increased sky cover.

During the summer of 1961, stations A34.0 and A34.12 had very close monthly averages and varied together. Stations A34.7 and A34.14 also followed each other closely. Since the differences in angle and direction of their respective slopes are minor, and their horizons low enough so that major differences in their sunrises and sunsets do not occur, the only explanation for these differences is random cloud or fog cover. It seemed that Crowbill Mountain, A34.14, was almost always obscured by fog or low stratus, especially in the early morning and evening. Also Station A34.7 possibly was covered more from stratus drifting from the hills to the southeast of the station and thus varied similarly.

IX. Air Temperature

In summer, a maritime climate prevails in northwestern Alaska, and is typified by lower maximum temperatures than inland areas because of the modifying effect of the cool Arctic waters. After the ice break-up, usually starting in late May in the Ogotoruk Valley area, the water temperature of the surface layer rises from freezing to only the low fifties by the end of July and then gradually cools down to about 25° F. before the first freeze, usually in late October. Thus, the highest ever recorded at Kotzebue has been only 82° F. in July 1946, while further inland at Shungnak 90° F. is their all-time maximum recorded in July 1916. Along the north coast, Cape Lisburne's high so far has been only 72° F. while Barrow, with its longer record, had a 78 in 1927. Umiat, 75 miles inland, has had 85° F. in its short period of record, and temperatures about 80° F. have not been uncommon. Thus, it seems that the highest probable that would be reached in Ogotoruk Valley in a standard Weather Bureau shelter at a height of about 120 cm. would be 80° F.

In winter, the adjoining coastal areas experience lower temperatures than would ever appear in a truly maritime climate where an open body of water exists, although some heat does appear to escape through the vast ice layer covering the Arctic Ocean. Features of a continental-type climate are shown which, in this part of the world, is characterized by extreme cooling of the air by uninterrupted terrestrial radiation during the long periods of darkness. The lowest ever recorded at Kotzebue was minus 48° F. and the lowest at Cape Lisburne, a minus 47° during its shorter period of record. The coastal area of Kotzebue Sound has less severe cold than the areas north of the Brooks Range. The lowest ever recorded at Point Barrow was minus 56° F. and further inland, at Umiat, minus 63° F. The lowest recorded so far at Ogotoruk was minus 45° F. in March 1961, but it seems probable that a minus 52° could be recorded some day.

Two years of monthly deviations from Kotzebue's normal maximum and minimum figures are also shown in Table 10 for Kotzebue, Ogotoruk Valley, and Cape Lisburne. Nothing unexpected appears in the deviations from the maximum temperatures. The annual deviations for 1960 show 1.9° F. for Kotzebue, minus 2.4° for Ogotoruk, and minus 5.6° for Cape Lisburne; for 1961, these are minus 1.2° for Kotzebue, minus 2.9° for Ogotoruk, and minus 6.0° for Cape Lisburne. The monthly exceptions to this pattern are February 1960 when Ogotoruk was warmest, October 1960 when Ogotoruk was coldest, and October and November 1961 when Cape Lisburne was the warmest and Kotzebue the coldest. The lee-shore snow-fall effect accounted for these temperature aberrations, as the heat of condensation of the snow warmed the surface air temperatures.

The annual deviations from the minimum temperatures were 2.4° F. at Kotzebue, minus 1.0° at Cape Lisburne, and minus 2.4° at Ogotoruk in 1960; and were minus 1.1° at Kotzebue, minus 1.5° at Cape Lisburne, and minus 3.3° at Ogotoruk in 1961. Kotzebue's monthly figures were colder than Ogotoruk's only three months in 24, while Cape Lisburne's were lower nine months in 24. Two factors may account for Ogotoruk having the lowest minimum temperatures. During the summer months, the nighttime drainage winds brought colder inland air into the Ogotoruk Valley. This air had been cooled more by nighttime loss of radiation because it is relatively drier inland. Kotzebue and Cape Lisburne are exposed more frequently to air with water trajectories and neither is in a pronounced drainage basin. In the fall and winter months, Ogotoruk's normal drainage was greatly reinforced by extremely cold air being channeled around the western end of the Brooks Range and undoubtedly Ogotoruk Valley came under this air without the benefit of modification by water or ice trajectory.

In view of the above comparisons, it would seem that the normal maximum monthly temperatures of Ogotoruk Valley would run about 2 to 3 degrees F. below those of Kotzebue and the minimum about 2½ to 3½ degrees below, with seasonal deviations from these differences being due to the factors mentioned above.

Differences in air temperatures within Ogotoruk Valley itself have been noted. Table 10 shows the mean monthly deviations at A34.7 and A34.12 from the base camp readings at A34.0 for the summer months of 1960 and 1961. The mean maximum temperature deviations seem to be an inverse function of the average monthly cloud cover when 1960 is compared to 1961. Thus, 1961 differences were minimized because of the greater cloud cover. The effect of the cold Arctic Ocean water in depressing the temperature at the base camp was again noticed in May and June 1961, while its warming influence was also noticed in July, August, and September, similar to 1960, as the surface temperature of the water rapidly warmed up to the low fifties in July.

