1971
USDA Forest Service Research Paper PNW-126

FIRE SEASON CLIMATIC ZONES OF MAINLAND ALASKA

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ABSTRACT

Calculated values of precipitation effectiveness index and temperature efficiency index for 48 weather observation stations on the Alaska mainland are used to delineate areas that have different climatic subclassifications during the wildfire season of April through September. The paper outlines procedures, provides maps showing step-by-step analysis along with the resulting areal boundaries, and suggests possible uses of the information.

Keywords: Climatology, fire prevention.

ACKNOWLEDGMENTS

This study was produced in cooperation with the Forestry Sciences Laboratory, Pacific Northwest Forest and Range Experiment Station, Forest Service, U. S. Department of Agriculture. Many helpful ideas were received from Mr. Albert L. Comiskey, Fire Weather Supervisor, National Weather Service, Anchorage, who also cooperated in the analysis of the maps.

INTRODUCTION

The fire weather forecaster's area of interest in the climate of Alaska is the Alaska mainland--that part of the State lying between the Canadian border on the east and the Bering Sea on the west and between the Brooks Range on the north and the Gulf of Alaska on the south. A major problem in making forecasts for this area, however, is that the only classifications of climate hitherto available have shown broad categories, each containing wide ranges of precipitation and temperature. Furthermore, all the classification systems have been based on annual values of these parameters. The climatological regions of mainland Alaska were described by Watson[1/] as four zones:

1. A zone dominated by maritime influences, which would include the north coast of the Gulf of Alaska.

2. A zone of transition between maritime and continental climatic influences.
   a. The Copper River basin.
   b. Cook Inlet.
   c. West-central area--southern Seward Peninsula and the deltas of the Yukon and Kuskokwim Rivers.

3. A zone dominated by continental climatic influences, referred to as the interior basin.

4. A zone of dominant arctic influences, referred to as the Arctic drainage.

Other climatological systems, among them those of Fitton,[2/] U.S. Department of Agriculture,[3/] and U.S. Army Air Force,[4/] display similar classification patterns. Thornthwaite[5/] categorized the climate of mainland Alaska into two types--taiga and tundra, both moisture

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1/ D. C. Watson. Climate of the States - Alaska. Weather Bur., U.S. Dep. Commer. Climatography of the United States No. 60-49, 8 p., 1959.

2/ Edith M. Fitton. The climates of Alaska. Mon. Weather Rev. 58(3): 85-103, illus., 1930.

3/ U.S. Department of Agriculture. Climate and man, yearbook of the Department of Agriculture. Washington, D.C. 1,248 p., illus., 1941.

4/ U.S. Army Air Force. Climatic atlas for Alaska. Weather Inform. Br. Rep. 444, 229 p., 1943.

5/ C. Warren Thornthwaite. The climates of North America according to a new classification. Geogr. Rev. 21: 633-655, illus., 1931.

deficient--on the basis of calculated values of precipitation effectiveness index (PEI) and temperature efficiency index (TEI), which integrate temperature and precipitation. All these classification systems are acceptable for general climatic considerations but lack sufficient detail to be of value for forecasting for a single-season activity such as fire control. These broad climatic regimes in Alaska can be subdivided into smaller areas of reasonably homogeneous climate. The objective of this report, therefore, is to outline more specifically the fire-season climatic zones of the Alaska mainland.

SCOPE

The scope of this report is that afforded by available climatic data. These data consist of observations of temperature and precipitation from 48 weather observation stations, as listed in table 1 and shown on figure 1, operated by the Bureau of Land Management, the Federal Aviation Administration, the U.S. Air Force, the National Weather Service, and the Alaska State Highway Department, for the months of April through September, 1956 through 1965. The restriction limiting the stations to mainland Alaska serves to exclude the Arctic Slope, the Aleutian Island chain, and the Alaska Panhandle southeast of Yakutat, but encompasses the portions of the State that are chiefly affected by wildfires.

This report is intended to provide a "first look" at some of the differences that exist in what can be called fire weather climate classifications.

