NOAA TECHNICAL MEMORANDUM NWS AR-14

THUNDERSTORM CLIMATOLOGY OF ALASKA

Gary K. Grice, WSFO, Fairbanks
Albert L. Comiskey, Regional Headquarters

National Weather Service, Regional Headquarters
Anchorage, Alaska
February 1976

noaa NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION / National Weather Service

NOAA Technical Memorandum NWS AR-14

THUNDERSTORM CLIMATOLOGY OF ALASKA

Gary K. Grice, WSFO, Fairbanks
Albert L. Comiskey, Regional Headquarters

Weather Service Regional Headquarters
Anchorage, Alaska
February 1976

UNITED STATES DEPARTMENT OF COMMERCE
Frederick B. Dent, Secretary
/ NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
Robert M. White, Administrator
/ National Weather Service
George P. Cressman, Director

ABSTRACT

Six years of thunderstorm data (1969-1974) from a variety of of sources were used to derive thunderstorm distributions and frequencies. The average frequency of thunderstorm days, in both time and space, over Alaska is derived for the period of May thru August. The diurnal frequency distribution of Alaska thunderstorms shows that 80% of observed thunderstorms occur between 1200 AST and 1800 AST. Graphic depictions of the areal and temporal distribution of thunderstorm days indicate that most thunderstorm activity occurs over elevated terrain and near the summer solstice. One-third monthly maps of thunderstorm areal distribution were developed for operational purposes.

THUNDERSTORM CLIMATOLOGY OF ALASKA

Gary K. Grice and Albert L. Comiskey

INTRODUCTION

The permanent population of the State of Alaska is rapidly increasing. Tourism is increasing even more rapidly. Major building projects are underway or planned, exploration for minerals is being accelerated, fossil fuel exploration, production, and processing are expanding. The Native land claims have caused renewed interest in overall land management. Numerous dissenting factions are debating the merits of allowing wildfires to burn, and numerous organizations and individuals are watching, studying, analyzing, and monitoring the above activities. Because of the increased activity and interest in Alaska, the need for an up-to-date thunderstorm climatology of the State has become obvious.

Sullivan (1963), working with very meager data, derived an average annual thunderstorm day pattern over Alaska. Although Sullivan was working with limited data, the resultant seasonal pattern was similar to the pattern developed in this study; however, Sullivan's thunderstorm frequency values were considerable lower. Barney and Comiskey (1973) discussed briefly wildfire and thunderstorm patterns over Alaska's North Slope (Fig. 1). Jayaweera and Ahlnas (1974), using satellite imagery from 1973 and early 1974, inferred areas of preferred thunderstorm formation during June and July. Other studies have dealt mainly with the problems of forecasting thunderstorms.

DATA SOURCES

Thunderstorm data for the years prior to 1968 were obtained primarily from pilots and widely scattered observing stations. In 1968 the thunderstorm observation program was significantly improved by the implementation of high-level aircraft patrols. In addition to the more extensive patrol system, data from one radar site was available both from 1972 to 1973, and coverage from three radars, as well as satellite imagery was available during 1974.

The extensive thunderstorm and wildfire surveillance program conducted by the BLM during the summer months of 1969-1974 provided a large portion of the data used in this study.

The total BLM surveillance program included radar, high-level aircraft patrols, low-level aircraft patrols, and fire-weather observing stations. The National Weather Service (NWS), the Federal Aviation Administration (FAA), the military weather stations, satellite imagery, and commercial and general aviation pilot reports provided the remainder of the data.

Table 1 shows the data sources available for each of the 6 years. It can be seen from the table that thunderstorm reports during the summers of 1969, 1970, and 1971 did not include radar or satellite imagery. The best coverage was in 1974 with data from all sources. Because data were not available from every source for each year, a brief discription of each is provided.

TABLE 1

DATA SOURCE	YEAR					
	1969	1970	1971	1972	1973	1974
RADAR (MURPHY DOME ONLY)				X	X	X
RADAR (THREE RADARS)						X
HIGH-LEVEL AIRCRAFT PATROL	X	X	X	X	X	X
LOW-LEVEL AIRCRAFT PATROL	X	X	X	X	X	X
WEATHER STATIONS	X	X	X	X	X	X
PILOT REPORTS	X	X	X	X	X	X
SATELLITE IMAGERY						X

Radar data were obtained from three, 23-cm Air Route Traffic Control radars operated by the U.S. Air Force and located at Murphy Dome, Tatalina and Indian Mountain (Fig. 2). The maximum effective range of 150 nm (Fuertsch, 1973) resulted in good coverage over much of Alaska with considerable overlap in the central interior. Unfortunately, several areas which experience thunderstorm activity were not covered, namely the eastern Brooks Range and the eastern Tanana Valley. Radar reports were received only from Murphy Dome during the summers of 1972 and 1973, whereas data from all three sites were available in 1974.

The locations of radar echoes were obtained by placing an overlay on the Plan Position Indicator (PPI) and manually marking echo locations. This procedure was performed every hour on the half-hour beginning at 1030 AST and continuing through 1830 AST. Range Height Indicators were not available, and, due to the primary use of radars for air traffic control purposes, gain stepping was not permitted. Cell strengths were determined by intensities on the PPI.

The limitations of such information are obvious. Echo intensities can be affected by cell distance. Stronger echoes may be heavy showers as opposed to thunderstorms. A heavy shower with larger and more hydrometers may result in a stronger echo than that of a drier thunderstorm. The subjectivity introduced by each radar observer must also be considered. However, all radar observers were experienced NWS personnel.

The primary advantage of the radar information was the almost continuous coverage of many sections of Alaska. Although thunderstorm cells could not be determined from the radar echoes, stronger convective areas could be inferred. According to Fuertsch (1973), convective weather echo patterns on the Air Route Traffic Control radar are similar to those on a WSR-57 to a range of at least 150 nm.

High-level aircraft patrols were flown at 40,000 ft. each day thunderstorms were possible, even when the possibility was slight (10-20% probability). The areas patrolled were based on the thunderstorm forecasts and past lightning activity. Also, patrol routes could be modified in flight and adjusted to observed conditions. Preflight patrol planning decisions were made by the BLM based on information provided by the NWS.

The aircraft, a Gates Lear Jet, usually carried a BLM observer and an NWS meteorologist as part of the crew. The aircraft was equipped with air-borne radar for determination of cell strengths and Automatic Direction Finding (ADF) equipment which was used for detection of lightning static. A record was maintained on each flight showing aircraft track and probable thunderstorm locations. A narrative of each flight was also made. Thunderstorm determination was based on radar echoes, ADF static, observed cloud heights, horizontal cloud extend, general cloud appearance, and information from low-level patrols and ground stations. The approximate effective visual limits (at 40,000 ft.) for accurately locating convective activity is shown in Fig. 3 (Thurston, 1968). However, maximum visual limits for generally locating convective activity were much greater. The patrol route depicted in Figure 3 is only one of many which varied with the day-to-day weather situation. For the years 1969-1973 a representative patrol pattern would be to depart Anchorage in the late morning, fly a long patrol around the State and land at Fairbanks in early afternoon for refueling. Depart Fairbanks about mid-afternoon, for another long patrol around the State and back to Anchorage. During the summer of 1974, the aircraft was based in Fairbanks which generally allowed for more and longer patrols.

The extensive visual limits at 40,000 ft. coupled with the aircraft's speed, 550 mph at altitude, resulted in large areas being observed during each patrol. In addition, the equipment and trained observers on the aircraft combined to produce thunderstorm data of relatively high quality. Even so, some thunderstorms were undoubtedly missed. Although a given area could be observed continuously for up to 40 minutes from the Lear Jet, the same area might go unobserved for several hours during the course of the control. During this time convective areas could develop and dissipate; however, experienced observers could sometimes deduce that thunderstorms had occurred by the large amounts of dissipating stratiform clouds near the tropopause. The high-level patrol was the most effective tool for identifying thunderstorm activity and integrating thunderstorm data on a day-to-day basis.

Although extensive low-level patrols were made during the summers of 1973 and 1974, the remaining years had only limited coverage. Prior to 1973, only two aircraft were available for routine patrols: however, extra aircraft could be requested if needed. During 1973 and 1974, seven airplanes patrolled with extra planes on standby. In general, flights at the lower altitudes complimented the high-level patrol for thunderstorm and wildfire detection. Probable or possible thunderstorm areas discovered by the Lear Jet were investigated by the low-level planes for possible lightning ignition of the forests and tundra. However, in many instances, thunderstorms were first detected by low-altitude patrols.