X. Soil and Near-Surface Temperatures

We are greatly indebted to Geiger (5) for much of our knowledge and reasoning regarding soil and near-surface temperature phenomena. Figure 7, adapted from Geiger (page 140) shows three soil temperature profiles measured over a dry three day period in August 1893 by Thomas Homen in Finland for a swamp, dry sandy soil, and rocky soil. Readings from Ogotoruk in August 1960 during a dry period plotted in a similar manner in Figure 8 definitely place the Valley in the category of a swamp, except the profile for Ogotoruk is about 15-20 degrees F. colder. Figures 9 through 22 show that, in general, the same profile is evident for all the stations in Ogotoruk Valley.

Figure 7 also highlights different characteristics of these three soil types. Rocky granite soil has good heat storage characteristics--the maximum occurs on the surface and the daily heating penetrates deeply into the rock. At night, a good deal of heat is passed out from within which accounts for the high level of temperatures in the rock at night, higher even than that of the air temperature at 120 cm. height. Thus, dry rocky soil would have higher minimum soil temperatures.

Dry sandy soil heats up to an extraordinary degree at the surface level, but the temperature decreases very rapidly both upward and downward. It has much lower heat conductivity on account of the air spaces between the sand grains and thus a day's heat does not penetrate as deeply as in granite rock.

In the damp moor (swamp), the maximum temperature is above the surface at about 5 cm. as the surface temperature is cooled by evaporation and absorption of heat by the vegetation. The temperature drops so rapidly just beneath the surface that the daily range at 5 cm. below the surface is as insignificant as at a depth of 45 cm. in rock. At 25 cm. below the surface, the range has disappeared entirely. During the night, the moor shows the lowest temperature of any, with the minimum also occurring at about 5 cm. above the surface. The extreme daily variation of temperature and its low thermal conductivity are properties of the moor despite its high water content. Figure 8 also lists the thermal conductivity and diffusivity for various substances of meteorological interest and shows that peaty soil is very near the bottom of the list for thermal conductivity. A soil analysis conducted by the University of Ohio (6) shows that most of Ogotoruk Valley is overlaid with at least a foot of peat. Thus, Ogotoruk's similarity with Homen's marsh temperatures is not surprising.

Figure 9 shows the mean monthly maximum and minimum figures of all stations in Ogotoruk Valley plotted in a manner similar to Figure 7. As no surface measurements were made, the lines were drawn straight from 5 cm. above to 5 cm. below the surface. Homen's profiles showed little deviation from a straight line for the swamp readings. It is possible that in rocky or any dry sandy areas in Ogotoruk Valley, the maximum temperature readings would show higher than the 5 cm. reading above the surface.

Certain facts about the mean profiles in Figure 9 stand out. In April and May, the maximum temperatures were at 50 cm.; while in June, July, and August, the maximums were at 5 cm. above the surface. In April, the minimum was at shelter (120 cm.) level while in May, June, July, and August, the minimums were at 50 cm. below the surface with a secondary minimum at 5 cm. above the surface. The greatest amount of increase in both the soil and surface temperatures occurred between the April and May mean figures and this rate of increase decreased as the summer progressed. This great increase was due to the snowmelt effect; as the surface and to a lesser extent the deeper soil temperatures follow closely the temperatures of snowmelt and rainwater (5). The range between the maximum and minimum temperatures was greatest in April and became smaller as the summer progressed, especially at 10 cm. and below. This was because ice has better thermal conductivity than water and the ground thawed more as summer progressed.

The time lag in heat penetration to deeper depths is evident even on the monthly figures from May through August while in April, the profile was almost straight up and down. In the winter months, over bare ground, the profile would tilt to the left, indicative of colder temperatures nearer the surface. This time lag is evident even on the daily readings when a large temperature increase appears for several days and it has been noticed that it takes from 18 to 36 hours for the increase to penetrate down to 50 cm. in the soil. This time lag cannot be measured precisely from daily readings and for the purposes of this study, the maximum amount of heat conduction into the soil was investigated more fully than the daily time rate of conduction.

Thermal diffusivities were computed from these monthly all-station average figures and gave fairly consistent results only for the soil layer between 5 and 10 cm. The standard formula using the amplitude decrement with depth gave figures of .0029, .0014, .0013, .0023, and .0019 for the months of April through August 1961. For comparison, Geiger (5) gives a figure of .0018 for peaty soil. The results became too inconsistent and meaningless at lower depths because the temperature

ranges were too small in relation to the one degree of accuracy to which the thermometers were read. Non-uniformity of the soil could be another reason for these inconsistent readings. Different types of compaction in the peat layer, and the change-over into the clayish soil could cause this. Some of the individual temperature profiles showed warmer temperatures at 20 cm. depth than 10 cm. and was undoubtedly a result of these factors. Figure 8 gives values of thermal diffusivities for several materials of meteorological interest and also the relation between thermal conductivity and diffusivity. Several writers have cautioned against the computation of thermal diffusivities of natural soils because of their limited use in explaining the heat balance. Thus, a more rigorous treatment was not made.