METHODS

Thornthwaite's PEI and TEI were selected as the basis of the climatic subclassification because large quantities of data were involved; and since the calculation of PEI and TEI is entirely numerical, computer techniques were easily applied. Minor modifications were made to Thornthwaite's procedures. Maximum daily temperature was used in this study because it was the only data available. This use of maximum daily temperature does not change the relationships between the various climatic subclassifications which are only relative. Thornthwaite's precipitation index is

$$I = \sum_{n=1}^{12} 115 \left(\frac{P}{T-10}\right)_n^{\frac{10}{9}} \qquad (1)$$

where P is the normal monthly precipitation in inches and T is the normal monthly temperature in degrees F. ($T < 28.4^{\circ}$F. = 28.4°F.).

For the purpose of this study, Thornthwaite's formulas 1 and 3 were modified. PEI and TEI as used in this study are average values for the

Table 1.--*Station values of the precipitation effectiveness index and the temperature efficiency index for the stations used in the report*

Station number,[1/] name, and agency[2/]	Station precipitation effectiveness index (PEI)	Station temperature efficiency index (TEI)	Data base, number of months (M)
1. Allakaket, NWS Climat	15.5	20.8	54
2. Anchorage, NWS	17.6	21.0	60
3. Aniak, NWS	22.1	20.3	48
4. Bethel, NWS	23.7	16.3	60
5. Bettles, FAA	14.5	21.6	60
6. Big Delta, FAA	15.5	20.8	60
7. Cape Newenham, USAF	43.3	13.0	43
8. Cape Romanzof, USAF	43.7	11.2	57
9. Chitina, NWS Climat	7.5	23.5	46
10. Circle Hot Springs, NWS Climat	12.4	23.4	60
11. Dillingham, NWS	26.7	21.2	57
12. Eagle, NWS Climat	11.7	21.2	54
13. Eielson Air Force Base, USAF	15.2	23.6	57
14. Fairbanks, NWS	11.8	22.8	60
15. Farewell, NWS	25.2	17.6	60
16. Flat, NWS Climat	14.7	22.7	30
17. Fort Yukon, NWS	7.7	20.8	58
18. Galena, USAF	19.4	19.3	60
19. Gulkana, NWS	12.7	22.0	60
20. Holy Cross, NWS Climat	20.5	21.3	60
21. Homer, NWS	21.2	18.1	60
22. Hughes, NWS Climat	18.7	19.8	54
23. Iliamna, NWS	33.9	17.8	60
24. Kenai, FAA	24.2	18.4	60
25. King Salmon, NWS	20.3	20.5	60
26. Kotzebue, NWS	15.2	13.3	60
27. Lake Minchumina, NWS	20.0	19.7	60
28. Manley Hot Springs, NWS Climat	16.7	25.0	59
29. McGrath, NWS	19.7	20.0	60
30. Moses Point, FAA	24.2	16.4	60
31. Nenana, FAA	14.8	21.9	60
32. Nome, NWS	22.0	14.2	60
33. Northway, FAA	13.6	21.1	58
34. Palmer, FAA	14.8	23.7	53
35. Paxson, NWS Climat	30.0	18.2	26
36. Puntilla, NWS Climat	15.2	17.8	56
37. Sheep Mountain, NWS Climat	17.0	19.7	52
38. Slana, NWS Climat	21.0	24.9	46
39. Sleetmute, BLM	20.6	20.6	35
40. Sparrevohn, USAF	29.2	17.3	35
41. Summit, NWS	28.6	14.4	60
42. Talkeetna, FAA	32.4	22.3	60
43. Tanacross, BLM	10.6	25.3	46
44. Tanana, FAA	19.3	20.7	60
45. Tok, NWS Climat	7.4	24.5	53
46. Trim's Camp, ASHD	41.8	17.5	55
47. Unalakleet, FAA	27.3	14.6	60
48. Utopia Creek, USAF	18.7	19.8	60

1/ Keyed to location of station on figure 1.