Since input from the low-level patrols was in the form of narrative reports, some subjective interpretation was required. At times, reports of intensity and areal distribution of convective activity were vague. Decisions were required as to what specific areas experienced thunderstorms.

Of all contributing sources in this study, weather observing stations were least useful. This lies in the fact that in Alaska, most weather stations lie in low elevation valleys where a minimum of thunderstorm activity occurs. Also, continuous reporting stations are sparsely distributed (Fig. 4). Location of weather stations, with a respect to neighboring hills or mountains, is another factor which can influence reporting of thunderstorms in Alaska. However, these disadvantages are offset somewhat by the continuous coverage offered by most stations.

Data from all National Weather Service, military, FAA, and BLM stations were used for determining areal distributions of thunderstorms. However, only selected stations, those which report continuously from 0900 LST to 1800 LST, were used for seasonal temporal distributions.

Many thunderstorm reports were provided by the commercial and general aviation activities in the form of pilot reports (PIREPS). During the summer months, aviation traffic over Alaska is at a maximum. The large number of daily flights combined with the area visible to each pilot resulted in almost total daily coverage.

As with low-level BLM patrols, the largest difficulty in using PIREPS was that of interpretation. Also, experience and training of the pilots was variable. Showers at times were probably reported as thunderstorms and vice versa. Satellite information was beneficial in remote areas of the State.

During the Summer of 1974, the data sources discussed above were supplemented with imagery from the Very High Resolution Radiometer (VHRR) on the polar orbiting NOAA II and NOAA III satellites. Both the visible and thermal infrared imagery were utilized. Areas of cumulonimbus activity were determined from both visible and infrared as described by Anderson, et al. (1969) and Anderson and Smith (1971).

There are limitations to using satellite data for locating thunderstorms in Alaska which should be noted. Experience and high-altitude patrols have shown that many cumulonimbus clouds in Alaska do not contain lightning. Therefore, thunderstorms cannot be confirmed from satellite imagery, only inferred. In addition, since the average life of a thunderstorm cell is only about one hour (Byers and Braham, 1949), different areas of convective activity could grow and die between satellite passes. The obscuration of cumulonimbus clouds from the satellite by cirrus (formed by previous thunderstorms) is a common occurrence.

From the discussion above, it can be seen that each source of information has strong and weak points. The dangers of preparing a thunderstorm climatology from only one source are apparent. However, when all sources are considered, errors are minimized.

Of all the sources used in this study, only weather station reports and aircraft reports could be used for positive confirmation of thunderstorm occurrences. The remaining sources only inferred thunderstorm activity. However, by combining information from all sources, climatological patterns could be realistically derived.

DATA INTEGRATION PROCEDURE

The degree of accuracy and homogeneity of available data prohibited a detailed areal investigation of thunderstorm distributions. A more appropriate procedure was to study the general variation of thunderstorm days. In this manner, the resolution of the data in both time and space would not be exceeded.

For purposes of plotting, analyzing, tabulating, and averaging available thunderstorm reports, a numbered grid system covering most of the State was constructed. The size of the grid squares, 30x30 nm, was selected for best resolution of topographic features. This size also proved convenient for data handling. For each day areas of probable thunderstorm activity, as deduced from all available sources, were plotted on a work map of Alaska. The grid was placed over the work map and the numbers of each square of probable thunderstorm activity logged for that day. The occurrence of at least one probable thunderstorm in a grid square qualified as a thunderstorm day for that square.

Because of the short thunderstorm season in Alaska, monthly distributions of thunderstorm days would have little meaning; therefore, one-third monthly periods were used. The months of May, July, and August were each divided into two 10-day periods (1st-10th and 11th-20th) and one 11-day period (21st-31st), June was divided into three 10-day periods (1st-10th, 11th-20th, and 21st-30th). The thunderstorm days for each grid square were totaled for the appropriate period. The final result for each year was the number of thunderstorm days for each time period for each 30x30 grid square.

Since both the quality and quantity of data for certain areas of the State varied over the 6 years, it was necessary to utilize the strong points of each year's coverage. As indicated earlier, the most complete coverage was during the Summer of 1974. The summers of 1972 and 1973 were next with the remaining 3 years having about the same quality of information. It should be noted that the ranking of the time periods was based on general coverage only. Over some areas of interior Alaska, thunderstorm reports during 1969-1971 were as reliable, detailed, and numerous as those during 1972-1974. Only in the outlying regions were 1972-1974 data superior to that of 1969-1971.

To utilize the generally better coverage for the latter 3 years, thunderstorm days for 1972-1974 for each grid square were averaged, plotted, and analyzed by time periods, as well as for the entire summer. The same procedure was performed on data for all 6 years. Data for 1974 were also plotted and analyzed separately. The result was that for each 10 or 11-day period, as well as the entire summer, thunderstorm day analysis for the three time periods of 1974, 1972-74, and 1969-74 were available.

Final analysis of thunderstorm days was based on the averaged data for 1969-1974 with some areas modified as indicated by the patterns of the 1972-1974 period. Analysis for 1974 was used as an indicator of possible patterns in remote areas. Minor subjective changes in isoline patterns were made based on 23 years experience between the authors.

DISCUSSION OF RESULTS

Most thunderstorms in Alaska are of the air-mass type associated with intense solar heating and little vertical wind shear more than (1 knot/1,000 ft.). Of the 154 Alaskan thunderstorms examined by Sullivan (1962), it was determined that about 85% were of the air-mass variety. The remaining 15% accompanied fronts and troughs aloft and were associated with moderate to strong vertical wind shear and differential temperature advection.

According to the Glossary of Meteorology (1959), the definition of an air-mass thunderstorm is that produced by local convection within an unstable air-mass and not associated with a front or instability line. This is also the definition adopted for this study. In most cases, solar energy associated with a favorable vertical temperature profile is the initiating force.

One of the most interesting features of the thunderstorm season in Alaska is its relatively short length (June and July). Over most of the state, a large portion of the thunderstorm days occur near the summer solstice (Fig. 5).

Figure 6 shows the diurnal frequency distribution of thunderstorm occurrences (solid line) for a 10-year period at Fairbanks. Occurrences were consolidated into 3-hour intervals beginning at 0000 LST. Thunderstorm values are plotted in the middle of the period. Also shown (broken line) are 3-hour cumulative values of direct solar radiation for a level surface at 60 degrees north latitude on July 22 at an elevation of approximately 400 ft. (Buffo and others, 1972). From Fig. 6 the correlation of solar heating to thunderstorm activity is obvious. Almost 60% of all thunderstorms occur between 1200 LST and 1800 LST, with 80% of all activity occurring between 1200 LST and 2100 LST.

Since Fairbanks is located in a valley, the distribution in Figure 6 is probably representative of many interior valley locations. No fixed station data exists on the diurnal distribution of thunderstorms over the higher terrain of Alaska; however, numerous authors have documented the earlier formation and higher frequency of thunderstorms over higher terrain for other parts of the world. Thunderstorm activity is also a function of the orientation, slope, and height of the mountains.

Byers and Braham in The Thunderstorm (1949), indicated hills and mountains may contribute to the development of cumulus clouds by: (1) forming obstructions to the horizontal wind and forcing air to rise vertically on the windward sides, (2) the roughness of the terrain resulting in a series of vertical perturbations, some of which may trigger the formation of a cumulus cloud in a conditionally unstable air-mass, and (3) differential heating of the tops of higher terrain and of the free air at the same altitudes.

Brahm (1958), using radar data, found that convective clouds formed over the Santa Catalina Mountains of Arizona with a frequency at least 30 times that of the surrounding valley land during the Summer of 1955. Other authors, too numerous to mention here, have shown the pronounced effect of mountains on convective activity.

Higher terrain in Alaska plays a major role in triggering convection (Sierra Research Corporation, 1972). On marginally unstable days, convection will occur only over elevated terrain, and when convection is possible over the valleys, the higher terrain will be preferred areas where cells will first develop (Cooper and Heikes, 1973). The affinity of thunderstorms for mountainous areas is clearly shown in Figure 7. Thunderstorm days are most frequent over the Yukon-Tanana Upland east of Fairbanks with secondary maximums over the Kuskokwim Mountains, west slopes of the Alaska Range and the south slope of the eastern Brooks Range. A maximum area extends from the Yukon-Tanana Upland westward to near the Nulato Hills, and another area of preferred thunderstorms is over the Talkeetna Mountains. The scarcity of thunderstorm days over the valley areas is apparent, even though maximum surface temperatures frequently occur over the valleys (Fig. 8).