Thus, the characteristics of summer soil temperatures in Ogotoruk Valley have been examined in general and deviations from the average monthly profiles in Figure 9 should show little variation from year to year. It is conceivable that a late thaw could make May's mean figures resemble April's a little more, and a dry warmer August could move the maximum soil temperature lines a little more to the right, especially near the surface. However, it is questionable whether Ogotoruk Valley ever dries out to such an extent as inland, better-drained areas, such as Umiat, described by Conover (2) "when the cool easterlies weaken or cease, temperatures rise rapidly, sometimes exceeding 80° F. at shelter level...then tundra surface temperatures may reach 105°F." The highest near-surface temperature recorded during 1960 and 1961 was 86° F. at 5 cm. in August 1960 at station A34.5 after a five day dry spell.

Geographic differences in Ogotoruk Valley cause differences in soil temperatures. To explain these with respect to location, a closer look at each station's environment is necessary. From a geographic standpoint, four different temperature regimes appeared in July 1961 in the Ogotoruk Valley area: (1) the rocky outcropping (dryas fellfield) of the hilltop areas, (2) the grassy and tussock meadowland, (3) the black rocky creek bed, and (4) the level shelf or overflow area bordering the creek bed, which is called the gravel bar or bench community.

(1) The tops of the hills which border the valley are the remains of eroded mountains of the Brooks Range which were formed by upheaval and which slope into the ocean. For the most part, they are composed of small pieces of grayish rock with small amounts of moss between them. Two stations, A34.1 and A34.10, were in this regime. A34.1 was within fifty feet of the top of one of the eastern range of hills and although the angle of incline was only seven degrees in the vicinity of the station, the surrounding land appeared to have at least a thirty degree

downhill slope. Mosses and lichens were widely scattered among the small rocks over the temperature probes, and grass-like sedge began about 300 feet downhill. Station A34.10 was further inland and on the opposite side of the Valley. Here, the soil was also very rocky in general with mosses and lichens interspersed. The station was at the base of a very steep rise toward the top of the hill, and sloped downhill at a 21° angle, and the grassy vegetation began about 300 feet downhill. It would have been preferable if the thermometers had been placed ten feet further downhill, away from the base of the steep rise.

(2) The second regime was the grass-like sedge and tussock areas of the Valley, which started about one-third of the way down from the crest of the hills, where the angle of incline decreased enough for this grassy vegetation to get a root-hold. This regime extended to the bench and bar area of the creek and the sedge and tussocks presented a dull greenish tan color. The soil was a mixture of peat and clay, with a varying amount of small rocks mixed in. Station A34.0 was in a level grassy area about 200 feet west of the base camp towards Crowbill Mountain. Station A34.2 was in a muddy area between large tussocks and the surrounding area was very level. A34.4 was very similar, but the ground appeared softer and mushier. A34.5 was composed mostly of grasses with a little moss in between and overlooked the Valley. It had an angle of inclination of nine degrees, and the rocky outcropping of the hill started about 200 feet up the hill. Station A34.6 was almost at the top of a grassy meadow extending downward about two miles to the creek, and the rocky outcropping of the hill began about 150 feet further up the hill. Moss grew between the grasses and the ground was soft. Considerable black rock occurred above the thermometers, probably from overturning the earth when installation was made. Station A34.7 was in a grassy meadow area with some moss between the grasses. The ground was extremely soft and mushy. Station A34.9 was similar to A34.6 and A34.7; grass and moss grew over the thermometers and the ground was very mushy between the large tussocks. Station A34.12 was about thirty feet from one of the ponds and about four feet above the water level. The thermometers were installed at the edge of a tussock and the grass grew over them. Station A34.15 was installed in clayish-type mud between large mossy tussocks. Several rocky outcroppings (dryas fellfield areas) appeared within 100 feet of the station.

(3) A third temperature regime was the creek bed itself, which was composed of black rock varying in size from sand particles to rocks six inches across. No microclimate stations were located in this regime, as it was under water in the early spring and under heavy accumulated

snow most of the winter. It is mentioned because this exposed black rock can absorb greater amounts of heat which can result in greater warming of the air along the sides of the creek. Upvalley, near Station A34.11, it was only about thirty feet across and widened to about 125 feet near the ocean. Several small tributaries fed into the main creek and some, although only ten to twenty feet across, had steep dropoffs. After the spring flood stage, most of this creek bed is exposed, with the water confined to narrow channels on either side of the bed and only about twenty feet across at the maximum.

(4) The fourth temperature regime consisted of level spots called benches which varied in width from 20 to 200 feet and were located along either side of and about three feet above the creek bed and before the land rose noticeably. The vegetation here was mostly mosses and scrub willows one to four feet high. Station A34.3 was fifteen feet from the black rocky creek bed and a low hill began fifty feet to the east. Scrub willows about one foot high with mosses between them dominated the area. Black dirt was exposed over the immediate area of the thermometers. Further upcreek was station A34.8, which was about fifty feet from the black rocky creek bed, and had a low hill rising about 200 feet to the east. The ground was very soft and the same type of vegetation existed. Furtherest upcreek was Station A34.11 which appeared more sheltered from any cooling effects of a north wind, as it was located near the rocky creek bed in a narrow east-to-west valley, and higher hills began much closer than they did at the downcreek stations.

