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THE CLIMATES OF ALASKA

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CONTENTS

INTRODUCTION

Popular opinion once pictured all Alaska as a frozen, treeless waste, inhabited only by polar bears and Eskimos, the latter living the year round in snow igloos and subsisting on seal meat. That such a description is more or less applicable to the tundra areas of the Bering and Arctic coasts can not be denied, but Alaska is too varied in relief, climate, and resources to be pigeonholed with a phrase. In complete contrast with the flat, treeless tundra is the bold, fiorded coast of the "Panhandle" whose scenic beauties of glacier and forested mountain side, coupled with cool summer temperatures, have made of it a summer goal for an increasing number of tourists each year. In contrast again is the broad interior plateau region, drained by the mighty Yukon, where long hours of sunshine bring summer temperatures high enough for grains and vegetables to ripen and where berries are produced in abundance. Still further contrast is offered by the majestic mountain ranges which flank Alaska to north and south, the Alaska Range having the highest peak in all North America—Mount McKinley. Truly Alaska does not warrant a blanket description of any sort.

Many people have been attracted to Alaska—explorers, prospectors, settlers, and tourists. Its resources of gold and copper, seals, salmon, and scenery are the main support of the inhabitants, which according to the 1920 census numbered 55,061.

Of primary interest to prospective Alaskan travelers and settlers are climatic conditions. The two nations that have controlled Alaska have always been interested in its climate, because, being on the borderland for human habitation, the extremes that would have to be endured there were of special concern. Before 1867, when the United States purchased Alaska, Russian missionaries to the Eskimos kept weather observations at their various posts and Government officials kept records for Sitka, the Russian capital. Other nations, chiefly the English and Americans, early sent ships of exploration into Alaskan waters, and there are scattered meteorological records available for various points where these vessels wintered along Alaskan shores (**7**, p. 137).

After the United States purchased Alaska, the United States Army surgeons kept weather records in connection with the post hospitals. "In 1878 and 1879, soon after the organization of the United States Weather Bureau, first under the Signal Corps of the Army, later as a bureau of the Department of Agriculture, a few first-class observing stations, together with several voluntary stations of lower order, were established in Alaska" (**1**, p. 133). In 1917 an appropriation of $10,000 permitted the establishment of additional first-class observing stations in Alaska (**39**, p. 464), so that there are now 9 such stations, while 44 cooperative observers bring the total up to 53 weather stations. The cooperative observers include United States experiment stations, radio stations, mining and railway companies, and religious missions as well as individuals.

The present study is an attempt to bring up to date the climatic data available for Alaska. Cleveland Abbe, jr., publishing in 1906 a section on climate in Alaska as part of Professional Paper No. 45, U. S. G. S. (**1**, p. 134), summarized the records used in his report as follows:

> The observations made up to the end of 1877 have already been summarized by Dall and Baker, and published, together with a very full bibliography, by the Coast and Geodetic Survey. The results of observations made at six United States Army posts, from 1861 to 1871, and the continuous series of Russian and American observations at Sitka, from 1847 to 1874, have been summarized by C. A. Schott, and published in two volumes by the Smithsonian Institution. They form valuable supplements to the earlier monograph by Dall and Baker. * * * The material summarized in the accompanying tables was taken from the manuscript records covering the period from 1868 to the present time, in the custody of the United States Weather Bureau. * * * These records were made by observers who may be grouped in four classes—post surgeons at regular United States Army posts, regular Signal Service or Weather Bureau observers, voluntary observers supplied by the Weather Bureau with instruments, and members of various expeditions.

In 1925, Melvin B. Summers, Alaska section director of the United States Weather Bureau at Juneau, published a Summary of the Climatological Data for Alaska, by Sections incorporating data from the establishment of the stations through 1921 (**29**). The present study makes use of these and other sources, as well as Climatological Data for Alaska, both monthly and annual publications (**37**), and some manuscript data supplied by the Weather Bureau.

Although the data are practically complete through 1927, a survey reveals the fact that only 29 stations have adequate records averaging over 10 years and covering (besides rainfall and temperature) wind direction, frost period, days with rain, snowfall, clouds, and so forth. Even these data are not for the same series of years in many cases, but in spite of the seeming inadequacy of the records they are much fuller than those available when former studies were made for they cover a longer and more nearly consecutive period of years.

I. FACTORS CONTROLLING ALASKAN CLIMATES

The title of this paper, The Climates of Alaska is used advisedly for Alaska, has no climatological homogeneity. Regions adjacent on the map are found to have widely different climatic characteristics and it is the study of these striking contrasts and the reasons for them that lend the major interest to Alaskan climatology.

The climatic provinces into which Alaska has been divided and the location of the climatological stations therein are shown in Figure 1.

The Pacific coast and islands region is marked by heavy rainfall, the rest of Alaska by little; the Pacific coast rainfall has a cold season maximum, the precipitation over the rest of Alaska has a summer maximum; the Pacific coast is equable, the interior extreme, in temperature characteristics. It is evident then that Alaska presents a marine climate along its Pacific border and a continental climate over the rest of its area.

The continuation of the North American Coast Ranges in Alaska and the Alaska Range bear the chief responsibility for this contrast in climate between the Pacific coast and the interior. The Alaska Range attains heights of over 20,000 feet and the whole of southeastern Alaska is backed by ranges of between 5,000 and 10,000 feet. Such high mountains effectively interrupt the surface atmospheric circulation; hence in Alaska, they cut off the interior from the winds off the Pacific, thereby concentrating precipitation on the coast and decreasing it in the interior; at the same time they prevent the oceanic winds from moderating the temperatures of the interior and hinder the passage of winter cold winds from the interior to the coast.

Back of the Coast and Alaska Ranges is a rugged plateau region of 1,000 to 2,000 feet elevation, stretching northward to the Brooks Range. This range was crossed several times by Wilkins (**42**, p. 530) in his air flights from Fairbanks to his base at Point Barrow preparatory to his exploratory trip that culminated in his famous flight from Alaska to Svalbard (Spitsbergen). He found the mountains to be approximately 10,000 feet high, or about 5,000 feet higher than was previously supposed. They, as well as the Alaska Range, play their part in keeping oceanic influences out of the interior, and consequently the wide

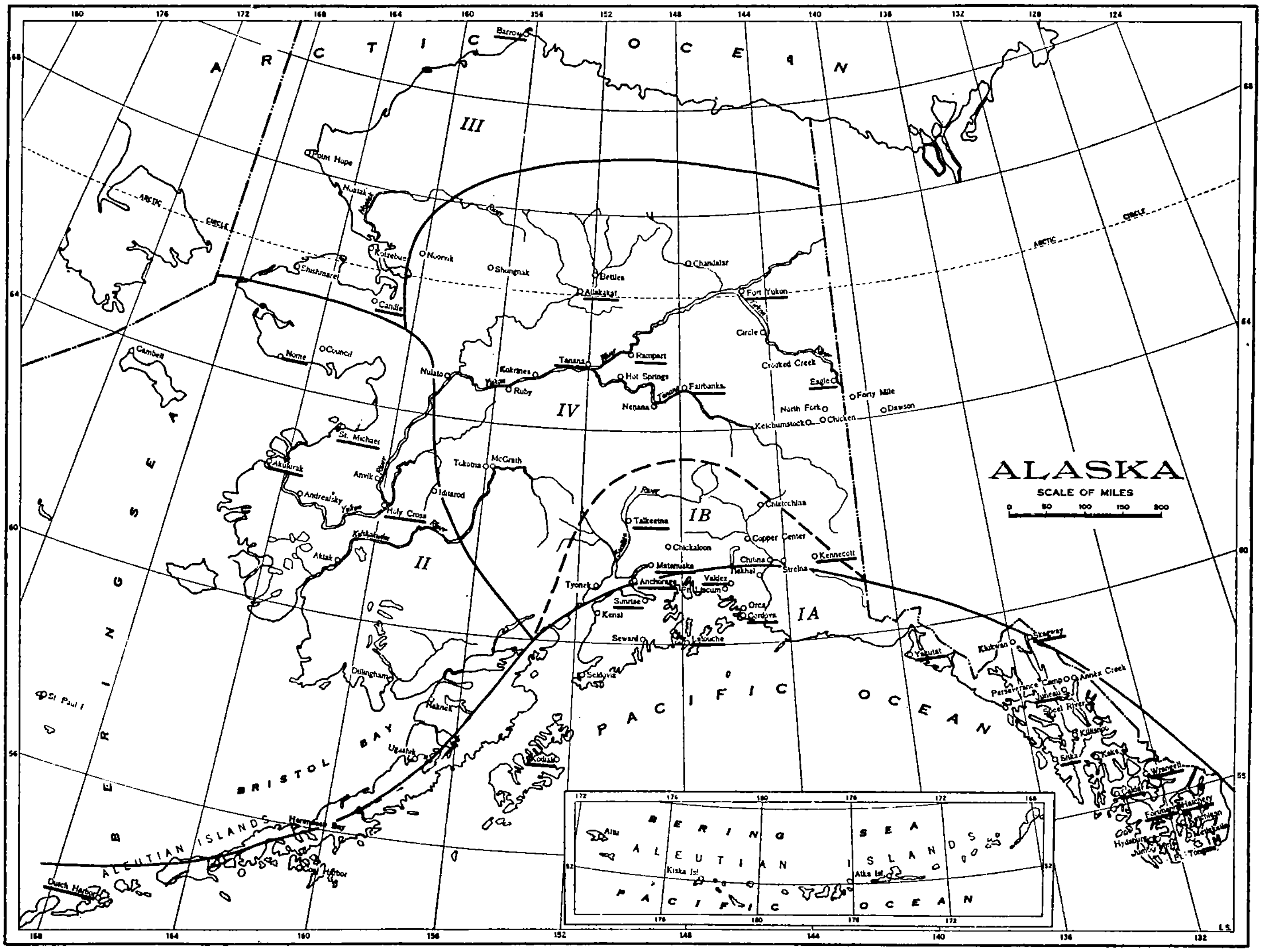

FIGURE 1.—Map of Alaska showing climatic provinces and the stations (underlined) used in the study

Yukon Valley has the coldest and hottest temperatures in all Alaska and only a meager precipitation.

Beyond the Brooks Range a coastal plain about 50 miles in width slopes to the Arctic Ocean. The interior plateau slopes from its elevation of 5,000 feet just over the Canadian boundary gradually westward and finally disappears under the Bering Sea; the Coast Ranges also gradually decrease in height to the westward but maintain their identity far out into the ocean as the volcanic chain of the Aleutian Islands.

This chain of islands, by interrupting the free circulation of Pacific waters, and especially by deflecting the Alaska current, the eddy of warm water from the Japan current drift which bears northward and westward along the coast in the Gulf of Alaska, allows the Bering Sea to stay colder than it might otherwise be, which in turn affects the climate of its coasts. The Bering Sea, being almost inclosed, freezes over much of its area during the winter (**17**) and, as snow-covered ice becomes almost like an extension of the land, takes on continental climatic characteristics. (Fig. 1.) The same is true to an even more striking degree of the almost completely and thickly ice-covered Arctic Ocean.

Some tempering effect of the sea is still felt, however, for the unfrozen water beneath the ice gives off more heat to the surface than would be conducted from below to surface ice covering a land area, and hence ice temperatures over the sea never reach such a low minimum as those over the land. Furthermore, the occasional "leads," exposing open water to the winds, moderate somewhat the coldness which those winds may carry onto the coasts. Minimum temperatures of −70° F. have been recorded in interior Alaska, but −56° F. seems to be the lowest for Point Barrow on the Arctic coast. Winds from these frozen seas in winter carry so little moisture that the Bering and Arctic coast regions, in spite of marine location, have a continental summer maximum of precipitation.

The Japan current drift and its Alaska Gulf eddy bring warmer water to the Pacific coast than would normally be found at this latitude, thus magnifying the moderating effect of the ocean winds on winter temperatures and increasing the moisture content of the on-shore winds.

One other factor important in Alaska's climates is duration of sunshine, which, as determined by Alaska's latitudinal extent from 52° N. to 71° N., is quite different in the north from that in the south. The third of Alaska which lies north of the Arctic Circle has no sunshine at all about December 21 and very little during any of December or January, while in corresponding parts of June and July it has almost or quite 24 hours a day. All of Alaska is far enough north to experience a wide range in daily hours of possible sunshine during the course of a year and temperature, convection, winds, and consequent precipitation are affected accordingly.

Duration of sunshine, mountain ranges, and surrounding seas, then, may be called the chief factors in Alaska's climates. What effect they have on the various climatic elements is discussed in the next section of this paper.

II. CLIMATIC ELEMENTS

SUNSHINE, CLOUDINESS, AND FOG

The daily hours of sunshine possible for different latitudes across Alaska vary from none to almost 8 hours in December and from 16 to 24 hours in June (**5**). But the percentage of the possible hours which is actually received is generally quite low in Alaska. If the figures for Juneau are compared with those for Boston (**36**) the striking fact is brought out that in no month does Boston's percentage of possible hours of sunshine received reach as low a figure as the highest for Juneau. Nor does Juneau, even in the long days of summer when its possible hours of sunshine are 17 or 18 a day, ever equal Boston in actual hours of sunshine month by month. Boston has a yearly total almost twice that of Juneau, though both places have, of course, practically the same yearly amount of possible sunshine. And yet Boston has a rather low percentage of sunshine in comparison with most of the United States (**31**, p 33), which makes apparent the excessive cloudiness of Juneau and presumably of the whole Pacific coast section of Alaska for which Juneau may be taken as representative. A very low percentage of possible hours of sunshine in the month of October is of interest and will be found to correspond to the month of heaviest rainfall in this part of Alaska.