Figures 9 through 19 show the average number of thunderstorm days per 900 square miles by one-third monthly periods beginning May 11. In general, thunderstorms are rare over Alaska during May (Figs. 9 and 10). The activity which does occur is confined mainly to the Yukon-Tanana Upland in the middle of May and develops over the Kuskokwim and Talkeetna Mountains by the end of the month. These areas continue to experience most of the thunderstorm activity in early June (Fig. 11), but by the middle of June (Fig. 12), thunderstorm activity increases over most of interior Alaska. However, the number of thunderstorm days is still small. Over the Yukon-Tanana Upland during the middle of June, thunderstorms occur on only 2 of the 10 days. Also, by the middle of June, thunderstorms begin to develop over the south slopes of the eastern Brooks Range.

By the end of June (Fig. 13), the frequency of thunderstorm days over most of interior Alaska is double the frequency of mid-June. By the end of the month, thunderstorms, on the average, occur on about 50% to 60% of the days over the Yukon-Tanana Upland and on about 40% to 50% of the days over the Kuskokwim Mountains. The remainder of the interior experiences thunderstorms during about 2 of the last 10 days of June.

The spacial distribution of thunderstorm days changes little from the late June (Fig. 13) to early July, (Fig. 14), but the frequency over the Kuskokwim Mountains is significantly lower in early July. However, by the middle of July, (Fig. 15), the number of thunderstorm days over the State is considerably lower, especially over the western portions.

The rapidity with which thunderstorm activity decreases after mid-July is apparent in Figs. 16, 17, 18, and 19. During the first 10 days of August, the average number of thunderstorm days varies from about two over the Yukon-Tanana Upland to generally less than one elsewhere. The main exceptions are the Kuskokwim Mountains and Talkeetna Mountains which average about one thunderstorm day during the period. However, by the middle of August, thunderstorms are almost non-existent. During this mid-August 10-day period, the frequency of thunderstorm days over the Yukon-Tanana Upland decreases from about two to almost zero.

To illustrate seasonal distributions of thunderstorms over Alaska, certain areas were selected that experienced the greatest propensity for thunderstorms. The areas selected were those with the maximum number of annual thunderstorm days. Thunderstorm-day frequencies, expressed as percent of the yearly average, were computed for each area. In addition, thunderstorm-day frequencies by one-third monthly periods for NWS, FAA, and military weather stations near the selected areas were combined, averaged, and expressed as percent of the yearly average. This was done for comparative purposes. The stations used are shown in Figure 20. Figures 21 thru 25 show seasonal distribution of thunderstorms for each area, as well as the combined frequency using the weather stations near their respective areas.

As can be seen from Figures 10 thru 25, the frequency distribution for the areas and the frequency pattern of the neighboring stations agree quite well. The only areas which do not show good agreement are in the Brooks Range and in the Talkeetna Mountains. Here again, the frequency of thunderstorm days over all areas increases rapidly during the middle of June and reaches a maximum by the end of the month or by early July.

CONCLUDING COMMENTS

From the various thunderstorm time distributions presented, it is clear that maximum thunderstorm activity occurs during or shortly following the most intense solar heating. This was indicated on both the diurnal and the one-third monthly time distributions. It was also shown that Alaska thunderstorms show a strong affinity for the moderately higher terrain. The Yukon-Tanana Upland, Kuskokwim Mountains, Talkeetna Mountains, Alaska Range, (lower elevations) and the south slopes of the Brooks Range are areas of preferred thunderstorm formation. The general absence of thunderstorms over valleys is notable.

ACKNOWLEDGEMENTS

The authors would like to thank Richard Augulis, Theodore Fathauer, and Henry Santeford for reading the manuscript and making helpful suggestions. A special thanks is extended to Ronald Willis for his many interesting and constructive conversations. Robert Clithero of the Bureau of Land Management read portions of the text which pertained to that agency for which the authors are grateful.

REFERENCES

1) Anderson, Ralph K., and others, 1969: Application of Meteorological Satellite Data in Analysis and Forecasting. ESSA Technical Report No. 51, National Environmental Satellite Service, Washington, D.C., 145 pp.

2) Anderson, Ralph K., and Arthur Smith, 1971: Application of Meteorological Satellite Data in Analysis and Forecasting. Supplement to ESSA Technical Report No. 51, National Environmental Satellite Service, Washington, D.C., 45 pp.

3) Barney, Richard J., and Albert L. Comiskey, 1973: Wildfires and Thunderstorms on Alaska's North Slopes. USDA Forest Service Research Note PNW-212, U.S. Department of Agriculture, Portland, Oregon, 8 pp.

4) Braham, R.R., Jr., 1958: Cumulus Cloud Precipitation As Revealed by Radar--Arizona 1955. J. Meteor., 15, 75-83.

5) Buffo, John, and others, 1972: Direct Solar Radiation on Various Slopes From 0 to 60 Degrees North Latitude. USDA Forest Service Research Paper PNW-142, U.S. Department of Agriculture, Portland, Oregon, 73 pp.

6) Byers, Horace R., 1949: The Thunderstorm: Report of the Thunderstorm Project. U.S. Air Force, U.S. Navy, NACA and U.S. Weather Bureau, Washington, D.C., 287 pp.

7) Cooper, L.W., and K.E. Heikes, 1973: Cloud Seeding: An Approach to Alaska Wildfires. Final Report Contract 08550-CT2-5, Sierra Research Corporation, Boulder, Colorado, 100 pp.

8) Fuertsch, Francis E., 1973: Weather Surveillance by Air Route Traffic Control Radar. NOAA Technical Memorandum No. SR-68, National Weather Service, Fort Worth, Texas, 29 pp.

9) Glossary of Meteorology, 1959: Amer. Metero. Soc., Boston, 638 pp.

10) Jayaweera, K.O.L.F., and Kristina Ahlnas, 1974: Detection of Thunderstorms From Satellite Imagery for Forest Fire Control. Journal of Forestry, December 1974, 767-770.

11) Sierra Research Corporation, 1972: Weather Observations and Cloud Seeding in Alaska. Final Report, Contract 08550-CT2-5, Sierra Research Corporation, Boulder, Colorado, 131 pp.

12) Sullivan, William G., 1963: Low Level Convergence and Thunderstorms in Alaska. Mon. Wea. Rev., 91, 89-92.

13) Sullivan, William G., 1963: Thunderstorm Forecasting in Alaska. Unpublished paper, 19 pp.

14) Thurston, James, 1968: High Altitude Thunderstorm Detection-Alaska 1968. Unpublished paper, 8 pp.