2/ Source of data: NWS Climat = National Weather Service Climatological Station
NWS = National Weather Service Observation Station
BLM = Bureau of Land Management Fire Weather Station
USAF = U.S. Air Force Weather Station
FAA = Federal Aviation Administration Station
ASHD = Alaska State Highway Department Station

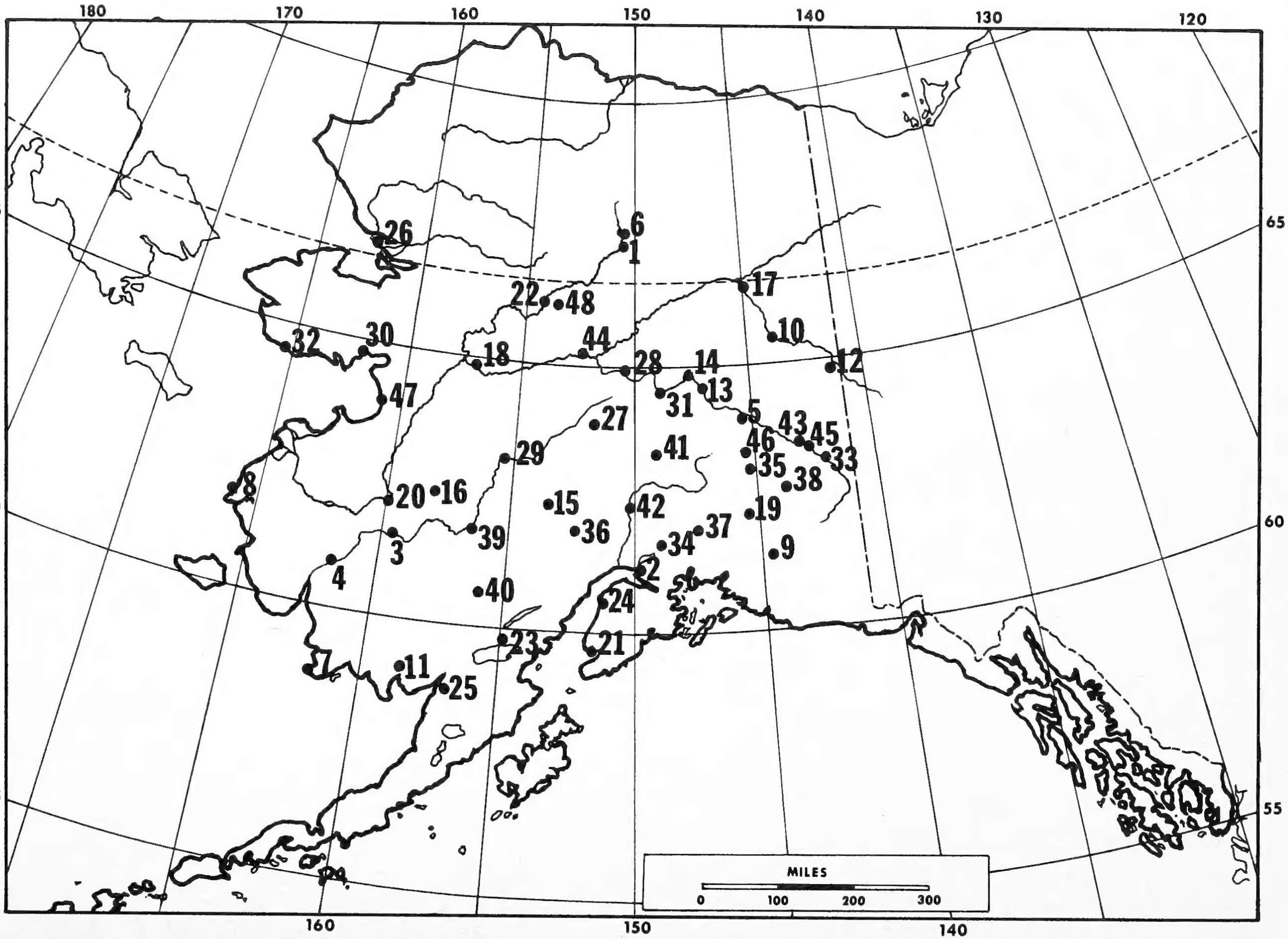

Figure 1.–Location of weather stations used as data source for this study.