Figures 2 to 6 show graphically for each of the climatic provinces the monthly distribution of clear, partly cloudy, and cloudy days, also the number of days with rain and with snow, the depth of snow in inches and the amount of precipitation in inches, and other data.

No station in the interior of Alaska has data on sunshine, but an examination of that for Swede Creek in the upper Yukon Valley in Canada shows that March, April, June, July, August, and October all have a higher percentage of sunshine than Juneau, but again every month has a lower per cent and a lower actual amount than Boston. However, Swede Creek has a total number of actual hours greater than that of Juneau in spite of one month of complete darkness, which indicates that the interior of Alaska (taking Swede Creek as representative of it) has more sunshine than the Pacific shores. This fact will now be brought out again in the study of the clear and cloudy days and days with precipitation throughout Alaska.

Since the actual number of hours of sunshine is available only for Juneau, the number of clear and cloudy days gives the best basis for the other Alaskan stations from which to deduce the probable amount of sunshine received during the month as compared with the possible amount. For practically all Alaskan stations the number of clear days is seldom over half the month and oftentimes less than one-third. The greatest number of clear days is found in the interior and along the Arctic coast, especially during the late winter and early spring months. Clear skies are to be expected there at this time considering the small amount of vapor that can be present during the cold weather of winter.

All Alaskan stations except three or four in the interior average more cloudy days than clear ones in the course of the year. The Pacific coast is much the most cloudy part of Alaska with 200 cloudy days a year; interior and Arctic coast stations average under 150. More moisture is available to the Pacific coast region for the formation of clouds, while the coldness and dryness of the interior and of the Arctic shores makes fairly clear weather more usual there.

The Panhandle stations, as would be expected, show a higher percentage of cloudiness in all months than other stations in Alaska, and have a winter rather than a summer or fall maximum of cloudiness as the rest of Alaska has.

Records for foggy days are not available for any station in Alaska except Juneau (see footnote 1) which reports only one or two days of fog each month. This is surprisingly low considering the emphasis laid on fogs by travelers who write about the region. However, the monthly pilot charts of the North Pacific Ocean (**35**) show from 15 to

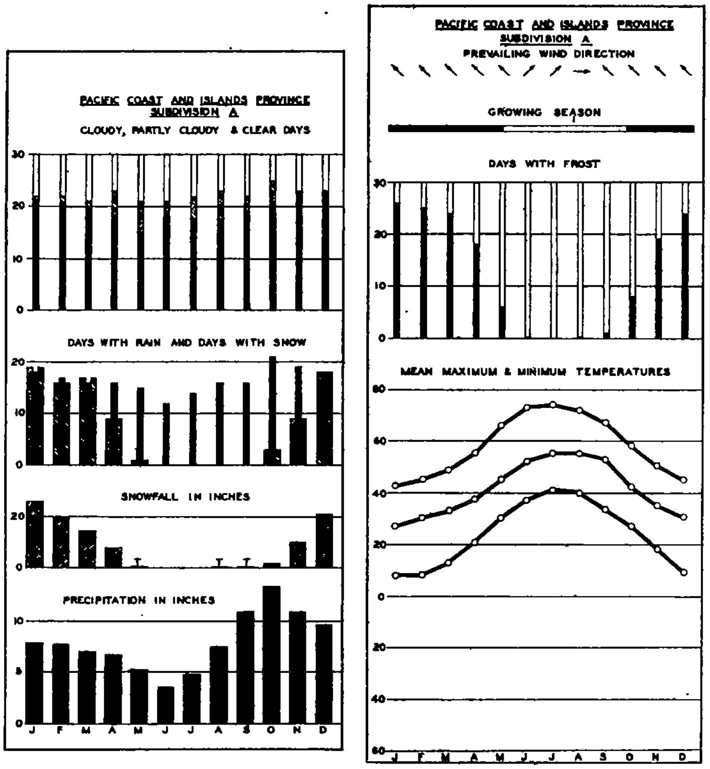

FIGURE 2.—Graph of climatic data for Pacific coast and island province, subdivision A

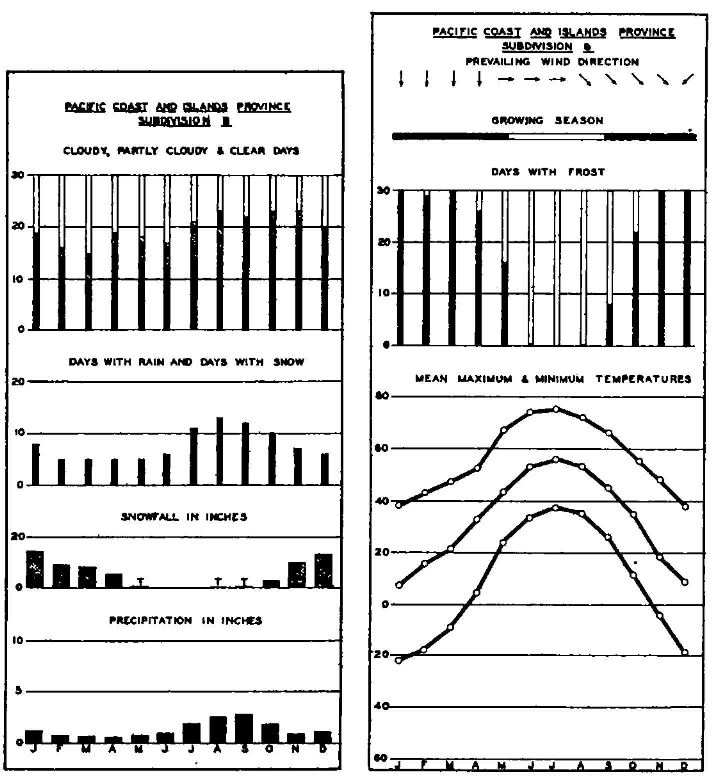

FIGURE 3.—Graph of climatic data for Pacific coast and islands, subdivision B

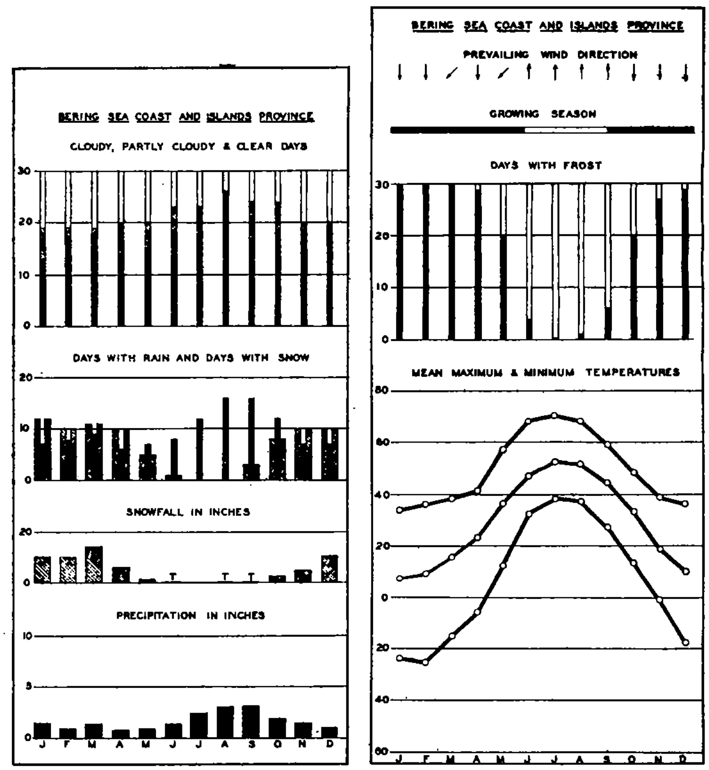

FIGURE 4.—Graph of climatic data for Bering Sea coast and islands

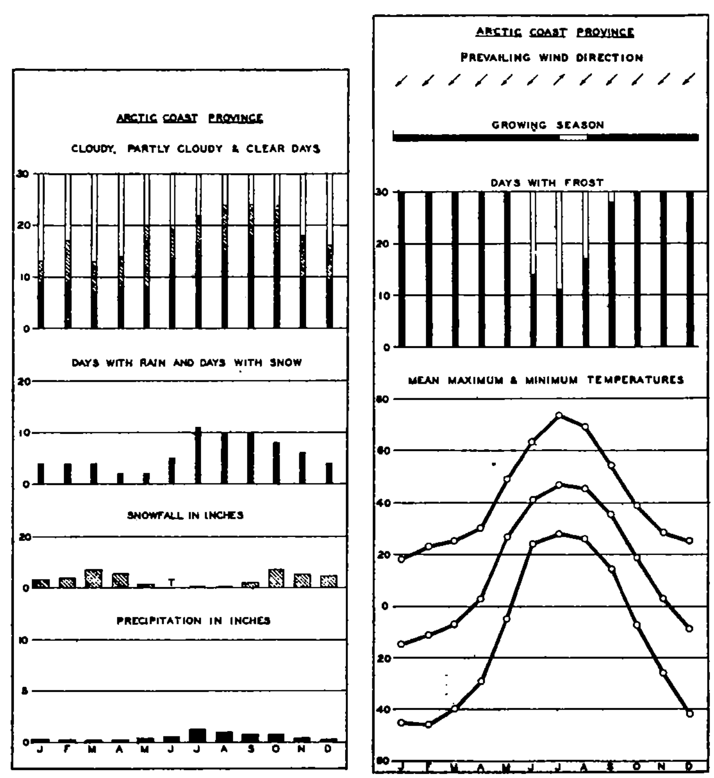

FIGURE 5.—Graph of climatic data for Arctic coast

25 per cent of the days as foggy in the Gulf of Alaska and about the Aleutian Islands during the winter season, which more nearly corroborates the statements of travelers. The warm winds off the ocean, blowing onto a colder land during the winter season, certainly would be conducive to a foggy condition so that probably this phenomenon is more common, on the outer coast at least, than Juneau's record of only one or two foggy days a month would indicate. Juneau probably has its low record because it is protected by intervening islands from the full effect of damp winds from the open ocean.

Unfortunately no records are available on which to base any definite statement regarding fog conditions over the rest of Alaska. Dawson, in Yukon territory, however, probably indicates fairly well the fogginess of the interior plateau of Alaska. The summer months are least foggy, early fall and winter most so, for the colder temperatures tend to cause condensation of what moisture the atmosphere may contain.

Fog is probably fairly frequent along the Bering Sea coast and Wilkins mentions heavy fogs around Point Barrow [1] as well as in the Yukon Valley in the spring season (**42**). All the seasons have conditions favorable for fog formation along the Arctic and Bering coasts; spring and summer bring a contrast between warm land and cold water and fall and winter bring a contrast between cold land and warm water. Open water in the northern seas, being of great extent only in summer and early fall, would tend to increase fogginess in those seasons along the coasts, for more moisture would then be available.

TEMPERATURE

Alaska, warmer during the year than is normal for its latitude along its Pacific coast but with that warmth shut off from the interior regions by high mountain ranges, naturally presents quite a wide difference in mean annual temperature between its north and south portions, though the distance is only about 800 miles. High relief is the chief contributing factor here, for in regions of similar latitudes but of low relief no such difference as 30° in mean annual temperatures is found. (Fig. 7.) For instance, in the Mackenzie Valley, Fort McPherson, north of the Arctic Circle, has a mean annual temperature of 14.1°, while Fort McMurray, 750 miles south in the same lowland, has a mean annual temperature of 30.3°, the difference being only 16.2° (**6**). In the Union of Socialist Soviet Republics similar temperatures for Archangel and Moscow are 32.4° and 38.5°, respectively, a difference of only 6.1° (**43**).

Examination of the annual temperature map of Alaska (fig. 7) shows that stations in the Alexander Archipelago, around the open parts of Prince William Sound, and on the southern shores of Kodiak Island all have annual temperatures over 40°. Slightly lower temperatures are found along the Pacific coast where the glaciers from the St. Elias Range descend to the sea.

The annual map shows that from the Pacific coast the temperatures decrease northward to the Arctic Ocean, the 5° isotherms forming fairly parallel bands east and west across Alaska. It is evident from a comparison of the January and July maps (figs. 8 and 9) that this fairly homogeneous decrease is due almost wholly to the conditions that prevail during the winter, for in summer there is an increase in temperature in going north, at least as far as the Yukon Valley. However, the contrasts in temperature during the winter months are evidently enough to overbalance the approaching equalities of the summer months, for the annual map shows an average difference of 30° for the entire year.

Eleven 5° isotherms are required in January to show the difference of temperature across Alaska from over 30° on the Pacific coast to less than −20° in the interior and on the north coast, while on the July map the four isotherms, 45° to 60°, suffice to show the whole temperature range. Of especial interest is the crowding of the January isotherms along the Pacific coast, showing the rapid decrease in temperature back of the coastal mountains which shut off the interior from the moderating influence of the ocean.

On the July map the tendency of the 5° isotherms to encircle the interior is of interest; the center and hottest region is the Yukon Valley, with a decrease of temperature in all directions toward the various coasts. This demonstrates very well the greater heating of land bodies as opposed to water bodies, especially when those land areas are cut off from cooler ocean winds by intervening mountain ranges.