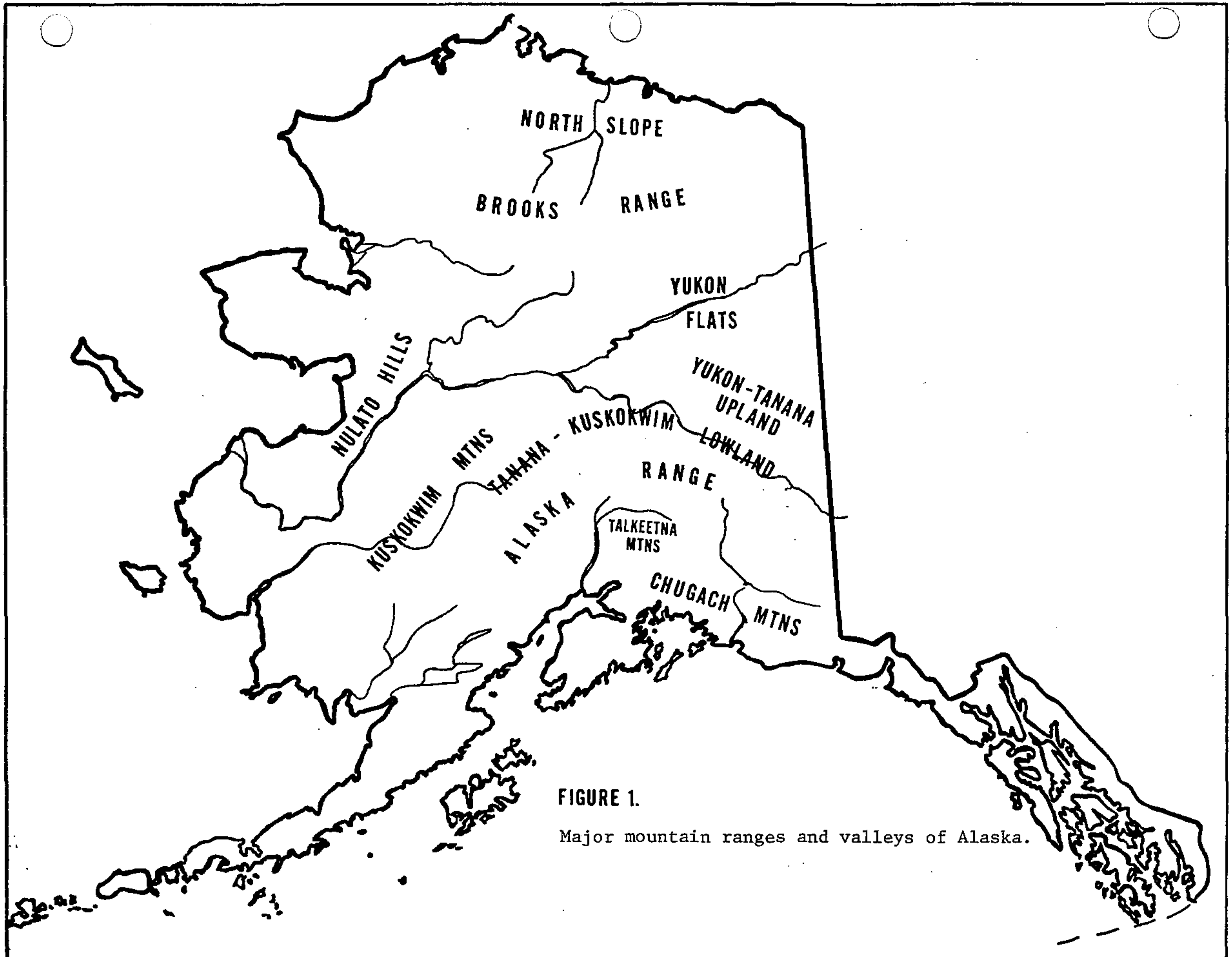

FIGURE 1.

Major mountain ranges and valleys of Alaska.

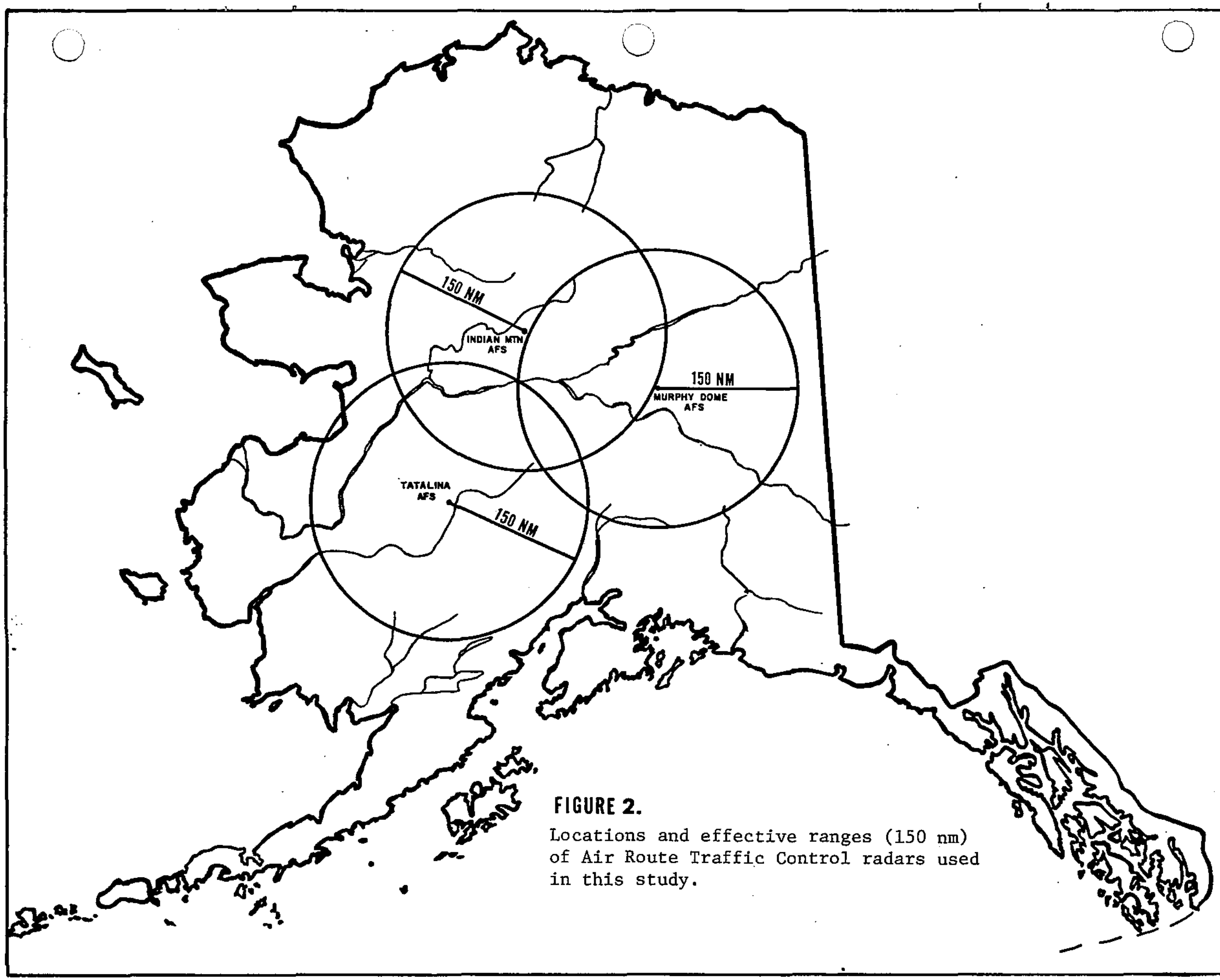

FIGURE 2.

Locations and effective ranges (150 nm) of Air Route Traffic Control radars used in this study.