6-month fire season of April-September covering the period of record as shown in table 1.

$$\mathrm{PEI} = \left[\frac{\sum_{n=1}^{M} 115\left(\frac{P'}{T'-10}\right)_n^{\frac{10}{9}}}{M}\right]_6 \qquad (2)$$

where P' is the total precipitation for each month, T' is the mean maximum daily temperature for each month in degrees F. ($T' < 28.4^{\circ}$F. = 28.4°F.) and M is the number of months of data.

Thornthwaite's temperature efficiency index is:

$$I' = \sum_{n=1}^{12} \left(\frac{T-32}{4}\right)_n \qquad (3)$$

where T = normal monthly temperature values in degrees F. ($T < 32^{\circ}$F. = 32°F.). Formula 3 was also modified for the purpose of the study. The modified version of the formula is:

$$\mathrm{TEI} = \left[\frac{\sum_{n=1}^{M} \left(\frac{T'-32}{4}\right)_n}{M}\right]_6 \qquad (4)$$

where T' is the mean maximum daily temperature for each month in degrees F. ($T' < 32^{\circ}$F. = 32°F.) and M is the number of months of data used.

Maximum daily temperature, which usually occurs about 1400 local standard time, is used to calculate the values of PEI and TEI. Landsberg[6] gives the approximate optimum length of record for observations of temperature for plains and mountainous terrain in tropical regions as 15 to 20 years; for humidity, the period is 5 to 10 years; and for rainfall, 40 to 50 years. In the area of Alaska, no stations being considered had 50 years of data as of 1965, and only four stations had data for 40 years. A total of 17 stations had data for 25 years. In order to obtain as dense a network of data as possible, the time period for the report was fixed at 10 years. This represents a compromise. High network density with short-term records was considered more important than the need for the smoothing effect produced by use of low network density with long-term records.

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[6] H. E. Landsberg and W. C. Jacobs. Applied climatology. *In* Compendium of meteorology, p. 976-992. Baltimore: Waverly Press, Inc., 1960.

A computer program was written to calculate the PEI and TEI for each month of the fire season period of April through September, 1956 through 1965, for each of the 48 stations. The monthly values were added to produce 10 seasonal values, from which a seasonal average was calculated to produce PEI and TEI values for the station (table 1). The mean and the standard deviation of PEI and TEI values for the 48 stations were then calculated. For TEI, the mean is 19.8 and the standard deviation is 3.3. For PEI, the mean is 20.4 and the standard deviation is 8.6. Station values of PEI and TEI were then plotted separately on two maps and isolines drawn (figs. 2 and 3) for the following intervals: at the mean, at one standard deviation above the mean, and at one standard deviation below the mean. Thus each map appeared with four classes of areas as described in table 2.

Table 2.--*Names and class limits of precipitation effectiveness index and temperature efficiency index in climatic zones*

Item	PEI name	Class limits	TEI name	Class limits
$>(\bar{x} + \sigma)$	Wet	>29.0	Hot	>23.1
$\bar{x}$ to $(\bar{x} + \sigma)$	Moist	20.4-29.0	Warm	19.8-23.1
$\bar{x}$ to $(\bar{x} - \sigma)$	Dry	11.8-20.3	Cool	16.5-19.7
$<(\bar{x} - \sigma)$	Arid	<11.8	Cold	<16.5

For the PEI, the classes were: an arid area encompassing those regions where the value of PEI fell beyond one standard deviation below the mean, a dry area where the PEI fell between the mean and one standard deviation below the mean, a moist area where the PEI fell between the mean and one standard deviation above the mean, and a wet area where the PEI was beyond one standard deviation above the mean. In a similar manner, the TEI map was divided into cold, cool, warm, and hot areas.