The temperature profiles of the stations in the rocky outcroppings, stations A34.1 and A34.10, showed marked similarity during the summer of 1961, as seen in Figures 10 and 11. In April and May, there was a lesser range of temperature to 5 cm. above the surface at A34.10 due to the heavy snow accumulation over its thermometers. More rock existed in the soil at A34.10 as the temperature range after May did not become negligible until down to 20 cm. below the surface whereas it became negligible at 10 cm. at A34.1. Comparable readings from August 1960 showed larger temperature ranges at 5 cm. above the surface, indicative of drier conditions. These larger ranges also demonstrated the insulating properties of the mosses and lichens and also indicated considerable peat and decayed matter in the soil in spite of the rockier surface cover at these two stations.

The effect of altitude in the Valley was noticed in the near-surface temperatures of these stations, and also those of stations A34.5 and A34.6 (Figures 18 and 19), all four of which were between 300 and 400

feet and near the top of the hills which overlooked the Valley. The temperatures at 50 and 5 cm. were generally within one degree F. of each other and there was slightly less range between their maximum and minimum temperatures: their maximums were a little less and their minimums a little higher than the average of all the stations. This agrees with Geiger's contention that "the greatest temperature extremes are found in the lower parts of a valley."

Differences between the three stations in the gravel bar and bench communities, A34.3, A34.8, and A34.11 (Figures 12, 13, and 14), and the other stations were not as pronounced as would be expected, and were undoubtedly due to the equalizing effect of the peat layer. However, below this layer, there was more rock or sand as the mean soil temperatures at 50 cm. were all about 35° F. in August and this indicated greater heat conduction from the upper layers. In addition, more rock and sand was indicated in the upper layers at A34.3 as its soil temperature range did not become negligible until down to 20 cm. Its near-surface air temperatures were also 5 degrees above the average. This was due partly to its proximity to the black rock of the creek bed and also to the greater amount of radiation received from being in the bottom of the Valley and away from the immediate effects of the ocean.

The temperature profiles of the balance of the stations are shown in Figures 15-23. The striking feature of five out of the remaining nine stations in the meadowland regime of the Valley was that their mean soil temperatures at 50 cm. still hovered near the freezing mark during August of both years 1960 and 1961. In addition, these stations, A34.0, A34.5, A34.7, A34.9, and A34.12, were all in or, in the case of A34.12, near the "wet meadow" area (*Eriophorum-Carex* wet meadow), as shown on the map entitled "Key to Vegetation Types" (10). Figure 24 is a map of the Valley with an isotherm analysis showing the August 1961 mean soil temperatures at 50 cm. more clearly. Whether these cold areas are an indication of shallow root structure or a thicker peat layer or both has not been determined, but, in these areas, there does seem to be a heavier insulating layer. Stations A34.12 and A34.9 had fairly large temperature ranges at the 5 cm. soil level while A34.7 had a negligible range at this shallow level. Otherwise, the differences were very minor and probably due more to variable incoming solar radiation, or coastal or altitude effects.

The remaining four stations, A34.3, A34.4, A34.6, and A34.15, had their thermometers in "mud" areas between large tussocks (*Eriophorum* tussock). This "mud" had a sponge-like feel underfoot between the

tussocks and possibly was an indication of loose compaction in this type of soil. The range of maximum and minimum temperatures of over one degree F. below 20 cm. depth and the above-average temperatures at the 50 cm. depth were a more definite indication of this loose compaction between the tussocks.

In summary, let us review some concepts about a valley's temperature distribution and see how the readings taken in Ogoturuk Valley agreed. Throughout his book, Geiger has said that the extreme temperatures are found in the bottom of a valley and more moderate temperatures on hill or mountain tops. Isotherm analyses of the mean maximum temperatures have shown that the warmer spots are in the center of the Valley and, by the middle and end of summer, nearer the relatively warm ocean. The mean minimum temperatures have tended to be also in the center of the Valley, but, in late summer, displaced further upvalley away from the warming effects of the ocean. Figure 25 shows that at 5 cm. above the surface at A34.6 and A34.7, an area appeared that was colder than can be accounted for merely by altitude. As the pyrlieliograph measured lesser amounts of radiation at A34.7, it is possible that fog hangs on longer in this large "wet meadow" area or that more stratus drifts over these stations from the nearby hills. The radiation that penetrated through to the surface turned A34.6 into a "warm" spot at a depth of 50 cm. as shown in Figure 24 because, as mentioned before, there was more rock in the soil near the top of the hills than in the meadowland. However, the peat or decayed matter that formed most of the soil in Ogoturuk Valley was seen to be an excellent insulator in maintaining the permafrost at a relatively shallow depth throughout the summer and excessive radiation either at the surface or in the soil will hardly ever be encountered in Ogoturuk Valley.