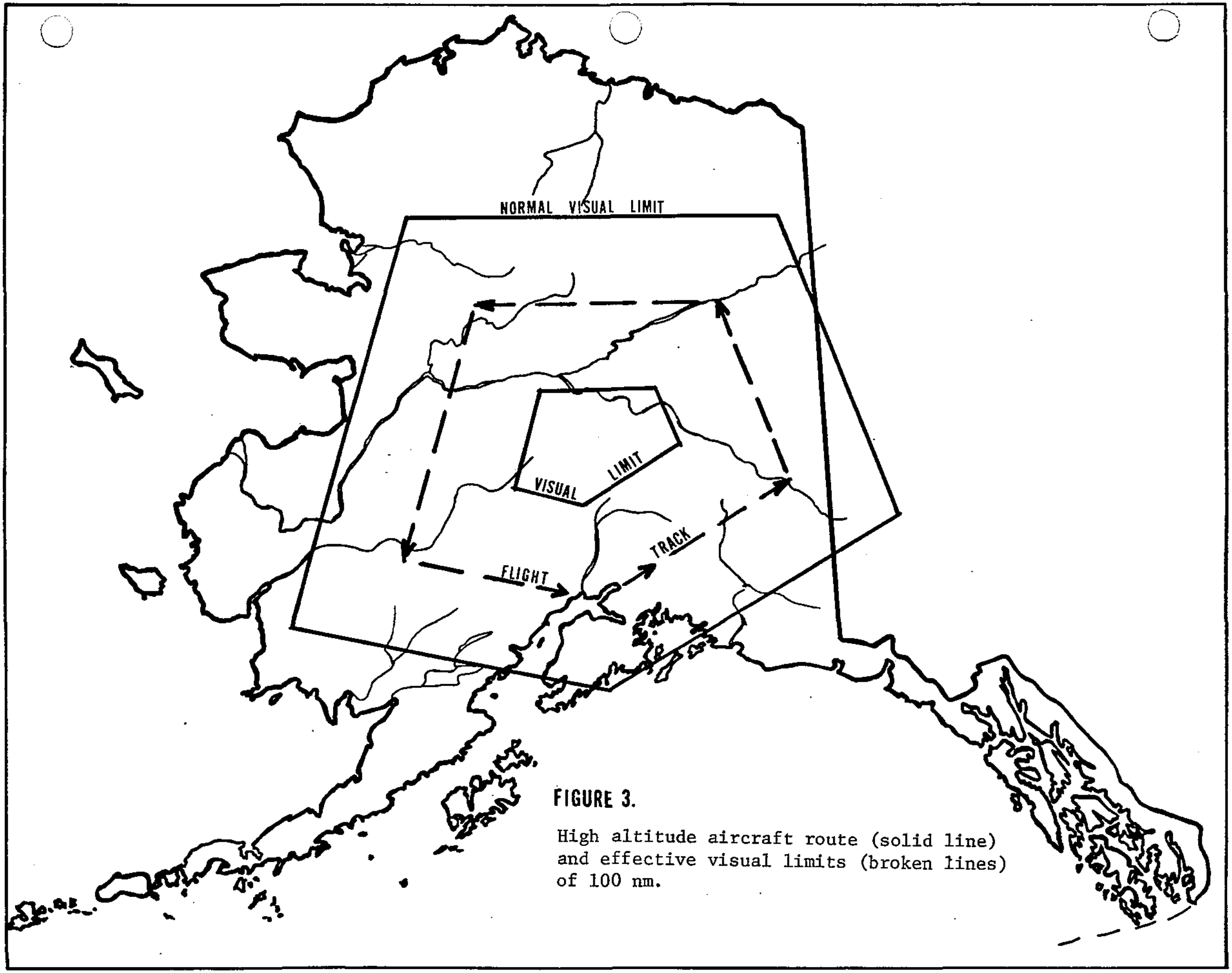

FIGURE 3.

High altitude aircraft route (solid line) and effective visual limits (broken lines) of 100 nm.

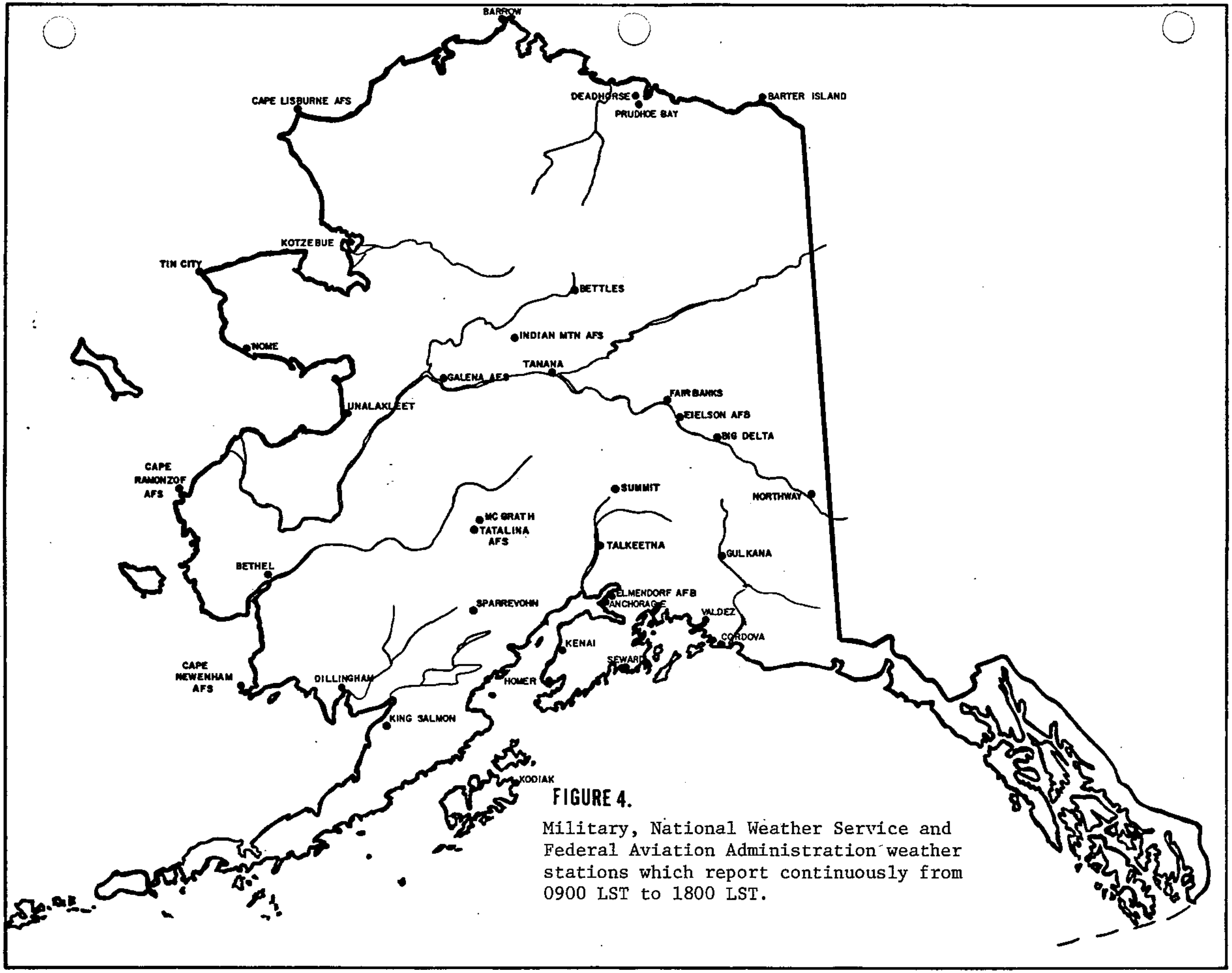

FIGURE 4.

Military, National Weather Service and Federal Aviation Administration weather stations which report continuously from 0900 LST to 1800 LST.