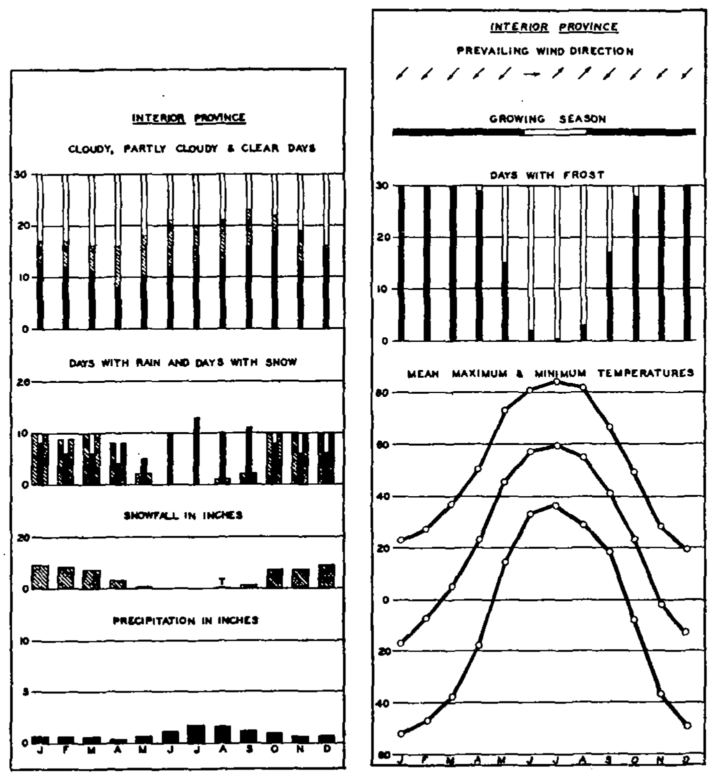

FIGURE 6.—Graph of climatic data for the interior

The greatest ranges of temperature, both absolute and annual, are found in the interior of Alaska. Eagle has the greatest range of any single station, with an absolute maximum of 95° F. and a minimum of −69° F., the range being 164°. Allakaket has a lower minimum than Eagle, −70°, and Fairbanks has a higher maximum, 99°; but the ranges at these two stations are less, being 160° and 156° respectively. Verkhoyansk, Siberia, and Fort Good Hope, Canada, regions of similar geographic character except that, due to their position with regard to prevailing winds, they are even less subject to oceanic influences than

[1] The author evidently did not have access to the report of the International Polar Observations made at Point Barrow from November, 1881, to Aug. 27, 1883. These observations show that in winter months, November to March and April, fog is infrequent but there is a very considerable amount of haze which at times is so dense as to be mistaken for fog. The fog season at Point Barrow, judging from but two seasons, 1882 and 1883, begins in May and continues through September. In the 5 months, May to September, 1882, dense fog was reported on 43 days with a total duration of 240 hours. In the next following season or rather up to Aug. 27, 1883, dense fog was reported on 45 days with a duration of 270 hours; in August, 1883, lacking 4 days, dense fog occurred on 15 of the 27 on which observations were made. It is also apparent from the record for this station that light drizzling rain often continues for a number of hours consecutively, thus making visibility very poor.—A. J. H.

Eagle, have greater absolute ranges, the figures being 183° and 172° respectively (**15**, p. 176, and **6**).

Figure 10, showing the absolute yearly temperature ranges in Alaska, illustrates very well the fact that increasing distances from the equable ocean waters cause greater temperature extremes. A range of under 100° occurs all along the immediate Pacific coast, and even the Arctic Ocean and the Bering Sea, though frozen over entirely or partially during much of the year, moderate somewhat the temperatures of the adjacent coasts, and thus the greatest ranges are found in the interior. This region is shut off by mountain ranges from winds off the surrounding water bodies and so is not warmed by them in winter nor cooled by them in summer. Furthermore, the lesser water vapor and clearer skies of this inland region allow greater cooling by radiation on calm winter nights and greater heating by insolation on long summer days than do the higher absolute humidities and cloudier skies of the coastal regions.

St. Paul Island is the station par excellence to illustrate the equability of temperatures resulting from a marine location. This little island situated in the Bering Sea is of such slight extent that its temperatures depend almost entirely on those of the surrounding sea and it has the lowest temperature range in Alaska from April to October, inclusive. During the winter months, however, it is near or surrounded by the field ice of the Bering Sea which gives it lower temperatures and larger ranges than Dutch Harbor, an island station farther south and always surrounded by open water. With its minimum temperatures much lower and its maximums only slightly lower than those of Dutch Harbor, it yields first place for least temperature range in Alaska to Dutch Harbor during the months of November, December, January, February, and March.

January and February are the months of largest temperature ranges in Alaska. Earlier in the winter very low temperatures are not so probable and by March temperatures much higher than normal would be rare, for settled cold weather is thoroughly established over all Alaska then, unalleviated by warming influences from any source, for water bodies are cold or actually ice covered and land areas are snow covered. In January and February, however, some very low temperatures and some fairly high ones are recorded, bringing the maximum range in January for 10 of the 29 chief Alaskan stations and in February for 9 of them.

While absolute minimum temperatures are of interest in the climatology of a region so near the pole as Alaska, the duration of low temperatures especially with respect to the freezing point is of more consequence to inhabitants of such a region. "Frost days," those days during the course of which the minimum temperature falls at least as low as 32°, are numerous in Alaska, though Barrow, Eagle, and Fort Yukon are the only three stations having frost days in every month, while Fortmann Hatchery, Sitka, and Yakutat, with four months having no frost days, stand at the other extreme. Barrow, with an average of 324 frost days, has the greatest yearly number, while Juneau and Sitka, each with only 106, have the smallest. The Pacific coast stations and St. Paul Island have some days each month even in the winter when the temperature does not fall to freezing, while over all the rest of Alaska practically every day from November, to March, inclusive has freezing temperatures. Here again the moderating influence of the warmer Pacific Ocean is apparent.

The length of the frostless season, being dependent on the frost dates, is, of course, longer along the Pacific coast. However, the long hours of sunshine and great heating of the interior plateau make the shorter growing season of this region sufficient for grains, vegetables, and many berries. The period without killing frost is generally over 140 days (4½ months) on the Pacific coast; about 100 days (slightly over 3 months) on the Bering Sea coast; only about 35 days (1 month) on the Arctic coast; and 80 days (not quite 3 months) in the interior plateau.

"Ice days" are those when the temperature is never above 32°.[2] The contrast between the Pacific coast and the rest of Alaska is again apparent, the coast averaging about 40 such days in a year while all the rest of Alaska, with the exception of two stations with marine location on the Bering Sea, Dillingham, and St. Paul Island, has over 100 ice days a year, the maximum being an average of 253 at Barrow. Nome, Eagle, and Tanana, representative of the Bering Sea coast and interior Alaska, have almost entire and sometimes entire months of such weather from November to March, inclusive, whereas Juneau, representing the Pacific coast, never averages more than 14 such days a month and has over 10 days only in December and January.

From the point of view of temperature the Pacific coast region of Alaska has extreme cold no more unbearable than that found over much of the United States, while the yearly temperatures have a more moderate range, being influenced in this respect by the marine location, than many parts of the United States. The interior region of Alaska averages much colder than the United States, but the fact that there is little moisture in the air during the winter season probably helps to make the cold bearable, while the rather high summer temperatures relieve the monotony of continuous cold under which more marine locations in these northern latitudes suffer.

WINDS AND PRESSURE

The January and July sea level pressure maps show the general winter and summer pressure distribution over Alaska. (Figs. 11 and 12.) During the winter season the cold land and the polar ice cap, by greatly chilling and contracting the air, develop an area of high pressure, while by contrast the warmer Pacific Ocean causes expanding air and low pressure, resulting in the so-called Aleutian LOW, which has generally been thought to be the source of the great majority of the winter cyclones of North America. However, recent study of meteorological reports received from the Asiatic coast and islands and vessels crossing the Pacific has led to the conclusion that the cyclonic storms entering North America from the northwest originate far beyond the Aleutian Islands, the permanent Aleutian LOW simply affording a favorable channel through which the disturbances pass, rather than being their breeding place (**19**, p. 134).

The intensity of the winter-low pressure area seems to be in large part dependent upon the temperature of the North Pacific waters, and especially on the temperature gradient from a few hundred miles at sea to the shore. Several years ago the Canadian Meteorological Service equipped four of the ships of the Canadian Pacific Steamship Co. with thermographs for recording the temperature of the surface water between Vancouver and Yokohama in an attempt to determine the relationship between water temperature and the intensity of cyclonic development. While detailed results have not been obtained as yet, it would seem that the warmer the Pacific waters are the more favorable are conditions for deep cyclonic depres-

[2] Ice days are commonly defined as those when the temperature does not rise to 32°, but here the difference in definition is of no consequence since temperatures to the nearest tenth of a degree were used in the Weather Bureau tabulations.

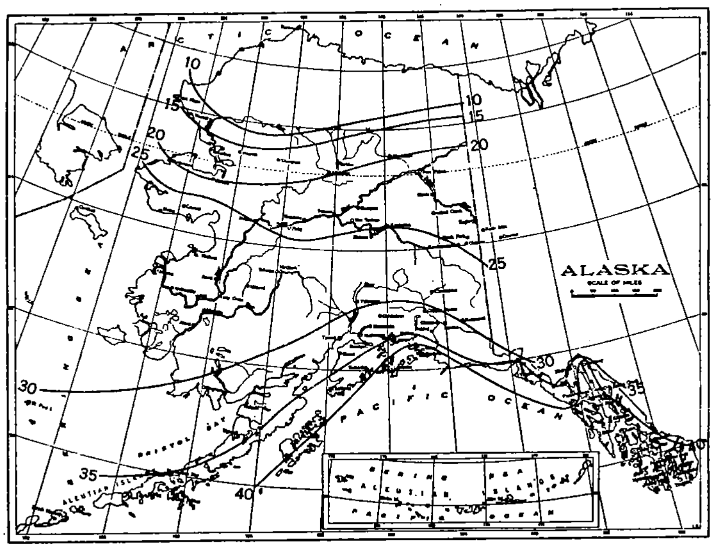

FIGURE 7.—Mean annual temperature

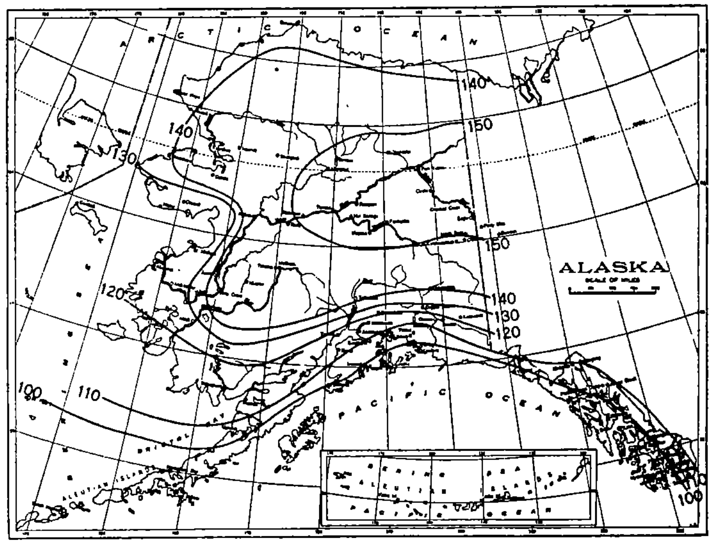

FIGURE 10.—Absolute annual temperature range

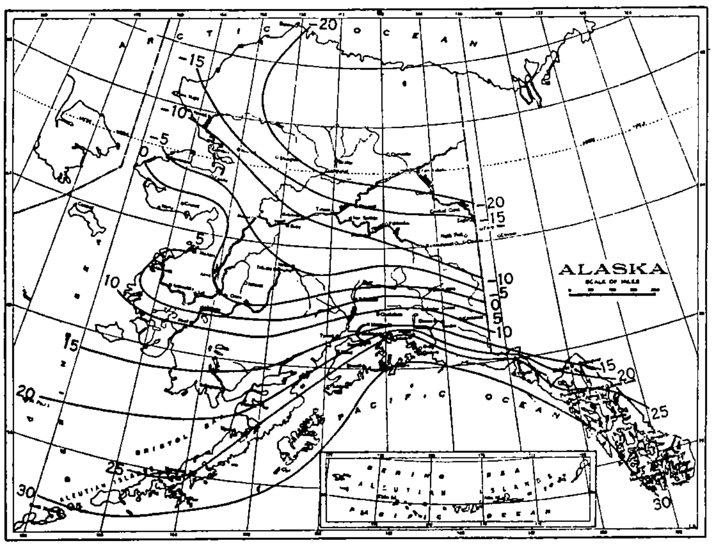

FIGURE 8.—Mean January temperature

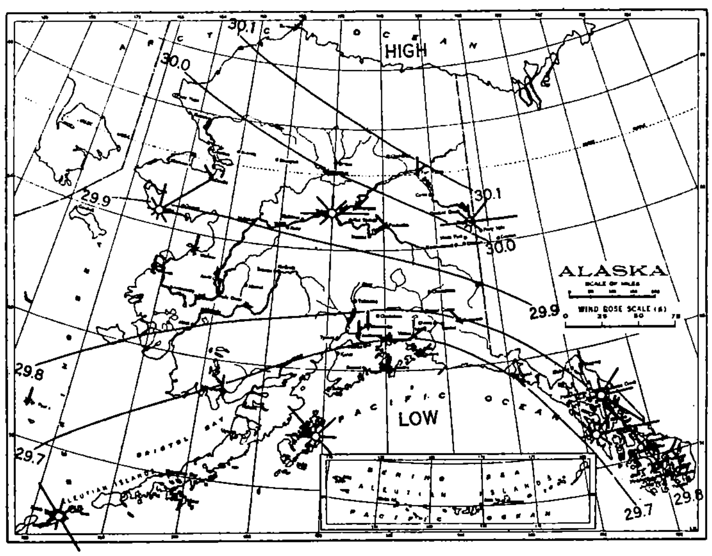

FIGURE 11.—Mean sea level pressure and wind roses, January; pressure in inches, wind frequency one-half inch equals 25 per cent