Mean and standard deviation of the station values were used to provide cutoff points for segregating the different areas in order to make the end product of this investigation, the bounding of areas of different climate, as objective as possible. It was soon recognized that much of the map analysis and the final decisions as to exact placement of the boundary lines between areas with different climatic regimes were bound to be subjective. The simplest example of this is the question of which side of a range of hills a line should be placed dividing two areas of radically different

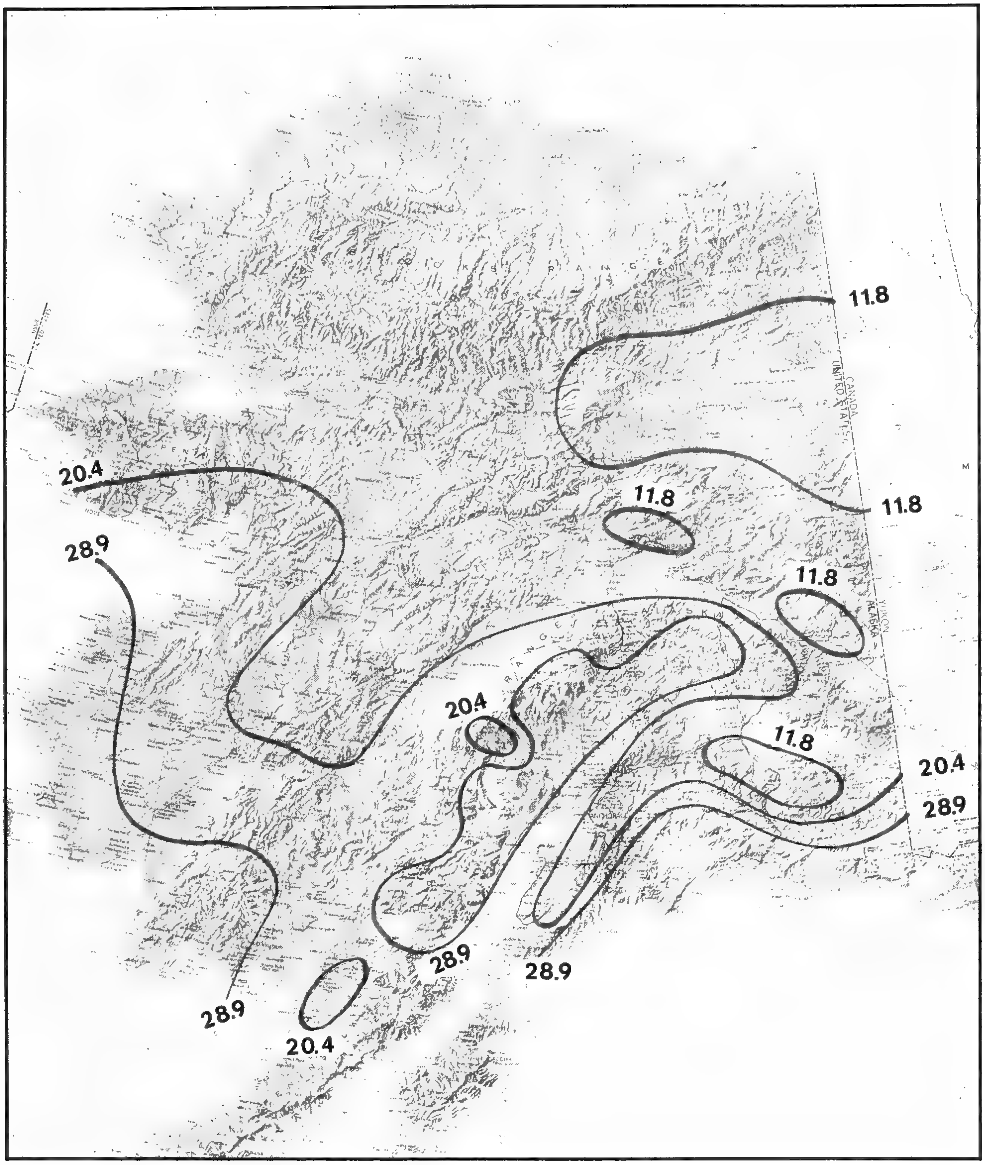

Figure 2.—Map of Alaska with isoline analysis of PEI. Isolines are drawn for the mean and for one standard deviation above and below the mean.