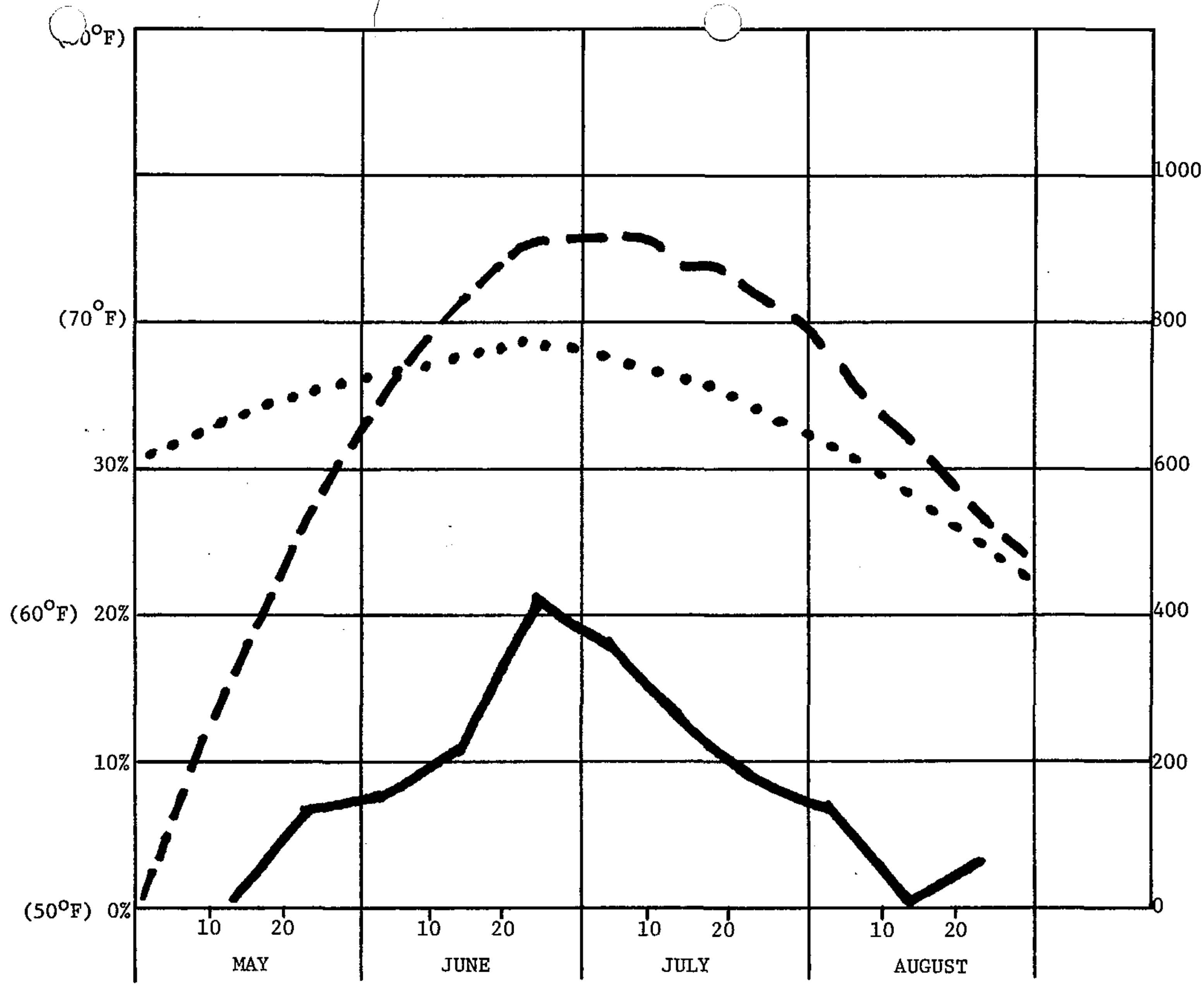

FIGURE 5. Percentage frequency of thunderstorm days (solid line) at Fairbanks, Alaska for the 10-year period, 1965-1974. Broken line represents the average daily maximum temperature also at Fairbanks. Dotted line represents daily values of direct solar radiation (Cal. $Cm.^{-2}$) on a level surface at 60 degrees north latitude (after Buffo and others, 1972).

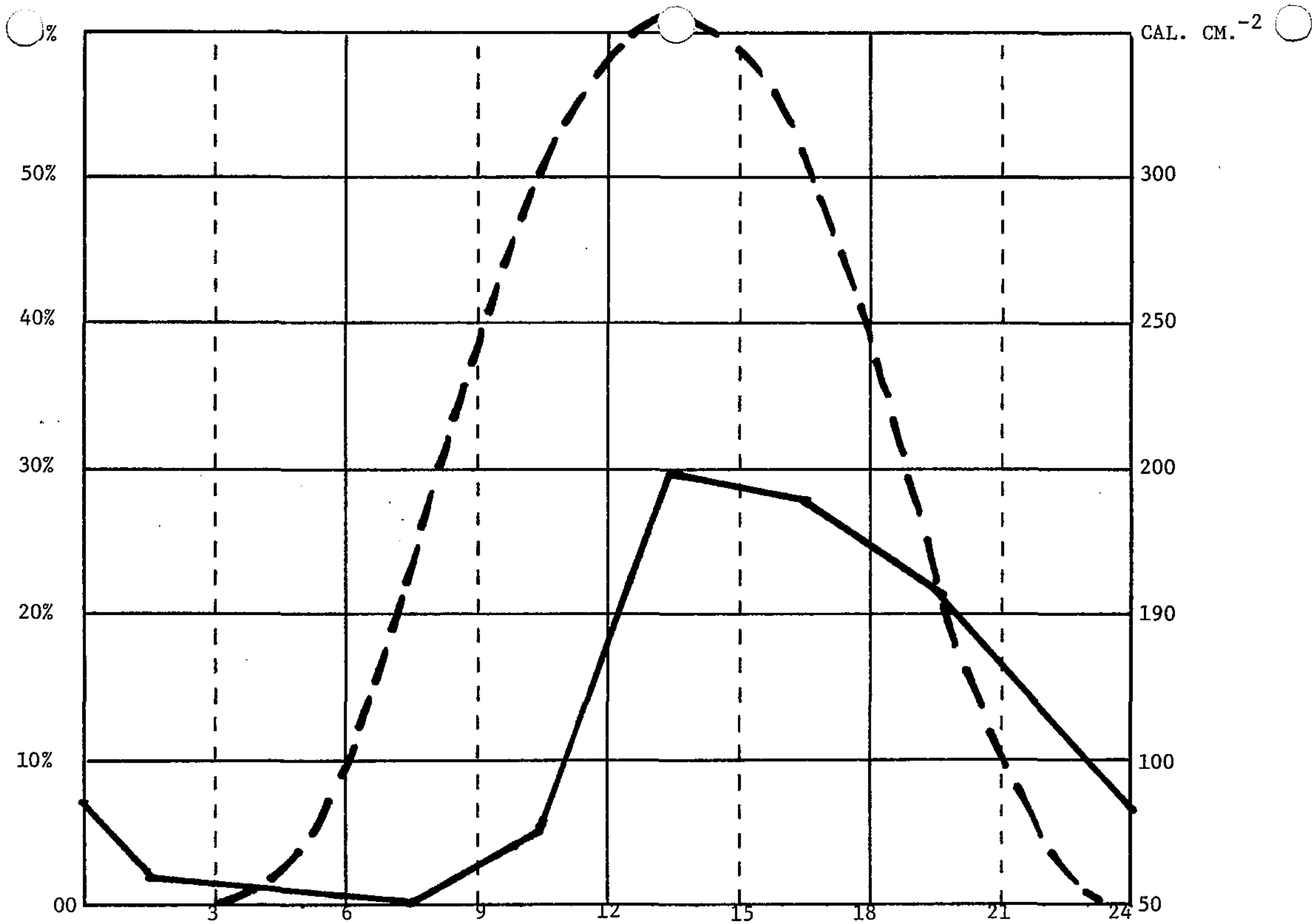

FIGURE 6. Percentage frequency of thunderstorm occurrences (solid line) at Fairbanks, Alaska for the 10-year period, 1965-1974. Broken line represents 3-hour cumulative values (cal. cm. $^{-2}$) of direct solar radiation for a level surface at 60 degrees north latitude on July 22 (after Buffo and others, 1972).

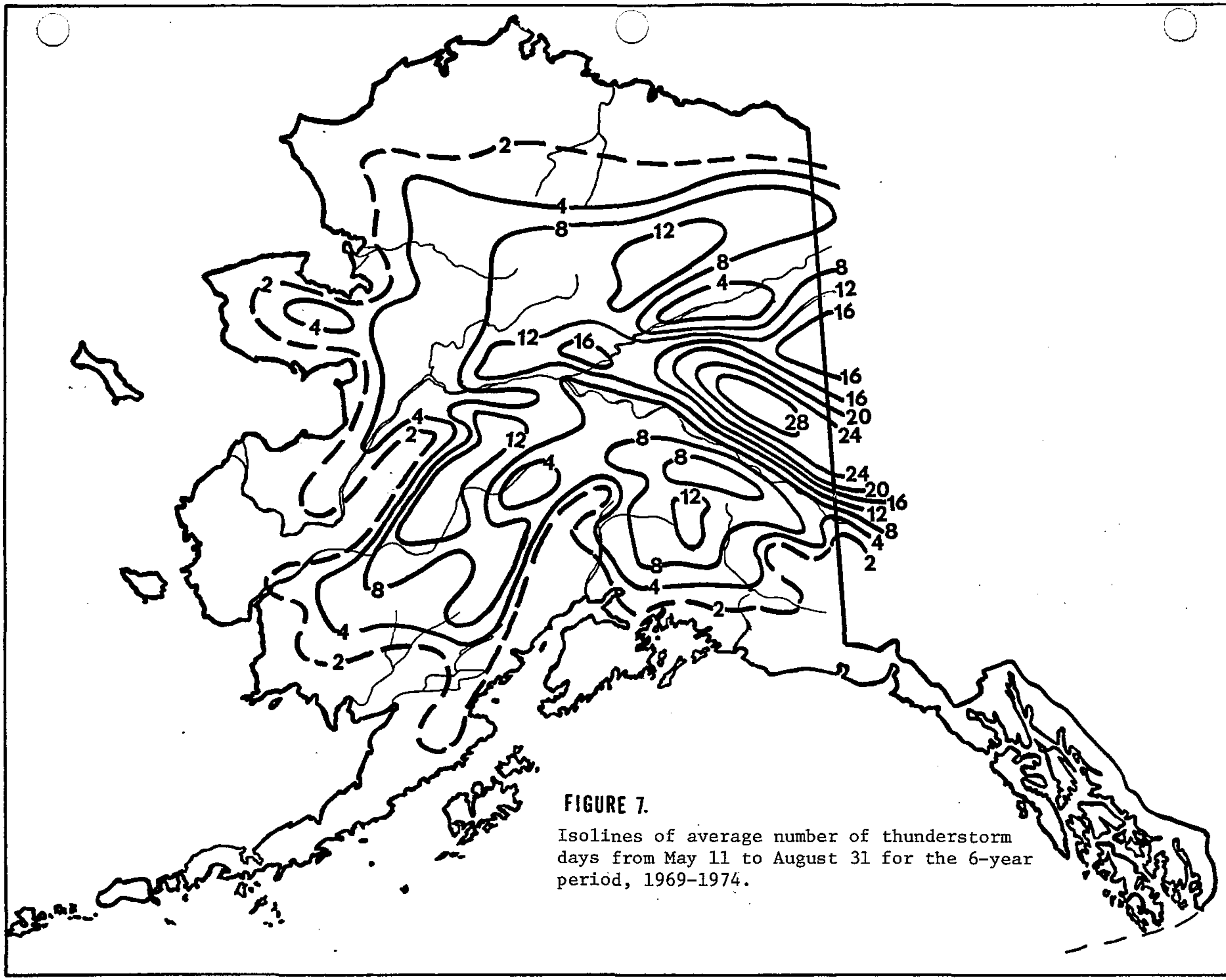

FIGURE 7.