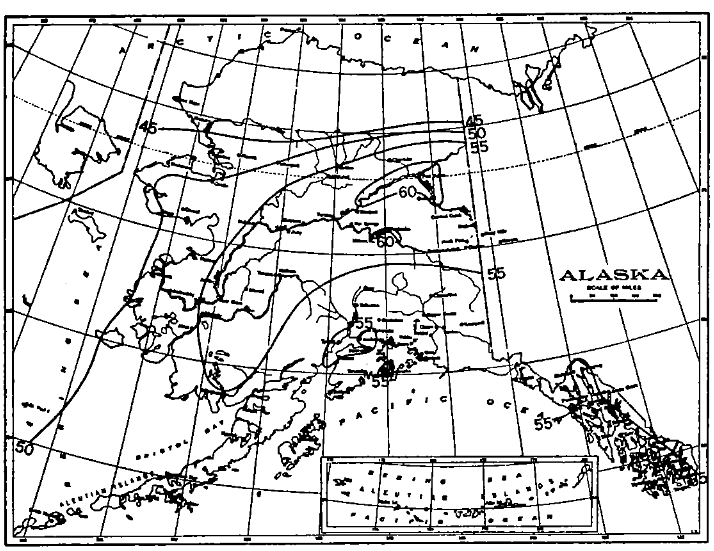

FIGURE 9. Mean July temperature

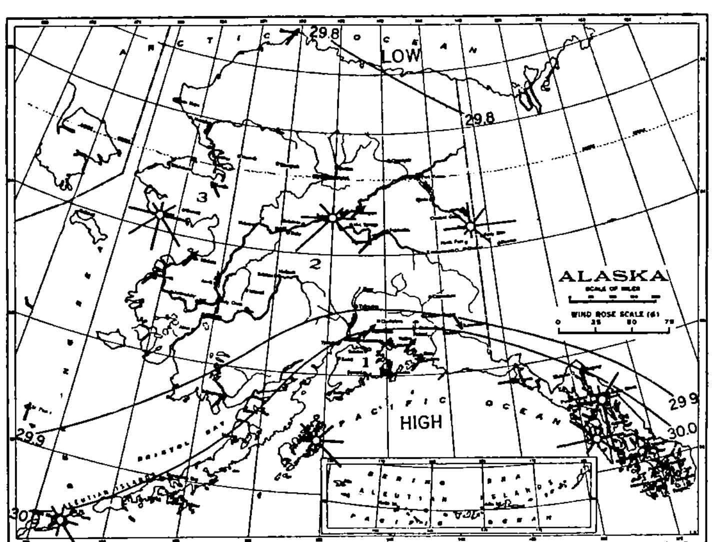

FIGURE 12.—Mean sea level pressure and wind roses, July; pressure in inches, wind frequency one-half inch equals 25 per cent

sions in the winter in the North Pacific, while colder water temperatures favor lows of less intensity.

In July the pressure distribution is nearly the reverse of that in January. The ocean, remaining cooler than the land, develops a high pressure while the heated land becomes a region of low pressure. However the HIGH of July is not so high nor the LOW so low as that of January. In January the high pressure of the interior, due chiefly to low temperatures, is intensified by the dryness of the air, and the LOW of the Alaskan Gulf, due mainly to relatively high temperatures, is intensified by the moisture in the air; in July the same moisture conditions reduce somewhat the natural intensity of the HIGHS and LOWS which results from temperature alone. However, the principal cause of the relative weakness of the July HIGHS and LOWS is the small temperature gradient at this season. Since the intensities are less in July than in January, the summer pressure gradients are not sufficiently strong to be of the great importance in atmospheric circulation that the winter pressures are.

The wind arrows on the maps generally fly in a direction in accordance with the pressure distribution and the deflective effect of the earth's rotation. Where they are at variance with what should be expected for the pressure distribution, the local topography is probably of greater influence. Wind roses are shown at those stations for which it was possible to calculate the actual percentage frequency of wind directions (**36**). The small arrows indicate the wind listed the greatest number of times over various periods of years at the different stations as the prevailing one for the month. In January and July the wind directions are quite definite, the strength of the well-established HIGHS and LOWS at these seasons determining an actual "prevailing" wind, whereas in the transitional months of spring and fall, when pressures are weakened, variable winds are more characteristic.

On the January map, southerly winds are of minor importance because the low pressure over the Pacific Ocean causes prevailing northerly winds. However, winds of strong southerly component are indicated by two of the wind roses—those for Juneau and Dutch Harbor. Probably local configuration determines the high percentage of southerly winds at Juneau; perhaps the almost equal percentages in southeast and northwest directions at Dutch Harbor indicate occasional shiftings of the low pressure area from the Pacific Ocean to the Bering Sea and back; or perhaps these opposite wind directions merely show that LOWS pass now to one side and then to the other side of Dutch Harbor.

On the July map it is the northerly wind directions which are unimportant on the wind roses for in this case the low pressure area is located to the north. A study of the direction of the arrows for the prevailing winds shows this same monsoonal character, exactly opposite directions being noted in many instances in January and July. This is to be expected since the pressure gradient is opposite in these two months. The reversal of direction is noticeable only where winds have blown over the sea or over land of comparatively low relief; in the mountainous Panhandle district the winds are more affected by local topography than by the general pressure distribution and therefore have their monsoonal tendencies modified.

The maximum wind velocities are obtainable for only two stations in Alaska—Juneau and Nome (**36**). February seems to be by far the stormiest month, since in 7 instances out of 20 the highest velocity for the year occurs in this month and the only two velocities of over 60 miles per hour occur in February. November and December are both stormy, having four and three instances, respectively, of highest yearly velocity. From May to August is apparently the most quiet time of the year as the maximum wind velocity in these months was never of force equal to the yearly maximum for the 11 years of the record.

In general, velocities throughout the year, but especially in winter, seem fairly high, as might well be expected considering the intensities of the winter LOWS and HIGHS and the short latitudinal distance between the two. The isobars indicate the resulting steep gradients and strong winds are the consequence of the gradients.

PRECIPITATION

The annual map brings out strikingly the heavy concentration of precipitation in a narrow band less than 50 miles wide along the Pacific coast. (Fig. 13.) In much of this comparatively small area the precipitation is well over 100 inches and is not less than 40 inches in the driest portion. Inland from this band of heavy precipitation the rainfall decreases rapidly, fully two-thirds of Alaska having an annual precipitation under 20 inches.

An explanation of this geographic distribution involves mainly a discussion of wind effects and of physiographic features. The heavy precipitation of the Pacific coast region is the result chiefly of a combination of six factors: (1) The prevailing winds are off the ocean and so generally carry an abundance of moisture. (2) Cyclonic storms, passing through the depression formed by the Aleutian low, frequently cross this region. They increase the moisture which the prevailing winds are able to bring onto the coast of Alaska, and the rising air currents in these cyclones induces precipitation by chilling and condensing the vapor carried. (3) The coastal ranges prevent dispersal of the moisture-bearing winds over a wide area, thus concentrating the rainfall along the coast. (4) The coastal ranges have a further effect in inducing heavy precipitation by causing adiabatic cooling of the moisture-bearing winds as they rise on approaching the mountains. (5) The shore temperature itself, when cooler than the ocean temperature, favors precipitation. (6) While the pilot charts for the North Pacific (**35**) show prevailing westerly or southerly winds in the Gulf of Alaska, the coast station records show frequent northerly or easterly winds. Those winds, blowing down valleys from the interior, are generally much colder than the winds off the Pacific. Consequently the warmer Pacific winds rise over the shore winds and precipitation results, both as a consequence of the cooling from increased elevation, and the mixing of the warm winds above with, and radiation to, the cold surface winds. The unusually heavy rainfall of 172 inches at Latouche is probably the result of the coming together here of cold interior winds and warm ocean winds.

The precipitation of the interior is reduced because of the concentration along the Pacific coast, but other factors also enter in. It is a region of high pressure during the winter months, with settling and outflowing winds, and consequent low precipitation at this season. Most of the rainfall comes in the summer in the form of convectional showers for the development of which the inflowing air from the sea, with wide extent of land, and long hours of summer sunshine are favorable. When northerly or westerly winds do blow across the interior they are not able to precipitate much moisture, because, being from cold, ice-hemmed seas, their moisture content is slight.