During the winter of 1960-61, about twelve readings were taken throughout the station network at an interval of about every two weeks. In general, the extreme low temperatures were closest to the surface, with temperatures 5 to 10 degrees F. warmer at 50 cm. below the surface. Temperature variations nearer the surface varied with the amount of snow cover which provided good insulation when present.

XI. Summary

Two years of study have shown that Ogotoruk Valley has unique topographic features which cause marked variations in its climate when compared to Kotzebue and Cape Lisburne. It is the mouth of a low topographic channel extending to the northeast and is part of the first channel around the western end of the Brooks Range through which strong northerly winds predominate most of the year. This strong stable flow of air depresses precipitation totals in the colder months and the frequent northerly gale force winds prevent heavy snow accumulation in the Valley, besides lowering the mean temperatures somewhat. Thus, normal precipitation totals are lower in Ogotoruk Valley than at Cape Lisburne, but still a little higher than at Kotzebue. The mean maximum temperatures run about $2\frac{1}{2}$ degrees F. below those of Kotzebue and the mean minimum temperatures about $3\frac{1}{2}$ degrees lower. Because of the nearness of the ocean, the extreme minimum temperature at shelter height should never be lower than minus 52 degrees F. while the extreme maximum should never exceed 80 degrees F.

A study of the microclimate within the Valley up to seven miles inland has shown that marked summer differences exist. Precipitation is heavier along the tops of the hills and away from the ocean. Air temperatures, and to a lesser extent, soil temperatures, are depressed more in May and June closer to the cool ocean; while in late summer near the relatively warm ocean, the minimum temperatures are somewhat higher than inland.

The temperature extremes occur in the lower parts of the Valley aside from the effects of the ocean. The temperature ranges are less near the rocky hilltops. The peat layer covering most of the Valley and even parts of the hilltops sometimes over a foot thick is an excellent insulator and has maintained the permafrost at shallow levels. This permafrost existed close to a depth of 50 cm. even in August in wet meadow areas where sedge was the dominant vegetation. Near the creek bed and the tops of the hills because of more rock in the soil, and in tussock areas because of looser compaction between the tussocks, the permafrost started deeper.

Fig. 1. Station network in Ogotoruk Valley. Stipled areas indicate elevations above 500 feet, shaded areas above 800 feet.

Fig. 2. Monthly Precipitation Totals (Liquid) in inches.

Fig. 3. Precipitation Totals in Ogotoruk Valley during June, July and August 1960.

Fig. 4. Precipitation Totals in Ogotoruk Valley during June, July and August 1961.

Cape Lisburne Average
 4.8 9.7 8.8 4.1 5.6 6.2 4.6 4.9 1.6 52.1

Point Hope 5-year Average
 1.2 6.3 4.1 3.2 4.0 2.6 1.9 2.3 3.2 29.5

Kotzebue
 1959-60 .0 1.9 2.7 3.9 6.7 5.7 Trace 5.5 2.2 29.3
 1960-1 5.4 4.3 11.6 8.9 3.2 1.2 3.6 14.9 0.4 53.8
 1961 0.0 7.9 7.2 5.6

Ogotoruk
 1959-60 Tra 5.0 7.5 Trace 2.8 1.9 0.5 2.9 2.0 22.6
 1960-1 3.2 6.6 1.5 0.5 1.6 0.0 2.0 5.5 1.3 22.2
 1961 Trace 1.8 3.8 2.1

Cape Lisburne
 1959-60 - - - - 5.0 7.1 2.1 3.7 3.0
 1960-1 4.7 9.2 4.3 9.3 4.1 Trace 0.2 3.6 2.3 37.7
 1961 Trace 8.1 11.7 5.5

Fig. 5. Snowfall Comparisons and Records (Inches of Snowfall).

* - derived from (2)

Fairbanks $64^{\circ}49'$ N. $147^{\circ}52'$ W. Elevation 454 feet.

Pt. Barrow $71^{\circ}18'$ N. $156^{\circ}47'$ W. Elevation 13 feet.

Ogotoruk $68^{\circ}06'$ N. $165^{\circ}46'$ W. Elevation 30 feet.

Fig. 6. Average Daily Insolation in Langleys on a Horizontal Surface from April to September for the Years Indicated.

Fig. 7. Soil temperature profiles made in Finland by Th. Homen in August 1893 during a clear weather period, adapted from Geiger (5). Average maximum and minimum readings are plotted for swamp, sandy and rocky soil.

Fig. 8. Maximum and minimum temperatures from Station A34.7, August 20, 1960.

Fig. 9. Maximum and minimum averages of 13 stations in Ogotoruk Valley.