Isolines of average number of thunderstorm days from May 11 to August 31 for the 6-year period, 1969–1974.

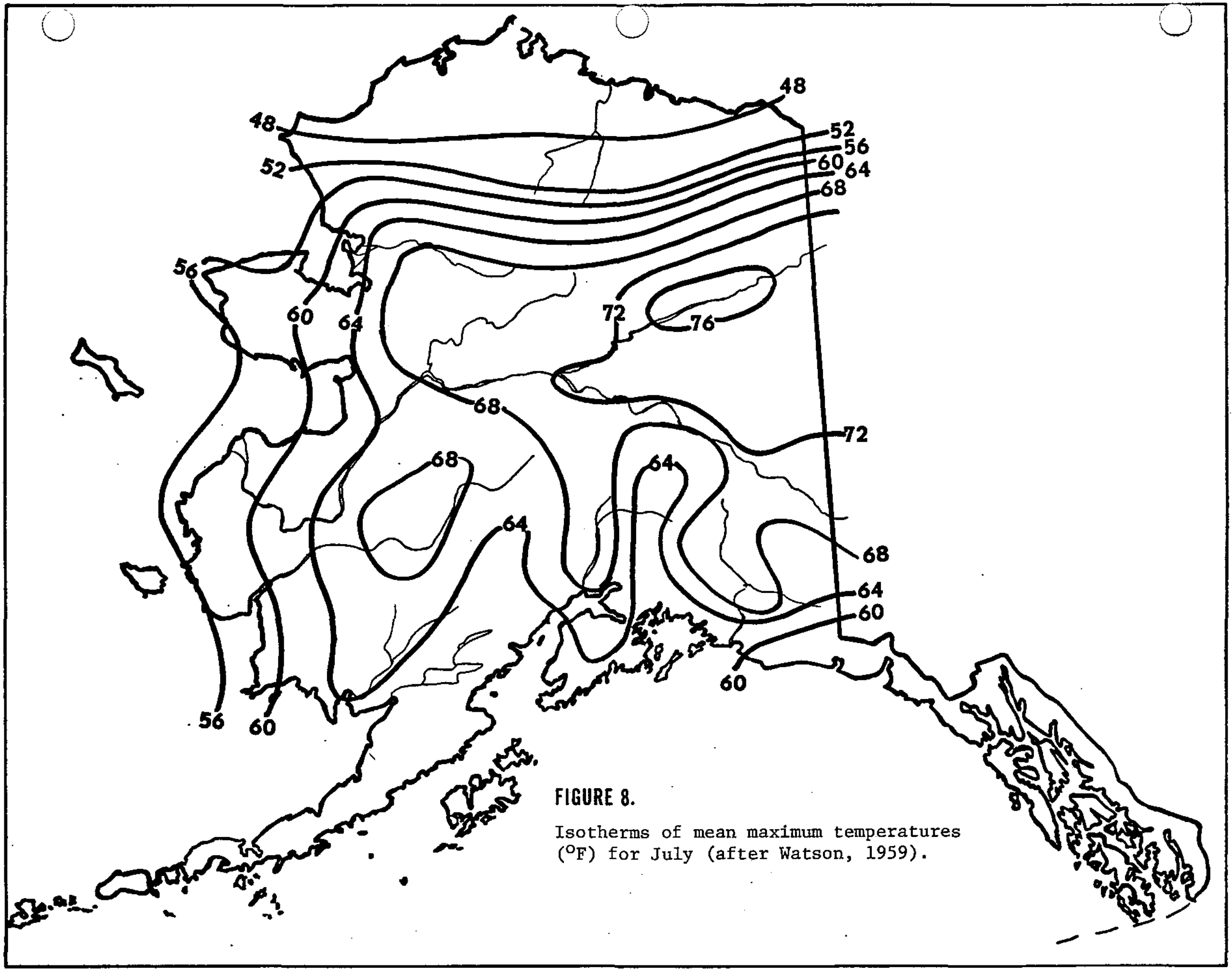

FIGURE 8.

Isotherms of mean maximum temperatures (°F) for July (after Watson, 1959).

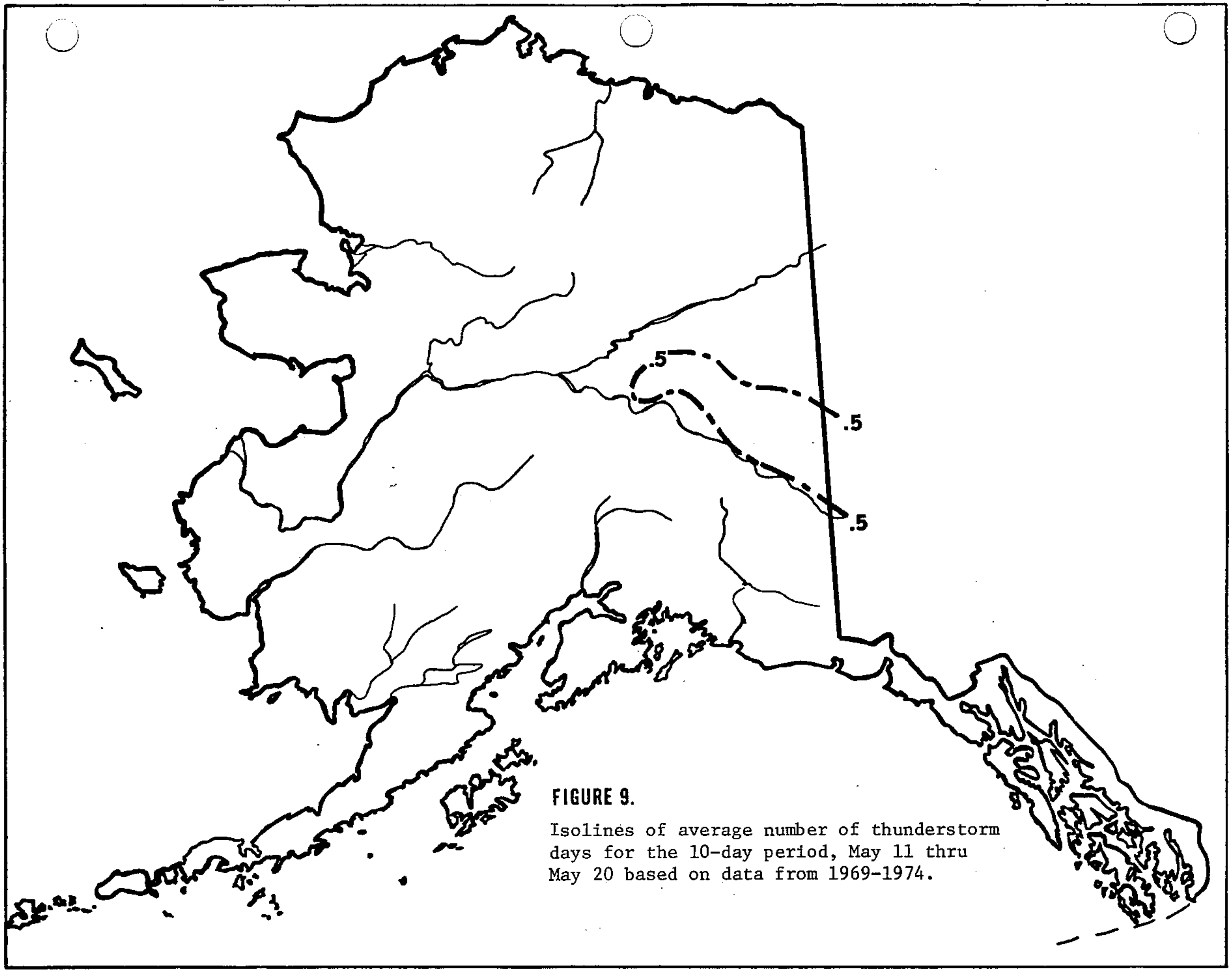

FIGURE 9.