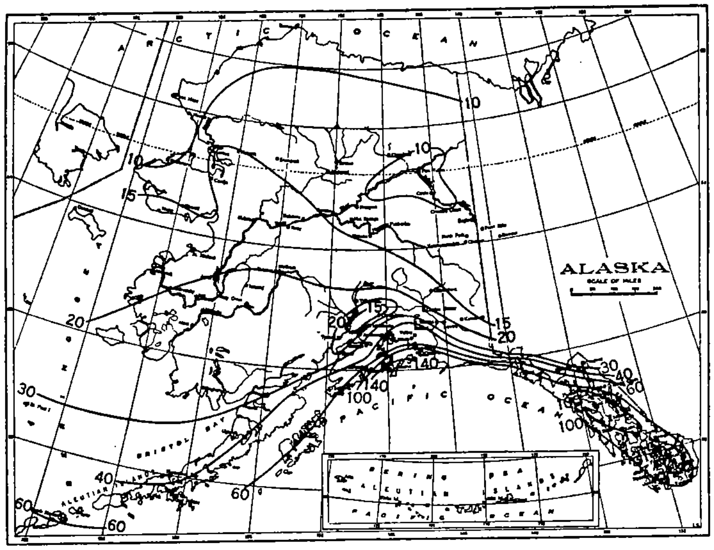

FIGURE 13.—Mean annual precipitation

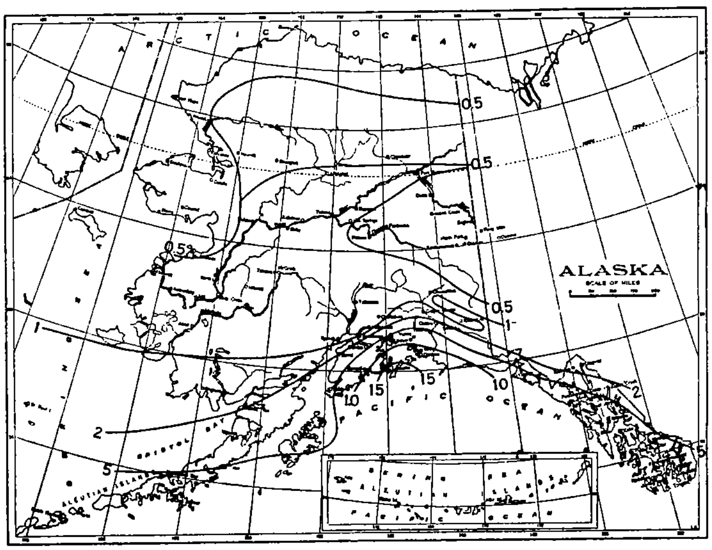

FIGURE 14.—Mean precipitation, January

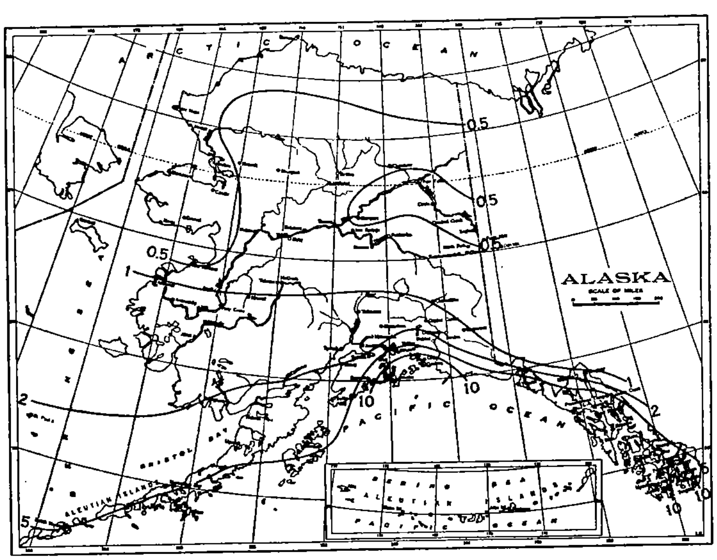

FIGURE 15.—Mean precipitation, February

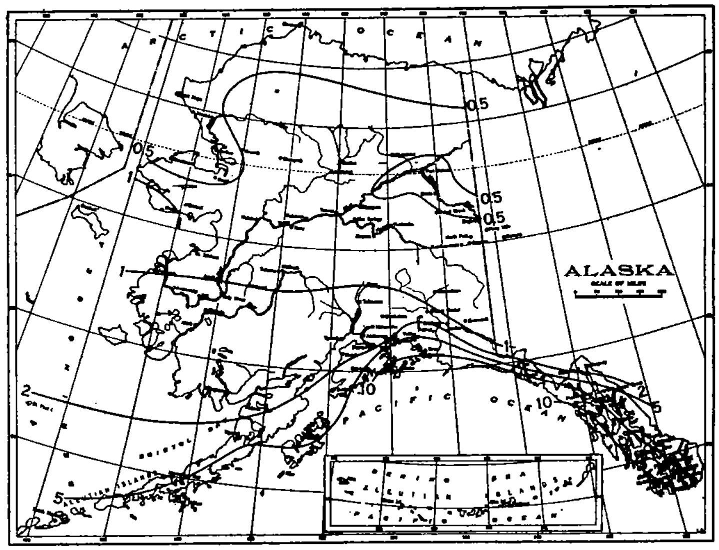

FIGURE 16.—Mean precipitation, March

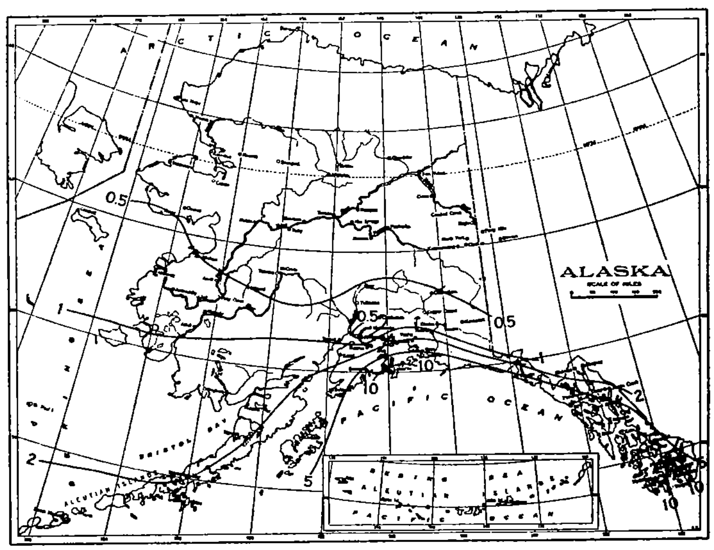

FIGURE 17.—Mean precipitation, April

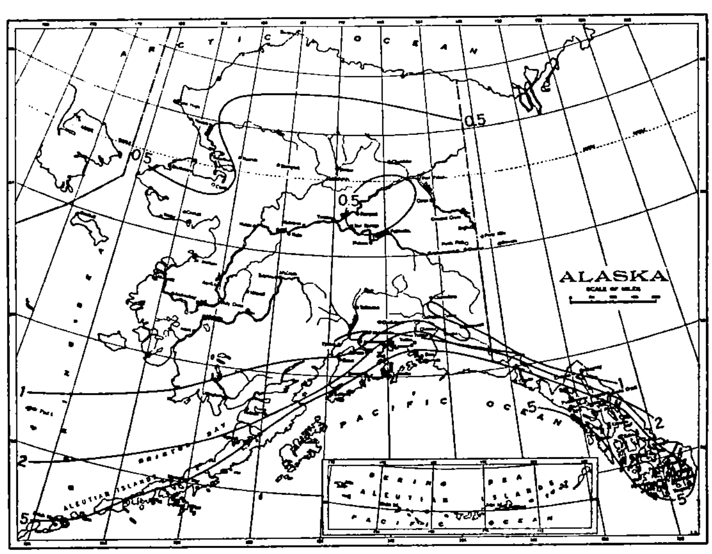

FIGURE 18.—Mean precipitation, May

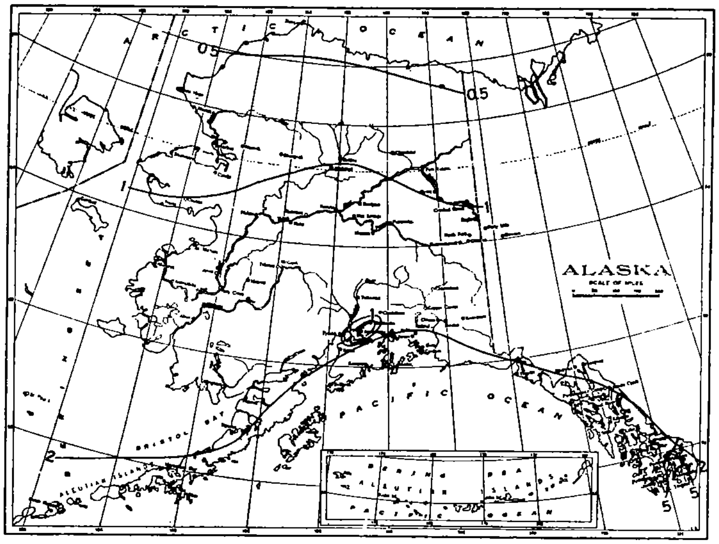

FIGURE 19.—Mean precipitation, June

FIGURE 20.—Mean precipitation, July

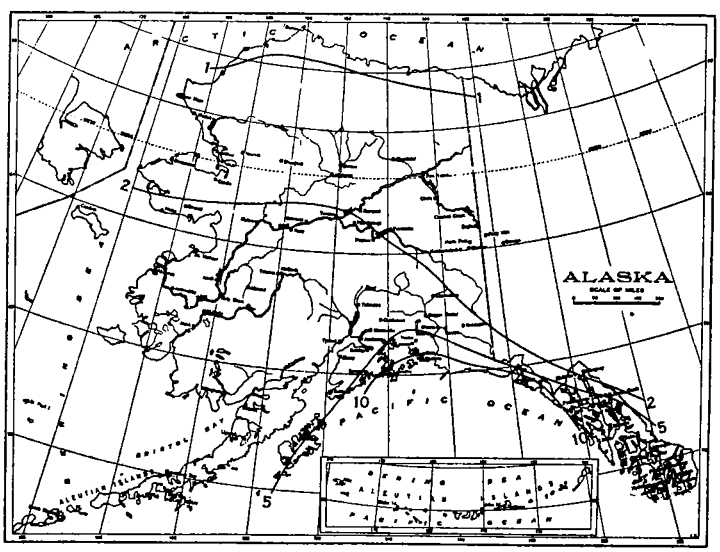

FIGURE 21.—Mean precipitation, August

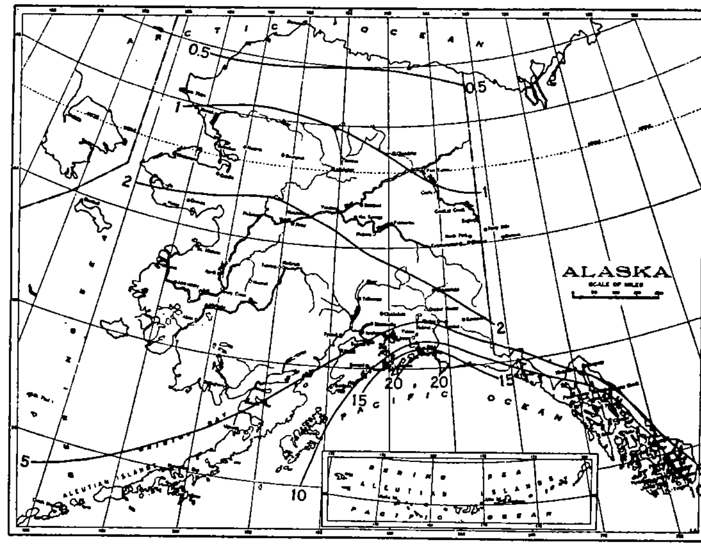

FIGURE 22.—Mean precipitation, September

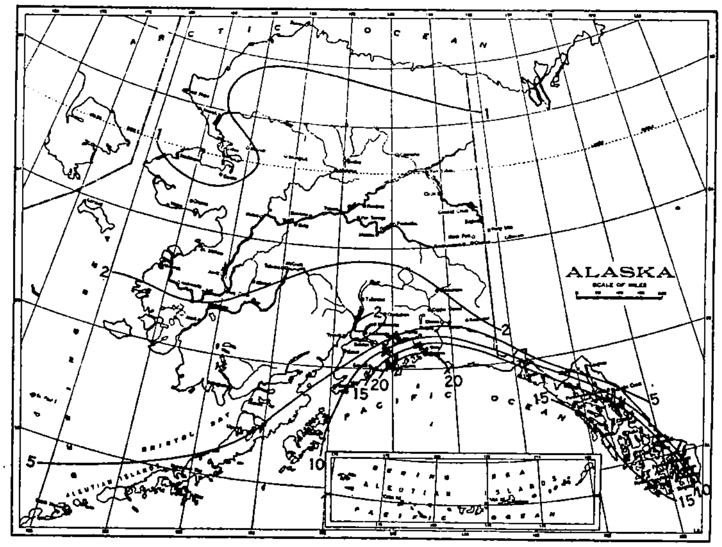

FIGURE 23.—Mean precipitation, October

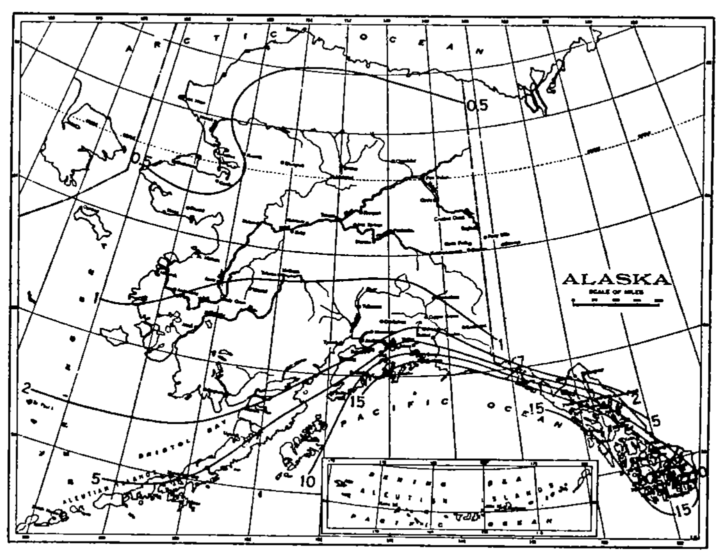

FIGURE 24.—Mean precipitation, November

Three islands of precipitation lower than that of surrounding areas are shown on the map—the Yukon Basin, the Matanuska River Valley, and the interior of the Alexander Archipelago. In each case the reduced precipitation is the result of a rain shadow effect and descending winds, because each of the regions is lower in elevation than the surrounding areas. The Yukon Basin with an elevation of 500 feet lies amid the interior plateau which

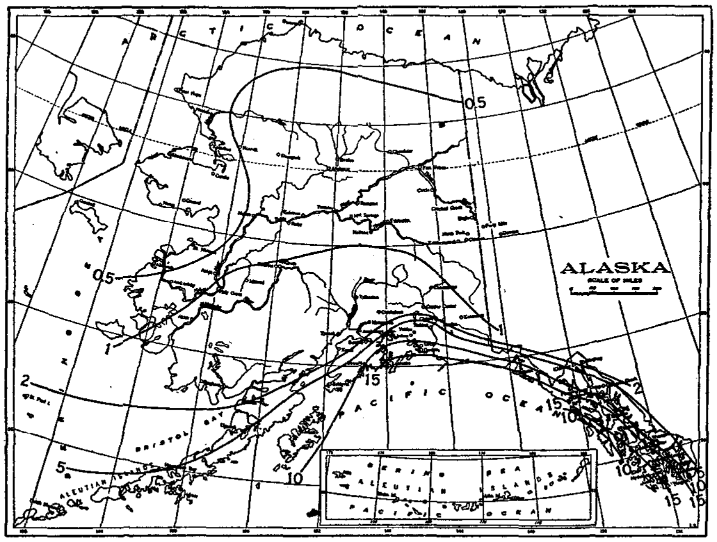

FIGURE 25.—Mean precipitation, December

averages 2,000 feet. The Matanuska River Valley is near sea level and is surrounded on three sides by mountains, the Chugach, Talkeetna, and Wrangell Mountains. It is in the rain shadow from the Chugach Mountains and receives descending winds from all directions. The low rainfall in the interior of the Alexander Archipelago is due to the rain shadow effect from the coast islands and

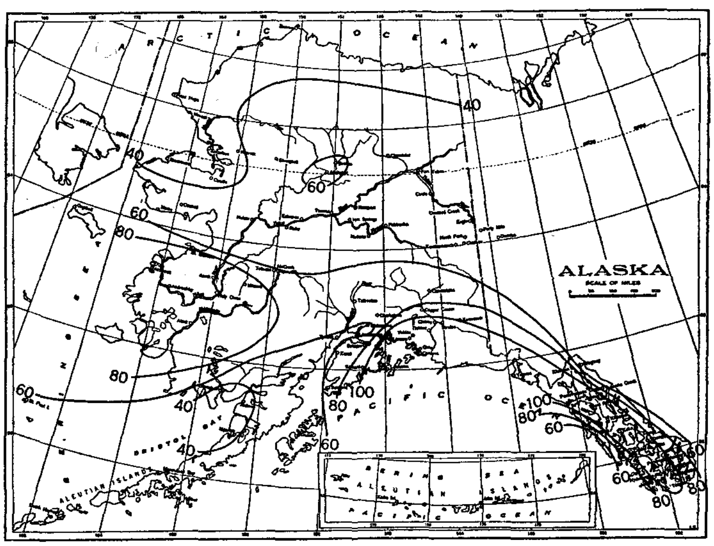

FIGURE 26.—Mean annual snowfall

to descending winds also from the eastward mountain ranges.

A generalized profile (fig. 27) extending directly north for 800 miles across Alaska from Latouche to the Arctic Ocean shows the great range in precipitation, from 172 inches to only 5 inches annually, and also brings out the effect of elevation on precipitation since it cuts across the Kenai Mountains, the Matanuska River Valley, the Alaska Range, the interior plateau, the Yukon Basin, the Brooks Range, and the Arctic coastal plain. Those points for which exact annual rainfalls are obtainable are indicated by the circles; the rest of the rainfall curve is only hypothetical. It is assumed that up to about 1,500 feet on the higher elevations of the Kenai Mountains back of Latouche the rainfall would be still higher than at Latouche,[3] but would fall off rapidly in the rain shadow region about the head of Cook Inlet. Another rise in amount is indicated by the 26 inches at Talkeetna and a still greater amount is assumed on the southward-facing slope of the Alaska Range, for this range reaches enough higher than the coast range to receive some moisture-bearing Pacific winds. North of the Alaska Range on the plateau there is a sharp falling off in precipitation. The generalization in the rainfall profile from the coast to the Yukon Valley is based, to some extent, upon parallel conditions from the California coast eastward to the Great Plains, where more data on which to base an exact profile are available.