Fig. 10. Maximum and minimum temperature profiles at Station A34.1

Fig. 11. Maximum and minimum temperature profiles at Station A34.10

Fig. 12. Maximum and minimum temperature profiles at Station A34.3

Fig. 13. Temperature profiles at Station A34.8

Fig. 14. Maximum and minimum temperature profiles at Station A34.11

Fig. 15. Maximum and minimum temperature profiles at Station A34.0

Fig. 16. Maximum and Minimum temperature profiles at Station A34.2

Fig. 17. Maximum and minimum temperature profiles at Station A34.4

Fig. 18. Maximum and minimum temperature profiles at Station A34.6

Fig. 19. Maximum and minimum temperature profiles at Station A34.5

Fig. 20. Maximum and minimum temperature profiles at Station A34.7

Fig. 21. Maximum and minimum temperature profiles at Station A34.9

Fig. 22. Maximum and minimum temperature profiles at Station A34.12

Fig. 23. Maximum and minimum temperature profiles at Station A34.15

Fig. 24. Mean Maximum Soil Temperatures at 50 cm. for August 1961.

	<u>Ogotoruk 1960</u>	<u>Kotzebue 1960</u>	<u>Ogotoruk 1961</u>	<u>Kotzebue 1961</u>
January	24.3	10.0	21.6	10.6
February	20.9	12.0	23.0	5.3
March	15.4	9.6	19.5	8.4
April	20.3	7.0	19.6	11.5
May	13.1	11.3	12.9	7.7
June	10.7	10.5	11.4	11.5
July	14.6	10.9	12.0	11.6
August	14.9	9.5	12.9	10.3
September	19.2	9.7	14.7	11.7
October	21.9	11.5	16.7	12.2
November	19.9	13.3	18.3	15.3
December	19.7	13.2	18.9	9.1
Annual Average	17.9	10.7	16.8	10.4

Table 1: Monthly Wind Speed Comparison.

Speeds are in knots. Ogotoruk's readings are averages of 3 observations per day, except from April through September 1961 when 7 per day were made. Kotzebue's readings were daily averages of 24 observations.

	<u>NNW</u>	<u>N</u>	<u>NNE</u>	<u>E</u>	<u>ESE</u>	<u>SE</u>	<u>SSE</u>	<u>S</u>	<u>Other</u>
Sept 59	1	17	49	11	0	0	7	10	5
Oct	0	23	48	4	1	1	5	3	15
Nov	1	36	39	10	2	2	0	2	8
Dec	14	48	27	0	0	0	0	0	11
Jan 60	3	62	19	4	2	5	0	0	5
Feb	1	40	10	5	22	10	8	1	3
Mar	11	53	13	0	1	13	1	1	7
Apr	6	58	17	1	6	0	3	1	8
May	2	30	8	1	7	5	3	8	36
June	0	23	0	2	4	11	17	8	35
July	0	41	9	1	11	9	7	7	15
Aug	2	33	14	2	2	10	10	4	23
Sept	4	52	4	10	2	4	3	3	18
Oct	4	60	4	3	8	4	9	3	5
Nov	8	60	10	3	4	3	0	2	10
Dec	2	59	11	6	7	3	3	3	6
Jan 61	3	57	22	4	8	4	0	0	2
Feb	2	89	8	0	0	0	0	0	1
Mar	1	82	11	0	5	0	0	0	1
Apr	0	55	9	6	9	7	4	2	8
May	4	38	17	1	4	13	4	2	17
June	2	24	3	4	16	13	4	5	29
July	5	17	3	3	10	19	7	11	25
Aug	3	41	2	2	1	9	5	11	26
Sept	3	39	4	11	1	14	5	8	15
Oct	2	50	16	9	2	4	2	6	9
Nov	5	35	5	11	7	7	3	0	27
Dec	6	74	5	0	1	5	0	1	8

Table 2: Most Frequent Wind Direction Percentages from Ogotoruk Valley.

Monthly average of 3 or 7 daily observations from A34.0

	<u>Cape Lisb.</u>	<u>Pt. Hope</u>	<u>Ogotoruk</u>	<u>Kotzebue</u>
<u>Present Average</u>	15.68	10.21	10.80	8.02*
<u>1945-52 Average</u>		10.21		9.77
<u>Annual Total</u>				
1960	13.25		8.90	11.93
1961	14.91		12.70	6.54
<u>Jan-May</u>				
Present Average	3.28	2.65	1.15	1.75
1945-52 Average		2.65		1.80
1960 Total	2.38		1.26	1.92
1961 Total	.76		1.04	1.68
<u>June-Sept</u>				
Present Average	10.71		8.69	4.91
1945-52 Average		4.54		6.33
1960 Total	7.68		6.34	7.57
1961 Total	11.24		11.04	4.49
<u>Oct-Dec</u>				
Present Average	3.69		1.26	1.36
1945-52 Average		3.02		1.64
1960 Total	3.19		1.30	2.44
1961 Total	2.91		1.21	.86

* - 30 year normal

Table 3: Average, Normal and Actual Liquid Precipitation at Selected Locations.