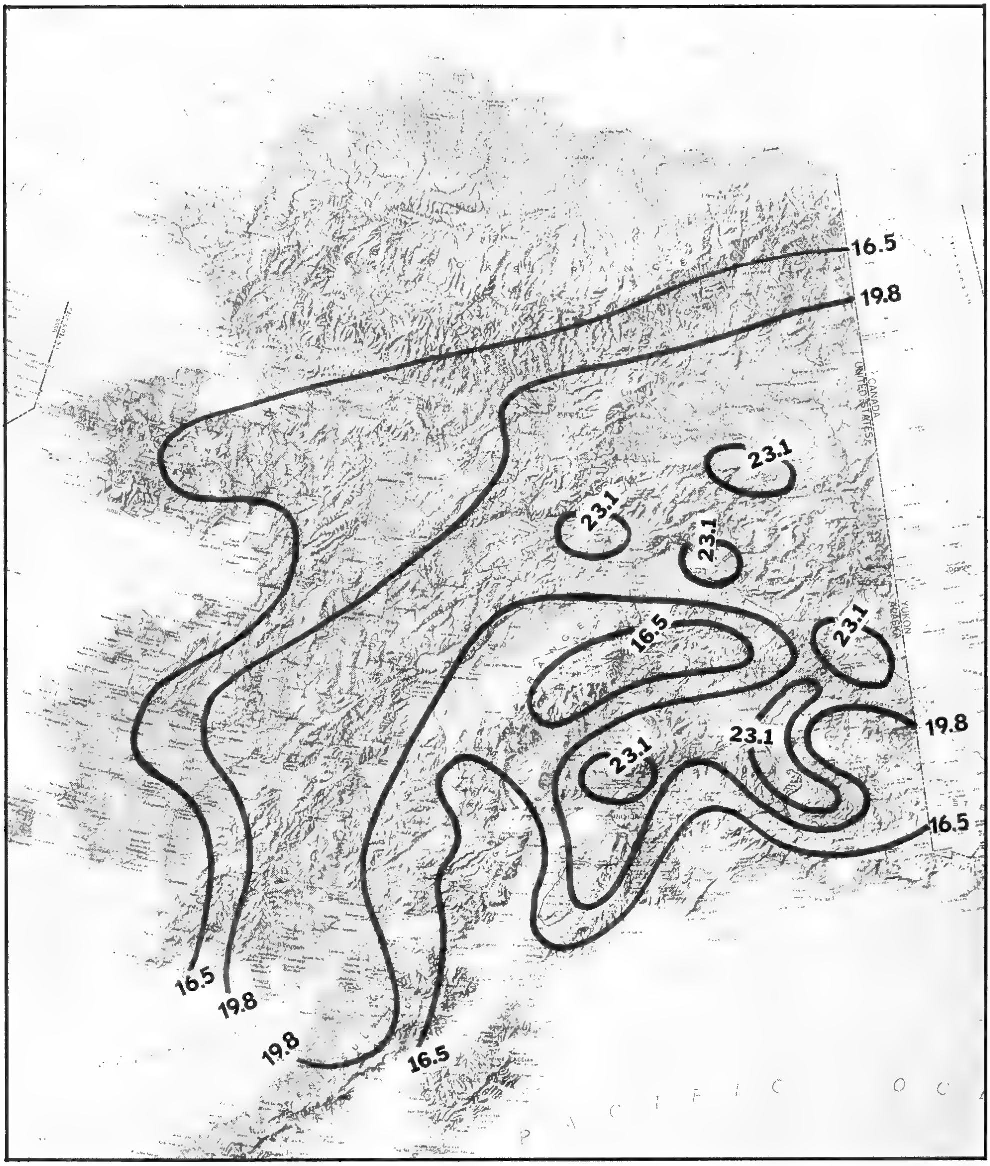

Figure 3.—Map of Alaska with isoline analysis of TEI. Isolines are drawn for the mean and for one standard deviation above and below the mean.