About the same amount of precipitation is indicated across the whole interior plateau region. This seems to

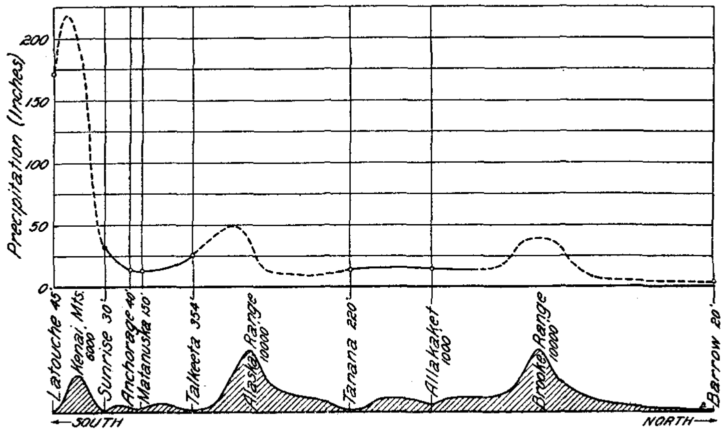

FIGURE 27.—Profile of precipitation north/south across Alaska

be justified because all the stations, of which two are on the direct north-south profile line, have annual precipitations varying no more than from 10 to 13 inches.

No actual figures for precipitation on the Brooks Range are available, but it is assumed that it would be relatively low in spite of the great height of the range. The north slope, depending on winds off the Arctic Ocean to bring in moisture, would receive little because of the coldness of the winds; the south slope, receiving winds off the Bering Sea, which are almost as much chilled as the Arctic winds and which, in addition, have crossed a broad extent of land, would also receive little precipitation. The profile shows, therefore, only about 35 inches annual precipitation for the range, the maximum probably occurring at an elevation of 4,000 to 5,000 feet,[4] with a rapid decrease in amount over the lower elevations on either side.

[3] The assumption is based on A. J. Henry's conclusions in Increase of Precipitation with Altitude. (MONTHLY WEATHER REVIEW, vol. 47, 1919, pp. 33–41.) Henry finds that on the Cascades in Washington the maximum precipitation apparently comes at an altitude of about 1,500 feet, though in Oregon the station on his west-east cross section, which has the maximum precipitation, has an elevation of only 575 feet. In Norway also the maximum is found at an altitude of 1,500 feet, Kvitingen, a station of that altitude, showing the maximum precipitation for all Norway (46). Since the Pacific coast of Alaska has geographic conditions resembling those in Washington and Norway, the maximum precipitation on the Kenai Mountains is placed at 1,500 feet.

[4] A special study of precipitation in Norway by H. W. Ahlmann (44) brings out the fact that summer time precipitation reaches its maximum at an elevation of 5,000 feet because of the lower relative humidity with high summer temperatures. Since the Brooks Range receives a summer maximum of rainfall, it is assumed that the zone of maximum precipitation on the range would be more or less in accord with that of Norway in the summer, the zone therefore being at approximately 4,000 or 5,000 feet.

The monthly rainfall maps again show the heavier precipitation along the Pacific coast. (Figs. 14–25.) It holds for every month of the year, but in July the precipitation contrast between the coast and the rest of Alaska is least and in September it is greatest. In July no place receives more than 5 inches nor less than 1 inch while in September a portion of the coast around Cordova receives over 20 inches and the Arctic coast receives less than 0.5 inch. In the summer time the HIGH in the Alaskan Gulf is conductive to on-shore winds so the rugged Pacific coast receives summer rainfall from that source as well as from the few and relatively weak cyclones which pass over the region; the amount, however, is by no means so great as the numerous cyclonic storms and great land and sea temperature contrasts of fall and early winter cause. On the other hand the rest of Alaska, becoming comparatively hot in July and August, causes convectional rainfall and this also at a time when the air is hottest and can include the most moisture. Therefore the most uniform rainfall distribution over Alaska is found in summer, especially in July.

The early fall months are seen to be the rainiest along the coast, September, October, November, and December all having considerable areas with over 15 inches and sometimes 20 inches of rainfall each month.

The islands of reduced precipitation mentioned in the discussion of the annual map may be traced through the monthly maps, the actual island formation of the isohyets showing on the January, February, March, April, May, June, July, and October maps and the tendency being represented by a bend of the isohyets around these regions on the other monthly maps.

June is the month receiving the least rainfall over the whole of Alaska; at this time the 5-inch area is very small and there is no area receiving more than 5 inches, while the whole Arctic coast receives less than 0.5 inch. The greatest total rainfall comes in October when there is quite a large 20-inch area and no part of Alaska has under 0.5 inch. The occurrence of the least rainfall in June is mainly due to the fact that cyclonic action with accompanying strong on-shore winds, is relatively weak at that season; the greatest rainfall in October comes when cyclonic action is strengthening and land and sea temperature contrasts are great.

SNOWFALL

Snowfall over Alaska is found to have a general distribution similar to the rainfall, as would be expected. (Fig. 26.) There is a heavy fall along the Pacific coast with a decrease northward to a minimum, as with total annual precipitation, along the Arctic coast.

It is along the Bering Sea coast that the snowfall map differs most decidedly from the rainfall map. The surprising variation in amount from under 40 inches around Dillingham to over 80 inches a short distance to the north is hard to explain. For one thing, the records are not long and are not for a uniform series of years so that the mean monthly and annual snowfalls are found to vary considerably. However, the annual snowfalls for the same years may be compared at Dillingham and Holy Cross as follows (**38**):

Inches of snow

	Dillingham	Holy Cross
1920	45.3	67.8
1926	19.2	43.2
1927	64.9	113.6
3-year average	43.1	74.9

These three years show consistently the great difference in the annual snowfalls and seem to indicate that the difference is an actual one rather than an apparent one due to inadequate records.

A further explanation for the difference may be found in the fact that Dillingham shows a less amount of snow in early winter and late spring than do Akulurak and Holy Cross to the north, presumably because Dillingham, with higher mean monthly temperatures, receives rain from the same storm which brings snow to Akulurak and Holy Cross. In April, Dillingham has an average of 3.6 inches of snow while Akulurak and Holy Cross have 10.3 and 8.1 inches, respectively. In October, Dillingham averages 1.2 inches while the other two stations show 1.4 and 5.8 inches. It would seem, then, that lower temperatures to the north may account for some of the difference in annual amount of snowfall, but May shows Dillingham receiving more snow than either Akulurak or Holy Cross. This is occasioned by a heavy snowfall of 25 inches in one of the 8 years of the record, all but one of the other years showing no snow at all. This instance of an individual heavy snowfall having too much weight in the average, suggests again that inadequateness of records prevents the obtaining of good long-time averages and so may account for much of the 40 to 50 inches difference between the northern and southern parts of the Bering Sea coast.

Barrow is the only recording station averaging some snowfall in every month of the year. The Pacific coast in general has 4 months without snow, the Bering Sea coast 3 months, the interior 2 months, and the far North no month without at least a trace of snow.

In the interior June and July are the months without snow while in the same latitude the Bering Sea coast has July and August free from snow, again illustrating the effect of a cold sea in retarding the maximum heating an increased number of weeks beyond normal after the highest sun.

DAYS WITH PRECIPITATION

(See figs. 2–6)

The Pacific coast, with its heavy precipitation, naturally has the greatest average number of days with rainfall. St. Paul Island, however, which averages only a third as much precipitation as the Pacific coast, has more rainy days than the coast average. It is evident that St. Paul Island, like northwestern Europe, receives most of its precipitation in a more or less continuous steady drizzle which does not give a high total even when two-thirds of the year has been rainy.

The least number of rainy days is at Kennecott, in the rain shadow of the coast mountains. Barrow has only 66 days with precipitation of 0.01 inch or more. The interior high-pressure area giving Barrow frequent land winds and clear skies instead of ocean winds, and the coldness of the ocean winds which do blow prohibiting their including much vapor, explain why it should have such a low number of rainy days.

The whole interior, which has a low total of precipitation, also has few rainy days. Here the fact that much of the precipitation comes in summer convectional showers, which tend to concentrate most of the rainfall for a month in a few showers, helps to explain the low number of rainy days.

The heaviest rainfalls in the course of 24 hours occur along the Pacific coast. The summer convectional showers of the interior seldom produce more than an inch of rain in any 24 hours and never as much as 2 inches, whereas the heavy and steady orographic and cyclonic rains of the coast often produce 4 or 5 inches in 24 hours and sometimes as much as 9 or 10 inches. In one day the rainfall of the coast may equal or surpass the yearly total received at many stations in Alaska.

Those stations which are backed by high mountains have the heaviest rainfalls, but the fact that the greatest rains come in the fall and winter when cyclonic storms are frequent and land and sea temperature contrasts are greatest shows that these two factors as well as the orographic are amplifiers of the 24-hourly maximum rainfalls.

An endeavor has been made to present in this section of the paper each of the elements of climate—sunshine, temperature, wind, and precipitation—and to show how latitude, oceanic influences, and topography as found in Alaska have determined their intensities, extremes, and averages, and have made Alaskan climates what they are. Latitude determines the possible sunshine, sunshine dominates temperature, temperature differences lead to winds, and wind causes precipitation—so much is true for any extended part of the world. But individual characteristics depend on the other factors—land and water areas and topography; hence, in Alaska it was found that the surrounding seas and marked relief have a very profound effect on the climate, mitigating extremes in some instances, emphasizing them in others, but changing the climate very materially from what it would be if latitude alone were the basis of it.

III. SEASONAL CONDITIONS IN THE CLIMATIC PROVINCES

(See fig. 1 and figs. 2–6)

In undertaking a seasonal description of weather in Alaska it seemed best to organize the discussion around each of the several distinct climatic provinces into which Alaska naturally divides itself. There is an obvious contrast between the climates of the Pacific coast and the Yukon Valley and there is a gradual but increasing coldness and dryness found in going northward along the Bering and Arctic coasts. The general limits were therefore easy to determine and, as a guide in choosing more exact boundaries, the divisions made by Supan, Herbertson, Köppen, and Ward were studied, as well as physiography, amount and seasonal distribution of rainfall, and mean monthly temperatures and ranges for the 29 representative weather stations in Alaska.

Maps 22 to 24 (not reproduced) show the Alaskan climatic provinces as delimited by Supan, Herbertson, and Köppen. (Ward has made no map of his regions.) The lettering and numbering of the provinces is the same as that appearing on these authors' maps showing climatic provinces over the whole world. Supan characterized his provinces as follows (**40**, pp. 55–60):

24=Northwest American coastal province—mild, equable, rainy climate.
1=Arctic province—no trees, and mean temperature of the warmest summer month never over 50° F.
23=Hudson (North Canadian) province—great extremes of temperature and little precipitation.

Herbertson's major natural regions are based on a unity of temperature, rainfall seasons, configuration, and vegetation; the most characteristic region in each type gives the name to that type wherever it may occur in the world. Hence, in Alaska, the characteristics of Herbertson's climatic provinces are indicated by the lettering on the map as follows (**13** and **14**):

2 a=West European.
1 a=Norway.
1 c=Tundra.
1 d=Yukon.

(1=cold; 2=cool; a=western margin of continents; c=central lowlands; d=highland or plateau.)

The Köppen classification is made on a purely climatic basis, the letters indicating the following characteristics (**16**):

Cfb=Warm, temperate, rainy, climate; constantly moist; temperature of the warmest month less than 22° C. and more than four months greater than 10° C.; damp, temperate climate.
E 10=Tundra climate, snow.
Dfc=Sub Arctic climate; constantly moist; temperature of only one to four months more than 10° C.; coldest month more than −36° C.; cold climate with dry winters.

Ward does not delimit his climatic provinces in Alaska by exact boundaries, but he takes up his discussion using the following divisions (**41**, pp. 500–509):

I=Southeastern coast.
II=Alaska Peninsula and Aleutian Islands.
III=The Arctic Shore.
IV=The Interior.

Figure 1 shows the climatic provinces on which the seasonal weather discussion in this paper has been based, the numbers indicating the following names:

Ia=Pacific coast and islands (marine).
Ib=Pacific coast and islands (rain shadow).
II=Bering Sea coast and islands (semi-ice marine).
III=Arctic coast (ice marine).
IV=Interior (cold continental).

A study of all five classifications shows that in each case a differentiation has been made between the Pacific coast region, the interior, and the Arctic coast region, and in all but Ward's classification, the Bering Sea coast has been made a separate province. Figure 1 is distinctive in that:

(*a*) The Aleutian Islands and the Alaska Peninsula south of the Aleutian Range are included with the southeastern section of Alaska. This inclusion seemed to be justified by a study of temperatures and total and seasonal rainfall for the 12 stations included in the group. The boundary line was made the summit of the Aleutian Range.

(*b*) The boundary of the Arctic province has been made the summit of the Brooks Range, though of course no station data are available to indicate this, the assumption being merely that such a high elevation would be a very effective climatic barrier. The Arctic province is made to extend southward halfway across the Seward Peninsula, meeting the coast at the narrowest point of the Bering Strait, since this point probably marks a division between Arctic Ocean and Bering Sea influences on climate.

(*c*) Province Ib is indicated as a subdivision of the Pacific section because it depends on Pacific coast conditions for its temperature and rainfall, but being behind the coastal ranges, its temperature is not so equable nor its rainfall so great as on the immediate Pacific coast. Here again the boundary lines have been made the summit of ranges. The Alaska range protects this "rain shadow" province from the extremely cold winter temperatures of the Interior and the Chugach and Wrangell Mountains prevent its receiving the heavy rainfall and moderate temperatures of the coast.

The names of the provinces are intended to denote their geographic location, from which something of their climatic characteristics may be inferred. Further indication of the outstanding features of the climate of each province is made by the brief phrase in parentheses following the names. While it is hoped that from the names of the provinces themselves the general seasonal course of each of the climatic elements may be deduced, this section has been devoted to a rather full description of seasonal weather in each province. Since the reasons generally have been given before, this section aims merely to describe seasonal conditions without any discussion of causes.