<u>1961</u>	<u>Apr</u>	<u>May</u>	<u>June</u>	<u>July</u>	<u>Aug.</u>	<u>Sept</u>	<u>Oct</u>	<u>Totals</u> <u>Apr-Aug</u>
A34.0	.55	.15	1.63	2.90	1.71	4.80	.62	6.94
A34.1	.62	.19	1.59	3.08	1.86	4.97		7.34
A34.2	.60	.23	1.70	3.27	2.00			7.80
A34.3	.57	.24	1.60	3.11	2.06			7.58
A34.4	.60	.25	1.76	3.07	2.09			7.77
A34.5	.65	.28	1.74	3.19	2.00			7.86
A34.6	.77	.18	1.77	3.56	2.05			8.33
A34.7	.80	.17	1.67	3.16	2.15			7.95
A34.8	.64		1.58	3.10	2.25			7.57
A34.9	.67	.19	1.19	3.13	2.27			7.45
A34.10	.90	.24	1.47	3.44	2.45			8.50
A34.11	.90	.19	1.57	3.21	1.93			7.80
A34.12	.85	.23	1.47	3.18	2.18			7.91
A34.15					2.00			
Average	.70	.21	1.60	3.18	2.06			7.75

<u>1960</u>	<u>Jun-Sept</u>							
A34.0	.27	.73	1.22	1.13	2.41	1.58	1.16	7.50
A34.1			1.38	1.27	3.14	1.37	1.72	8.88
A34.2			1.46	1.39	3.14	1.96	1.86	9.81
A34.3			1.39	1.32	3.06	1.95	2.11	9.83
A34.4			1.41	1.35	3.47	1.82	1.71	9.76
A34.5				1.37	3.17	1.47	1.26	8.57
A34.6			1.02	1.03	4.11	2.66	2.04	10.86
A34.7			.99	.95	3.21	2.03	1.89	9.07
A34.8			1.07	1.22	3.34	2.15	1.44	9.22
A34.9			1.35	.80	3.35	2.13	1.62	9.25
A34.10			1.33	1.13	3.51	2.09	1.45	9.51
A34.11			.95	.92	3.36	3.06	1.82	10.11
A34.12			1.01	.68	3.06	2.18	1.39	8.32
Average			1.22	1.12	3.26	2.03	1.65	9.28

Table 4: Monthly Precipitation Totals in Ogotoruk Valley.

(Inches of Liquid Water.)

	<u>Cape Lisburne</u>	<u>Ogotoruk</u>	<u>Kotzebue</u>
Sept 59		0	0
Oct		2½	1
Nov		5	4
Dec		5	6
Jan 60	19	5	11
Feb	28	6	17
Mar	30	6	18
Apr	34	8	22
May	34	2	15
June	1	1	Trace
July	0	0	0
Aug	0	0	0
Sept	3	1	1
Oct	4	4	3
Nov	6	2	7
Dec	13	2	14
Jan 61	15	2	15
Feb	14	2	10
Mar	14	3	13
Apr	13	6	22
May	7	4	14
June	0	Trace	Trace
July	0	0	0
Aug	0	0	0
Sept	0	0	0
Oct	5	1½	3
Nov	11	7	5
Dec	15	3½	7

Table 5: Greatest Snow Depth on Ground (Inches).

	<u>A34.0</u>	<u>A34.7</u>	<u>A34.12</u>
May 1960	66		68
June	79		66
July	67		58
August	67		59
September	74		71

May 1961	64		
June	77		64
July	86	73	66
August	85	80	64
September	84	83	76

Table 6: Monthly Mean of the Daily Minimum Relative Humidity Readings from the Hygrothermographs. The decrease inland indicates a greater degree of afternoon warming inland.

<u>Monthly Averages</u>	<u>Kotzebue</u>	<u>Barrow</u>	<u>Umiat</u>	<u>Fairbanks</u>
January	57	-	58	67
February	55	53	47	64
March	61	51	59	63
April	58	59	65	62
May	65	84	76	70
June	70	80	79	73
July	77	82	69	72
August	83	90	79	77
September	77	92	91	79
October	72	87	79	81
November	66	-	89	70
December	62	-	-	71

<u>Monthly Comparisons</u>	<u>Ogotoruk</u>			<u>Kotzebue</u>		
	<u>1959</u>	<u>1960</u>	<u>1961</u>	<u>1959</u>	<u>1960</u>	<u>1961</u>
January		39	56		61	75
February		47	10		64	25
March		23	54		35	57
April		53	64		40	68
May		68	58		70	65
June		78	78		75	79
July		58	91		63	83
August		68	82		80	78
September	47	72	86	49	68	88
October	55	68	52	67	66	65
November	34	63	70	62	81	72
December	15	47	45	34	81	54

Table 7: Percentage of Sky Cover from Sunrise to Sunset at Selected Locations.

	<u>A34.0</u>	<u>A34.7</u>	<u>A34.12</u>	<u>A34.14</u>
August 1960		330	302	
September 1960	225	214	202	
- - - - -				
March 1961	224			
April 1961	384	376	384	344
May 1961	474	467	499	458
June 1961	418	447	428	450
July 1961	377	310	350	311
August 1961	271	234	246	244

Table 8: Daily Average in Langleys of Solar Radiation at Various
Locations in Ogotoruk Valley.