temperature--in the absence of data, how do you tell? Use of the mean and the standard deviation gave a consistent and reasonably objective foundation on which the analysis could be based, however, and narrowed the amount of subjectivity that had to be tolerated.

The next procedure was to superimpose one map above the other and draw all the lines from both maps onto a third composite map (fig. 4), so that any portion of the State could be referred to as one of the 16 combinations of TEI and PEI (fig. 5). An exact rendering of this composite map produced over mainland Alaska thus outlined 44 areas, for each of which it could be said that the climatic conditions varied from those of the surroundings. Some of these areas were enormous, but many were small and frequently were sharply elongated where the isolines on the PEI and TEI maps were essentially parallel to each other (fig. 4).

The next step was to consolidate these small and irregularly shaped areas with other areas nearby, both to reduce the total number of regions to a manageable level and to adjust the sizes of the regions to realistic values (fig. 6). This is the point where the greatest amount of subjectivity was encountered. Where it was possible, this adjustment was based on topography. Rarely, a station categorized as being in a particular climatic zone was shifted to an adjoining one. Unless the presence of two or more data points made it obviously incorrect, divisions between areas were alined parallel to mountain ranges and perpendicular to the direction of river valleys. This feature is particularly evident in the treatment of the areas which appear in figure 4, along the coastal ranges of the northern Gulf of Alaska and along the arc of the Alaska Range, and which are consolidated into fewer areas in figure 6.

The presence of numerous data points which define separate climatic regimes within the Knik, Matanuska, and Susitna River valleys south of the Alaska Range is also apparent from a comparison of figure 4 with figure 6. Within the range of the subclassifications derived by use of the mean and the standard deviation of the station values, the climate of the Palmer area differs from that around Anchorage, and both are different from that around Talkeetna, and so on.

The 44 original regions were eventually reduced to 25. This number, however, includes areas which could not, by any stretch of the imagination, be considered sensitive to wildfire such as the mountainous areas on the north coast of the Gulf of Alaska and the high sections of the Alaska Range. When these areas are removed from consideration, 20 separate climatic subclassifications still remain.

Figure 4.—Map showing composite PEI-TEI climatic zones produced when map in figure 2 is overlaid on that of figure 3.

Figure 5.—Names and identifying numbers for composite PEI-TEI climatic zones.

TEI CLASS	PEI CLASS ARID	DRY	MOIST	WET
HOT	Hot-arid 1	Hot-dry 3	Hot-moist 6	Hot-wet 10
WARM	Warm-arid 2	Warm-dry 5	Warm-moist 9	Warm-wet 13
COOL	Cool-arid 4	Cool-dry 8	Cool-moist 12	Cool-wet 15
COLD	Cold-arid 7	Cold-dry 11	Cold-moist 14	Cold-wet 16

DISCUSSION

This scheme of climatic subclassification is expected to provide fire control supervisors and fire weather forecasters with a first approximation of the size and shape of the areas for which particular weather stations' observations may be generalized and considered representative. In addition, the technique described of integrating temperature and precipitation values allows a comprehensive, graphic description of integrated parameters in the form of climatic zones. This same technique can be used to derive climatic zones based on longer or shorter periods of time. The zones as outlined in this paper, derived over the 6-month fire season, have value as a wildfire management planning tool.

This paper basically designates the maximum and minimum fire danger areas on a seasonal basis. It further points out where inadequate data exist as well as extreme or peculiar climatic variations of particular areas. Further work of a more detailed nature is probably desirable, but this depends on the needs and capabilities of both fire weather and fire control personnel.