Figures 2 to 6 show graphically the monthly weather conditions for each of the provinces. The data from which these graphs were drawn were obtained by averaging the figures of all the stations in each province.

PACIFIC COAST AND ISLANDS PROVINCE (MARINE)

As the parenthetical characterization implies, this province is marked by ample rainfall with a fall and winter maximum, and by equable temperatures throughout the year.

This region, judging from a study of thermometer readings, should be the most pleasant in Alaska during the winter season. Mean temperatures for December, January, and February are but slightly below freezing, while average maximum temperatures for these months range around 45° and minimums are well above zero. Extremely low temperatures are never encountered here and ranges are too moderate to cause any discomfort on that score.

But temperature is not the only factor to be considered in determining a pleasing winter climate. The number of clear and cloudy days, frequency of fogs, amount of precipitation, and velocity and direction of winds all combine with temperature to make weather either agreeable or disagreeable as the case may be. That their combination during the winter is distinctly detrimental to the perfection of Pacific coast winter weather is apparent from what Henry Gannett says of the region at this season (**10**, p. 186):

> Take the well-known climate of San Francisco, with its dampness, fog, and cold sea winds; reduce the temperature 15° to 18° and increase the dampness and fog in proportion, and you have a fair idea of the climate of the Alaska Pacific coast.

As in any marine type of climate, cloudiness, precipitation, and fog, with accompanying lack of sunshine, are dominant features of the winter season in this section of Alaska. Only 6 to 10 hours of possible sunshine a day during the winter season is allotted to a region situated between 53° and 63° north latitude, but this section of Alaska with only an average of 35 clear days from October to February, inclusive, gets but little more than one-fifth of its allotted sunshine. Juneau receives an average of but 295 hours of sunshine during the winter, while the possible amount for its latitude is about 1,200 hours. The most northerly parts of this province with as few as five hours of possible sunshine on the shortest days would, of course, receive much fewer actual hours of sunshine than Juneau, but no records are available to show this.

Over the whole province during the winter season the monthly average of cloudy days is 20 and of clear days is 7, the remainder of the month being classed as partly cloudy. Juneau has an average cloudiness of about eight-tenths during the winter.

Though records of foggy days are lacking except for Juneau, and here they seem to be quite infrequent, Alaskan literature is filled with references to fogs. Furthermore, the contrast between the chilly air over the cold land or Bering Sea in fall and winter and the warmer, moisture-laden winds off the Pacific would certainly lead one to expect an abundance of fog. Indeed, there are stories that ships, attempting to reach ports on the Aleutian or Pribilof Islands sometimes miss the islands altogether because of fog and are forced to sail about for several days hunting for their destinations. The raw chilliness of frequent fogs, then, may be added to the general unpleasantness of the winter conditions along the Pacific coast.

In this province winter is a season of heavy precipitation, much of it coming in the form of rain at the recording stations, though it is probably mainly snow on the higher elevations. In the matter of precipitation and temperature, the station records may well be misleading for all the stations are quite near sea level, and presumably precipitation is greater and temperature less on the adjacent mountain sides. Substantiating this contention are the innumerable glaciers with which the whole of southeastern Alaska abounds, many of them of such size that they even reach the sea in spite of quite high summer temperatures.

About two-thirds of the days have precipitation amounting to at least 0.01 inch and still other days have traces. From what one hears of the type of rainfall in this section of Alaska, a "rainy day" means a steady, continuous drizzle for hours, punctuated with occasional periods of heavier downpours. Because rains are of this drizzling type, even though they last all day the maximum amounts in 24 hours generally do not average excessively high (only about 2 or 3 inches). A few instances of over 10 inches have been recorded, however, and 4 or 5 inches in a day occurs usually in each of the winter months at Cordova, Latouche, and Yakutat, though the averages for 24-hour maximums are only about 2 or 2½ inches.

Winter winds are strong, maximum velocities well over 30 miles per hour occurring at Juneau in all winter months. The prevailing direction is easterly—northeast, east, or southeast—for most of the stations during the winter. This direction is determined by the winter pressure distribution or by local topography, the whole province being a region of high relief. These winds blow from a cold region to a warmer one, though they are somewhat heated adiabatically in their descent from the eastward mountain ranges; being land winds, clear as well as cold weather accompanies them. On the other hand, the general cyclonic movement is on-shore, bringing moisture and accompanying clouds, fog, and precipitation to the coast. In this province, therefore, it seems that winter winds are disagreeable whichever way they blow, for they bring either coldness or dampness, or both (when warm ocean winds ride over cold land winds).

Spring is a transitional season marked by lengthening days, rising temperatures, variable winds, and decreasing rainfall.

Then comes summer time, in this part of Alaska said to be ideal. It is cool and clear, with long hours of daylight, and rainfall reaches its yearly minimum. June and July average under 5 inches and August between 5 and 10 inches. This is the tourist season, the mountain scenery and pleasant, invigorating climate attracting them, as do also those tangible results of climatic conditions, the scenic wonders provided by the great glaciers and the deep coniferous forests.

Summer shortly gives way to fall. September, October, and November bring the heaviest precipitation of the whole year, the days get shorter and shorter as the autumn wears on, fog, clouds, and drizzle set in with occasional snow flurries, mean temperatures gradually decrease, their decrease being slow and retarded, as was their increase, by the adjacent Pacific waters. By December the disagreeable winter season is well under way again.

PACIFIC COAST AND ISLANDS PROVINCE (RAIN SHADOW)

Between the immediate coast ranges and the crest of the high Alaska Range is a valley running from Cook Inlet to the Wrangell Mountains. While close to the Pacific Ocean the coast ranges keep out much of the ameliorating influence of the warm ocean waters and also most of the moisture-bearing winds. This region, while depending mainly upon Pacific coast influences for its climatic conditions, yet has those conditions so modified by the intervening mountain ranges that it has been made a separate province, the Alaska Range being a climatic barrier which prevents its inclusion in the interior province.

Winter temperatures are more severe than those of the coast province, for besides being shut off from tempering ocean winds, the lowness of the region, surrounded by mountain walls, causes the cold air to settle and find difficulty in draining away. The high Alaska Range, however, protects this region from the extreme cold which develops in the interior, only rarely allowing the cold winds to "spill over" into the valley, though sea-level pressure gradients would normally cause such winds to be the prevailing ones.

The number of cloudy days in winter averages about five or six a month less than on the Pacific coast, clear days being correspondingly more frequent. This region, therefore, though more northerly than the coast, probably receives as much and perhaps more sunshine than the coast because of its greater number of clear days. The lack of cloud cover is undoubtedly a factor in the lower temperatures of winter here than on the coast, for clearer skies permit greater nocturnal radiation.

A still greater decrease from coastal averages is noted in the number of rainy days in this province, there being only about one-third as many such days here as on the coast. This is, of course, due to the fact that the winds are chilled as they cross the coast ranges, thereby losing so much moisture that little is left to be precipitated in this rain-shadow region, and, furthermore, the winds are descending, and therefore warming and drying winds, as they enter this lowland.

Winter precipitation is low, averaging only a little over an inch a month. It is the precipitation factor which mainly distinguishes the region from the Pacific coast province, for besides the very much lower yearly total (less than one-sixth as much), the seasonal distribution is somewhat of the continental type. The rain-shadow province has an August and September maximum of precipitation, whereas the coast of which it is essentially a part has a September, October, and November maximum.

Spring is the least cloudy and least rainy season of the year. The winds in spring come from an ocean at its coldest temperature and so bring in the least amount of moisture, which becomes increasingly less by the time it reaches the rain-shadow region. The land is too cold to bring about convectional rains. Thus it is evident that the action of neither the marine influences which bring fall and winter precipitation nor the continental influences which bring summer rains, is vigorous enough in the spring to cause much precipitation. Hence, this is the driest season of the year.

The June, July, and August mean temperatures are practically the same as those on the Pacific coast, but the absolute ranges average between 5° and 10° higher, the maximum and minimum extremes both being somewhat greater in the rain-shadow region. The fact that the mean temperatures are slightly higher in summer in this province than on the immediate coast is probably due to its being protected by the coast ranges from the chilly ocean winds and also to its receiving more insolation, because of less cloudiness, than the coast. In spite of somewhat higher temperature in the three summer months in the rain-shadow province, the growing season averages only 109 days, while that of the coast averages 141 days. Frost days last, on the average, about 8 days longer in the spring and begin 24 days earlier in the fall in the rain-shadow province, illustrating the fact that protection from marine influences allows more rapid heating of the land in spring and more rapid cooling in the fall, the warm Pacific Ocean, with is attendant dense cloud cover, being especially effective in retarding the approach of cold weather.

Rainfall increases month by month from May to September. It seems to be a combination of convectional showers in the hottest months and a chilling of damp winds in the colder month of September. The September maximum, however, only averages 2.82 inches while in the same month the coast is receiving almost 11 inches.

Fall brings a rapid decrease in mean temperature, a 10° drop from the summer level of about 55° occurring between August and September, a similar drop from September to October, and one of 16° from October to November. This is the season of greatest number of cloudy days, these days continuing to be numerous though the rainfall decreases considerably.

It will be noted that this province has features of both continental and marine climates. It has a fairly low annual range of temperature and an early fall maximum of precipitation, both of which characteristics are marine; on the other hand it has greater extremes of temperature than the coast, and its summer precipitation is more than that of late fall and winter, which shows continental influences. Furthermore, its distinctly low total of precipitation precludes its climate being thought of as essentially marine. However, the fact that this rain-shadow region has a comparatively low annual range of temperature and an early fall maximum of precipitation indicates that it is dependent on Pacific coast conditions for its climate and it is therefore made a subdivision of that province.

BERING SEA COAST AND ISLANDS PROVINCE (SEMI-ICE MARINE)

Much of this province is a level, deltaic or coastal plain area where physiographic and climatic conditions favor a tundra formation. Trees grow only along the stream courses where drainage is better (**3**, pp. 98 and 99). The hummocky, moss-covered, ground never thaws to any great depth and is therefore always undrained and swampy, often with water standing between the hummocks in the warm season. It has been found that clearing off the tundra vegetation allows the ground to thaw sufficiently to make agriculture practical, but of course, this has not been undertaken on any vast scale (**9**).

Being farther north and also bordered by a colder sea, winter comes earlier and attains greater severity here than on the Pacific coast, the mean temperatures averaging below 10° F. during December, January, and February, while absolute minimum temperatures average well below zero from December to March.

The maximum wind velocities for Nome are always higher than for Juneau, as would be expected, for Juneau is protected by high mountains while Nome and all the Bering Sea coast area is subject to high winds sweeping across the flat surfaces of the ocean or the tundra. There are not even trees to break the winds as there are in the interior, and with a prevailing northerly direction during the winter importing cold air from the polar ice cap, the importance of wind as one of the most disagreeable elements of the winter climate is evident.

Winter precipitation is light and comes practically all in the form of snow. An average of about 35 inches of snow falls from December to February, but the strong winds sweep many places clean and leave the snow piled in drifts where any protection is afforded. March brings a somewhat heavier snowfall than any of the three colder months, for in all this Arctic world the most severely cold weather is clear and it is the warmer springtime that brings clouds, snows, and rains.

Summer time shows a still higher percentage of cloudy days than spring, and has the maximum rainfall. In spite of a marine location, the Bering Sea coast has a continental seasonal rainfall distribution, apparently for two reasons. In the first place, the sea freezes over much of its area during the winter and this ice surface tends to take on land characteristics, which puts the Bering Sea coast, as it were, within a polar continent with no open seas close at hand from which moisture for winter precipitation could be brought; in the second place, the very low temperatures prevent the winds from gathering much moisture from open seas, "leads," or the ice itself, even when it is available. But the warmer days of summer, breaking up the ice and heating the land, cause convectional showers from the increased available moisture in the air and consequently the Bering Sea coast has a continental summer maximum of precipitation.

Maximum temperatures of over 80° may occur in June, July, and August, as may also minimums below freezing. George Byron Gordon, writing of a trip down the Kuskokwim River, says that the July sun "though not hot, had sufficient power to inflict a burn" (**11**, p. 47). He encountered only two thunderstorms during the whole summer's trip (1907), but apparently felt it to be rather unusual.

From August 10 on it begins to grow colder (**11**, pp. 99 and 100), but the figures show the greatest drop in mean temperature to be between September and October. September, Gordon says, is a month of heavy fog along the coast, as would be expected, for the land is at that time more chilled than the sea. By the end of September the sea has begun to freeze around Nome (**11**, p. 163), and winter is setting in once more.

While having a marine location, the fact that the Bering Sea is frozen during so much of the year modifies greatly the marine features of the climate. Hence, the name "Semi-ice Marine." The ice cover allows temperatures to go much lower than would be the case were the sea unfrozen; it provides much less moisture to the air and hence less precipitation to the land than open water would; it retards the coming of spring even more than ordinary large water bodies would, for so much of the sun's heat is needed to melt the ice before actual heating of the water can begin; it causes a summer maximum of precipitation by providing little moisture from its frozen surface and by chilling the air to such an extent that it can include very little vapor. Chiefly in these four ways does the ice cover modify the marine features of the Bering Sea coast climate, making it verge on the continental type.

ARCTIC COAST PROVINCE (ICE—MARINE)

> In the main the country traversed (the Arctic coast of Alaska) is as dreary and naked as I suppose can be found on earth, and cursed with as bitter a climate; yet it is not without scenes of great beauty and even sublimity, and its winter aspects have often an almost indescribable charm; a radiance of light, a delicate luster of azure and pink, that turns jagged ice and wind-swept snow into marble and alabaster and crystal. . . .