<u>Kotzebue</u>	<u>Jan.</u>	<u>Feb.</u>	<u>March</u>	<u>April</u>	<u>May</u>	<u>June</u>	<u>July</u>	<u>Aug.</u>	<u>Sept.</u>	<u>Oct.</u>	<u>Nov.</u>	<u>Dec.</u>	<u>Annual</u>
Normal Maximum	0.6	2.5	6.6	22.3	36.3	49.2	58.5	55.8	45.6	30.2	12.9	3.3	27.0
Normal Minimum	-13.7	-11.9	-9.7	5.2	22.8	37.3	46.7	45.6	36.1	20.7	2.1	-10.6	14.2

Deviation of Cape Lisburne's 6-year Averages from Kotzebue's Normals

Average Maximum	1.4	--2.9	--6.2	--5.3	-5.2	--5.9	--8.2	--7.8	--5.6	-3.6	--2.7	--3.0	--4.6
Average Minimum	4.5	--2.0	--2.6	--1.8	-0.2	--3.5	--6.5	--5.0	--2.0	-0.2	1.7	1.3	-1.4

Deviation from Kotzebue's Normal Maximum

Kotzebue 1960	1.8	6.6	7.0	-4.3	3.9	-4.2	0.9	2.2	-2.2	-2.6	-1.5	15.3	1.9
Ogotoruk 1960	-5.0	7.2	2.6	-12.9	2.6	-6.9	-2.6	-0.8	-8.0	-7.4	-6.3	8.4	-2.4
Cape Lisb. 1960	-9.4	5.7	1.9	-16.3	-3.1	-10.0	-9.4	-7.9	-10.5	-6.6	-7.2	6.2	-5.6
Kotzebue 1961	12.1	-8.3	-4.9	-0.3	6.3	-0.9	-1.8	2.1	1.9	-3.8	-5.9	-10.8	-1.2
Ogotoruk 1961	6.7	-11.4	-14.0	-7.8	5.7	-2.6	-8.3	-2.4	0.3	-1.7	3.5	-2.7	-2.9
Cape Lisb. 1961	5.5	-14.0	-18.3	-11.7	-0.8	-6.9	-9.6	-7.3	-2.7	-0.5	3.6	-9.8	-6.0

Deviation from Kotzebue's Normal Minimum

Kotzebue 1960	1.4	17.3	6.9	-10.6	6.0	-2.7	0.9	1.5	-4.3	-3.7	0.1	15.9	2.4
Ogotoruk 1960	-4.3	10.1	2.5	-12.2	3.2	-6.6	-6.5	-5.6	-9.0	-6.1	-4.8	10.8	-2.4
Cape Lisb. 1960	-3.4	10.3	6.7	-9.7	2.2	-5.6	-7.0	-4.5	-5.4	-3.0	-3.3	10.2	-1.0
Kotzebue 1961	14.2	-8.1	-4.4	-4.2	4.8	-0.4	-0.9	1.6	2.2	-5.5	-2.6	-10.4	-1.1
Ogotoruk 1961	11.4	-5.4	-10.0	-6.1	4.1	-5.3	-6.8	-6.7	-2.8	-9.3	-1.2	-1.4	-3.3
Cape Lisb. 1961	11.7	-6.4	-10.4	-7.7	3.6	-3.4	-7.7	-3.8	-0.6	1.7	7.0	3.3	-1.5

Table 9: Deviation of Mean Maximum and Minimum Temperatures from Kotzebue's 30-year Normals.

		<u>Apr.</u>	<u>May</u>	<u>June</u>	<u>July</u>	<u>Aug.</u>	<u>Sept</u>
<u>Maximum Temperature</u>							
A34.0	1960	9.4	38.9	42.3	55.9	55.0	37.6
<u>Deviation from A34.0's Maximum</u>							
A34.7	1960			4.1	2.5	0.7	-0.3
A34.12	1960			3.9	1.9	-0.2	-0.9
<u>Maximum Temperature</u>							
A34.0	1961	14.5	42.0	46.6	50.2	53.4	45.9
<u>Deviation from A34.0's Maximum</u>							
A34.7	1961					-0.8	-3.6
A34.12	1961	-2.0	1.0	0.9	-0.8	-1.5	
. . . . .							
<u>Minimum Temperature</u>							
A34.0	1960	-7.0	26.0	30.7	40.2	39.9	27.1
<u>Deviation from A34.0's Minimum</u>							
A34.7	1960			0.2	-0.8	-2.2	-1.8
A34.12	1960			0.0	-0.9	-1.6	-0.5
<u>Minimum Temperature</u>							
A34.0	1961	-0.9	26.9	32.0	37.9	38.9	33.3
<u>Deviation from A34.0's Minimum</u>							
A34.7	1961					-1.5	-1.8
A34.12	1961	-2.9	-1.1	0.1	0.3	-1.2	

Table 10: Mean Monthly Air Temperature Deviations from the Base Camp
Readings at Selected Stations in Ogotoruk Valley.