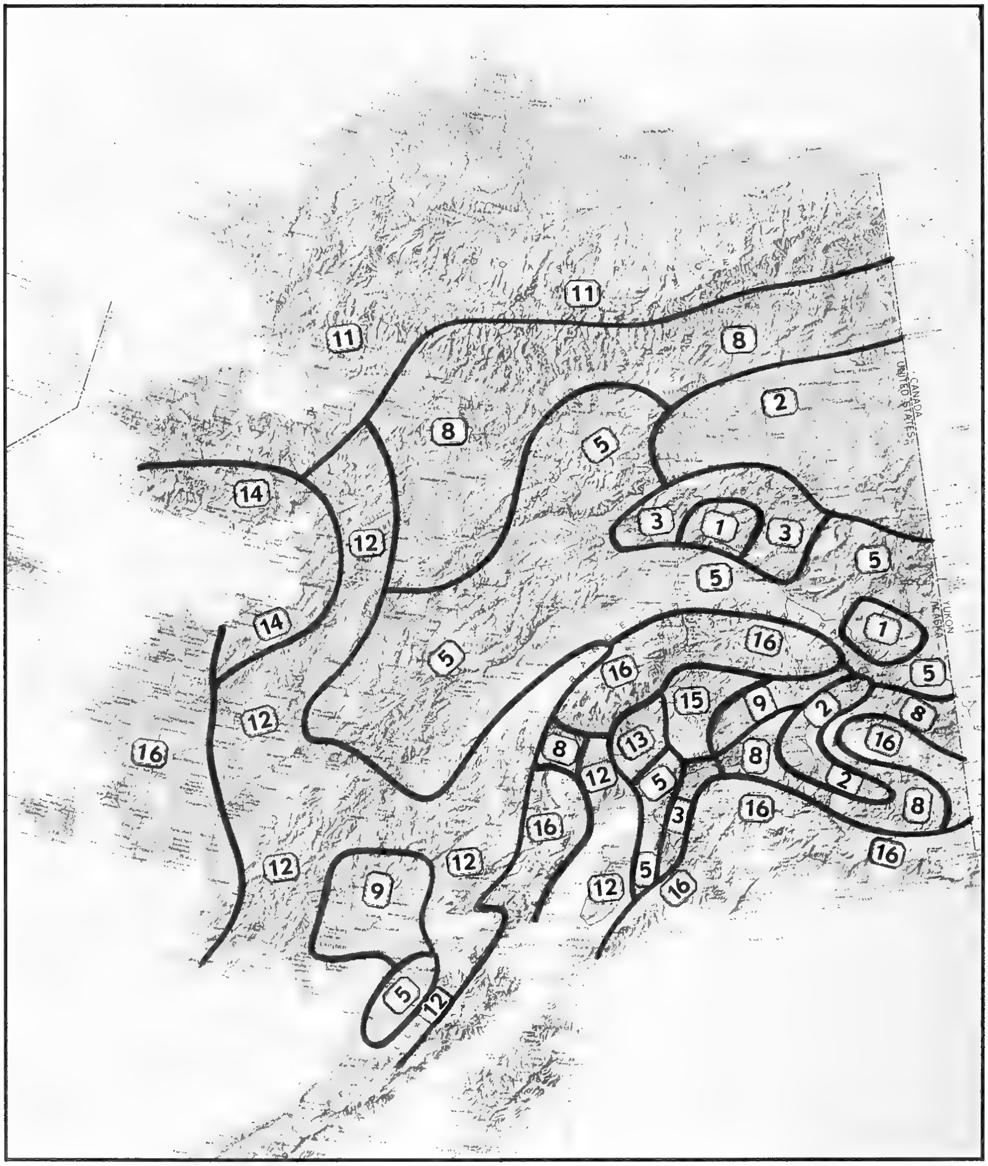

Figure 6.—Map showing composite PEI-TEI climatic zones produced when map in figure 2 is overlaid on that of figure 3—after consolidation.

GPO 795-371

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