So writes Hudson Stuck, archdeacon of the Yukon and the Arctic, describing a winter journey he made along the Arctic coast (**25**, p. ix).

Winter conditions may be said to last the year round in this province, the only seasonal differences being a variation in intensity. Every month may bring snow and freezing temperatures, and from October to May temperatures below zero occur. At Barrow at least a trace of snow is recorded in each summer month every year for which there is a record. Candle, the only other station in the province and almost 400 miles farther south than Barrow, is generally free of snow in June, July, and August; but this situation can not be depended upon, for one year out of five is likely to bring at least a trace of snow in any of these months.

Though snow may fall throughout the year, it does not reach any appreciable depth, averaging only about 30 inches annually. Due to the very high winds, much of the land is blown free of snow, what little there is being piled in drifts in sheltered places. For protection against these high winds and the cold made more bitter by them, most of the native buildings are put partially underground. Doctor Stuck most vividly describes winter stormy weather on the Arctic coast such as he experienced while staying at the little settlement of Point Hope, located on a sand spit jutting into the Arctic Ocean about 250 miles west of Barrow (**25**, p. 106):

> The country between these elevations (Cape Thomson and Cape Lisburne) seems to form a natural chute for the northeast blizzards that prevail during the winter, and lying thus at the mouth of the chute, the barren sand spit is swept by gales of a prolonged ferocity that we who knew only the forested interior of Alaska had no experience to match. From the 1st to the 8th of January, 1918, without, I think, a moment's cessation, day or night, a raging blast prevailed from that quarter, with the thermometer at 15° to 30° below zero F., and that was only one of many storms during our six or seven weeks at the place. At what rate the wind blew I could not guess. There had been several installations of an anemometer at the mission, and the interior mechanism yet remained, but the vane had been blown off every time. If the reader will add to these violent, persistent winds, first the driving snow and sand with which they are charged, then the cold that accompanies them, and then the darkness, at a season when the sun does not rise above the horizon at all, he will understand that any continuous travel against them is out of the question, and that even to be outdoors upon necessary occasions while they rage is fraught with discomfort and difficulty, not to say danger. Storms we have in the interior, in certain regions, and especially in certain reaches of rivers, high winds that blow for many hours in one direction, but nothing that I have known in 10 years of winter travel comparable to these awful Arctic blizzards.[6]

But storms, wind, and low temperatures are not continuous—cyclonic variations in weather occur and are welcomed even as they are welcomed in more temperate climates. Temperatures may rise from −40° to −10° and seem, by contrast, quite comfortable, especially if accompanied by a calm. "Thirty-seven degrees below zero is not a bad temperature for traveling if it be calm" (**25**, p. 286).

Calms, however, give rise to another disagreeable feature of Arctic winters—fog. Doctor Stuck says: "This whole coast is an exceedingly dangerous one, beset by fog when it is calm and lashed by gales almost whenever it is clear" (**25**, p. 166). Before the extreme and dry cold of winter becomes firmly established, the air contains more or less moisture which causes frequent fogs in November and December when temperatures go low enough to condense the moisture. Cyclonic storms

[6] Doctor Stuck made this trip in 1917-18 which is the worst winter on record in Alaska (8), so that perhaps the awfulness of his picture of Arctic winter weather may be modified somewhat in normal years.

cause the same conditions even in February for Doctor Stuck mentions the following occurrence during his February journey from Point Hope to Point Barrow (**25**, p. 203):

> A rapid fall of temperature to 30° below zero had brought the usual accompaniment of fog. The moisture with which the air had been loaded in the late snowstorm and comparative high temperatures, was now condensing and would presently be deposited as hoar frost, then the air would be clear.

March and April, when the cold has relaxed somewhat, bring frequent fogs. Wilkins and Stefansson both experienced and made note of these spring fogs. Wilkins writes (**42**, p. 534):

> But spring conditions had already set in at Barrow. The fog which had hitherto cloaked only the tundra was creeping out over the Arctic Sea ice. * * * Hoping that we might have at least one clear day, we waited for a period of two weeks; but the fog did not lift.

Stefansson, writing of conditions on the ice near Banks Island on April 10, says (**23**, p. 296):

> It was exceedingly cold and clouds of steam were seen rising here and there. These worried us a bit, for we thought they might be from opening leads, danger signals that the break up of our ice had commenced. But there was about an even chance they might be rising merely because 6-inch ice is so warm from the water underneath that it throws off clouds of vapor if the air is at a low temperature.

Climatologically speaking, ice conditions along the Arctic coast are of great importance because of their modification of the marine features of the elements of temperature and moisture. The effects of the ice cover are the same as those described for the Bering Sea coast, but are of longer duration. The "fast ice" breaks up perhaps only for six weeks in the summer, allowing the passage of ships along the coast. The United States revenue cutter makes a yearly trip to Barrow and trading vessels go along the coast as far as Herschel Island near the mouth of the Mackenzie. The ice begins to break up in May and June, starting from a "flaw" a mile or so offshore between the "fast ice" and the "pack ice" (**22**, p. 92). August is probably the best month for water travel though in some years the ice may never break sufficiently to let boats through. By October the ice cover is forming again from the shore, reaching its greatest extent about December, but continuing to grow in thickness the whole winter and spring up to May (**12**, p. 109).

Summer comes quickly, brought on by the rapid change in length of days. Then the coast reveals itself as a tundra area, flower and moss covered and very marshy, the still frozen ground below preventing proper drainage. Temperatures rise until a mean of about 45° is attained in July and August and maximums between 70° and 80° are recorded at Barrow and even over 80° at Candle. But winds off the Arctic ice still bring minimums below freezing.

After the darkness and semidarkness of winter one would expect inhabitants of these northern latitudes to look forward with joy to the long hours of daylight in the summer time. That this is not strictly the case is brought out in the following quotation from Doctor Stuck (**25**, p. 210):

> The sun is absent in the winter for two full months—from the 21st of November to the 21st of January, which, of course, does not mean that daylight is totally absent, as some seem to think, but only that the sun is not seen. Conversely, in summer he does not leave the sky for two full months and there is daylight all night for almost two months more. To most residents in these latitudes I think the perpetual sunshine is more trying than the darkness, for there are always three or four hours' daylight on the darkest day, but there is no escape from the glare of the sun, no kindly decent gloom for the hours of repose.

July and August bring the greatest amount of precipitation, these being the only two months of the year with over an inch. The delay of maximum temperatures and of heaviest rainfall until July and August, several weeks after the highest sun, results from the use of all the heat in early summer to melt and evaporate the ice and snow cover, rather than to warm up the land. By September days are getting shorter and by October the heat from the sun is easily overcome by nocturnal radiation and cold sets in again. The shores become icebound, precipitation comes in the form of snow and remains, the people don their fur clothes once more, and prepare to spend most of their days in their underground homes. From November till the next May no temperature above freezing can be expected at Barrow, and from December until April even the means are well below zero.

INTERIOR PROVINCE (COLD CONTINENTAL)

This is the province having the greatest diurnal and annual temperature contrasts in all Alaska, which, with its summer maximum of precipitation, characterizes it as "continental."

Winter, with its long hours of darkness every day, gets very cold—colder than anything along the Arctic coast, where tempering marine influences make themselves felt in spite of the ice sheet. Temperatures as low as −70° have been recorded and the winter mean temperatures are lower than those of the Arctic coast, though the maximums are higher. The lowest temperatures occur when the weather is clear, for clear skies foster the utmost radiation. Wind velocity in the interior does not compare with that of the Arctic coast, the sweep of the winds being broken by the varied relief and the forest cover, and, indeed, even being prevented from reaching a valley bottom because the valleys are often filled with very dense, cold air; furthermore, the air contains little moisture; therefore the low temperatures can be supported more easily here than the somewhat higher minimums of the Arctic coast, which are accompanied by strong, damp, northeast winds off the ice. Moreover, the variety of weather brought by cyclonic action does not usually allow the coldest weather to last for a very long time.[6]

Cloudy days in the interior province in winter number slightly over 10 a month, being somewhat more numerous than on the Arctic coast but by no means so numerous as in the other two coast provinces. Winter precipitation in this province is chiefly snow, the average for the year being about 50 inches, 20 inches more than in the Arctic coast province and about that received in Massachusetts. Each of the months from October through March receives about the same amount of snowfall, the average being 8 inches a month.

Rapid lengthening of the days brings a quite sudden shift from winter to spring for the long hours of sunshine exercise a thawing action even while air temperatures are low. As soon as the snow is melted and evaporated from exposed places, temperatures rise quickly, the greatest differences being noticeable between the means of March and April. Within a week flowers and green leaves appear on plants and trees, geese and ducks arrive, and other birds soon follow (**22**, p. 113). Then, too, come mosquitoes—"far more serious in the minds of all who know than winter darkness, extreme cold, or violent winds," says Stefansson (**23**, p. 245).

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[6] An instance of a long period of cold weather was that experienced at Eagle in December, 1917. The temperature never rose above −25° and the mean for the month was −46°; the lowest previous mean for the same month, in a more or less complete record covering 30 years, was −23° (**8**).

Summer is a more significant season in this Province than in the other Alaskan Provinces for it offers a greater contrast to winter conditions. In the other Provinces the contrast between summer and winter is very materially reduced by marine and ice influences, so much so along the Arctic and Bering coasts that summer can scarcely be said to come at all. Such conditions would obtain in the interior Province were it not for the smaller amount of snow or ice cover and the greater ease with which land bodies absorb heat and therefore the quite warm temperatures attained in the interior in the summer are the more conspicuous. The midsummer means are higher than those experienced in Massachusetts in May and October and maximum temperatures from May to August may be over 80° and in July even over 90°.

The rapid heating of the Yukon country quickly brings temperatures high enough for planting. The growing season lasts from the 1st of June until the end of August, allowing sufficient time for the ripening of native and cultivated berries, vegetables, and even some grains, though weather conditions are usually too precarious to make profitable any attempt to grow wheat.

Summer is also the season of maximum precipitation, which fact is favorable for cultivation. Though this precipitation is not high, being but little over an inch a month in the summer and only about 11 inches for the year, the low rate of evaporation when temperatures are low makes this amount sufficient for agricultural purposes as well as for the growth of quite abundant forests of birch, willow, alder, and spruce.

The shortening days of August and September bring in cold weather again, and greatest drop in mean temperatures occurring between September and October. The coming of the cold is hastened in the interior for there is no large water body to retain the warmth for a long period of time. Late in October the rivers are all closed for water travel but November finds them frozen solid enough to make smooth going, rapid ice travel possible (**25**, p. 4). The snow and ice covers increase the possibility of extremely low temperatures and so winter again grips the land.

In Alaska, as elsewhere, climate is really the basic element of the environment. But in polar regions more than in other parts of the world, the climate is so extreme that it demands a more perfect adjustment on the part of man, animals, and vegetation than a more temperate climate requires. In order to live at all every living thing must provide itself with adequate protection against the low temperatures, the high winds, and the scant precipitation. Climate is in no way a passive factor which matters little one way or another—it is a very active, paramount consideration in all phases of every day living.

Thus one finds Doctor Stuck, primarily interested in the human affairs of his large archdeaconry, continually hampered or favored in the accomplishment of his work by climatic conditions. His books have references to the weather on practically every page and the same is true of most Alaskan books. Alaskan weather is not something that may be taken for granted, it demands and receives notice.

In this section, as in Section II, the contrast between the Pacific coast region of Alaska and the rest of it has been brought out time and time again. The Pacific coast region has a really temperate climate resembling that of the northwestern coast of the United States, whereas all the rest of Alaska has a distinctly cold type of climate the year round, modified mainly by proximity to, or distance from, the surrounding oceans. Thus, in a broad way, this paper has been concerned mainly with describing the extremes of a polar climate in contrast to the moderateness of a temperate marine climate, the distinctive features of each being made more prominent because of the sharp differences between them.

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GULF STREAM STUDIES: GENERAL METEOROLOGICAL PROJECT

By CHARLES F. BROOKS

[Clark University, Worcester, Mass., March 15, 1930]

THE GULF STREAM AND THE WEATHER

It is the common impression along the Atlantic seaboard that the Gulf Stream has important effects on the weather. When the wind blows on-shore from an easterly to southerly direction for some time, balmy air, of soft springlike quality, usually reaches the shores. A number of such occurrences in a season suggest that the Gulf Stream is nearer or warmer than usual.

But there is another side to the matter. Winds are prevailingly offshore in the colder months, so the character of these land winds will dominate the season. Winds from the west or northwest are generally cool and dry on the Atlantic slope, and the stronger they are the more pronounced are these characteristics. More northerly winds now and then attend much snowfall.

Now, how can the Gulf Stream have anything to do with these winds blowing toward it? Through storms, is the answer. We know that, whatever the wind direction and velocity, they are in accordance with the particular distribution of pressure at the time. To provide a maximum of westerly to northerly winds, therefore, we should have a frequent occurrence of low-pressure areas centered off the coast (1). And this will occur most readily when conditions most favor storms there. It is generally agreed that the sources of energy for oceanic storms are abundant heat energy latent in water vapor and marked contrasts in temperature. The Gulf Stream supplies much water vapor and its warmth is in great contrast to the coolness of the neighboring continent. Therefore, the Gulf Stream favors the very winds and snows that make our eastern climates cooler than the averages for their latitudes.

THE GULF STREAM

High temperature, speed, magnitude, and location make the Gulf Stream the best known of all ocean currents. The habitability of northwestern Europe is commonly ascribed to the high temperatures of the Gulf Stream, though this current is only part of the warm flow that ameliorates European climate (2). The climatic importance of the Gulf Stream and the other warm waters of the western Atlantic has still to be fully appreciated. It is generally recognized, however, that these warm seas are the sources of rainfall for eastern North America and the progenitors of storms.