Isolines of average number of thunderstorm days for the 10-day period, May 11 thru May 20 based on data from 1969-1974.

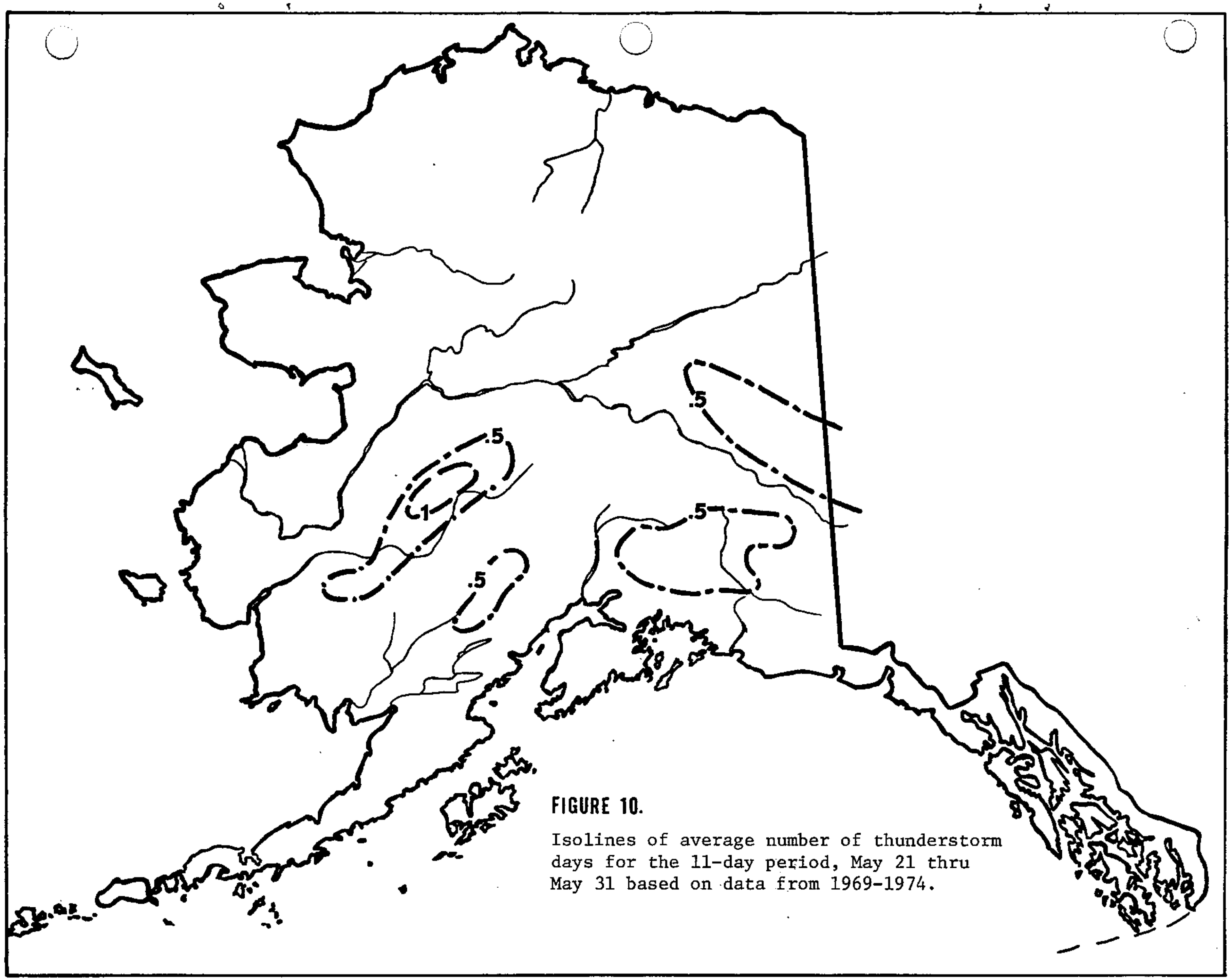

FIGURE 10.

Isolines of average number of thunderstorm days for the 11-day period, May 21 thru May 31 based on data from 1969-1974.

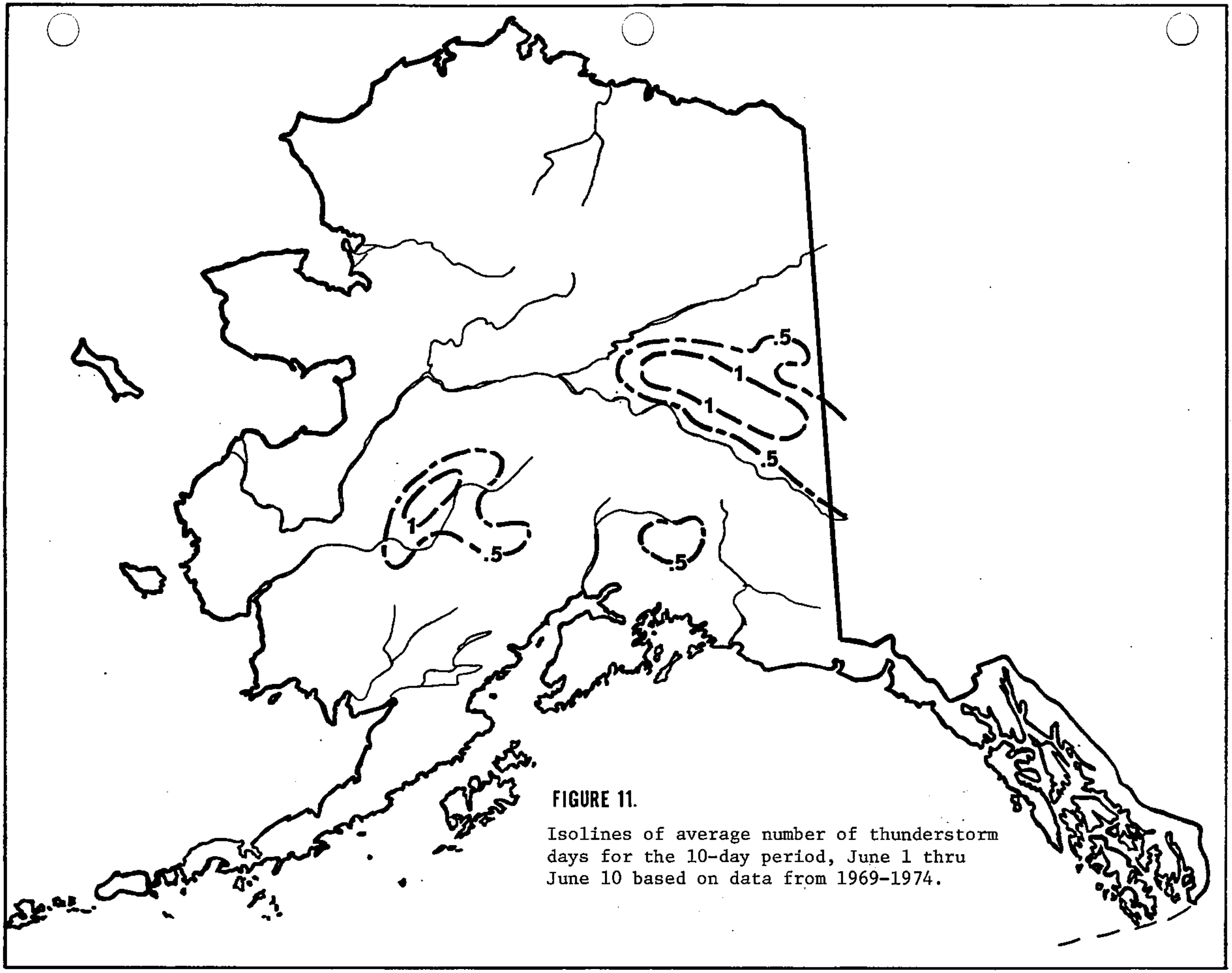

FIGURE 11.

Isolines of average number of thunderstorm days for the 10-day period, June 1 thru June 10 based on data from 1969-1974.

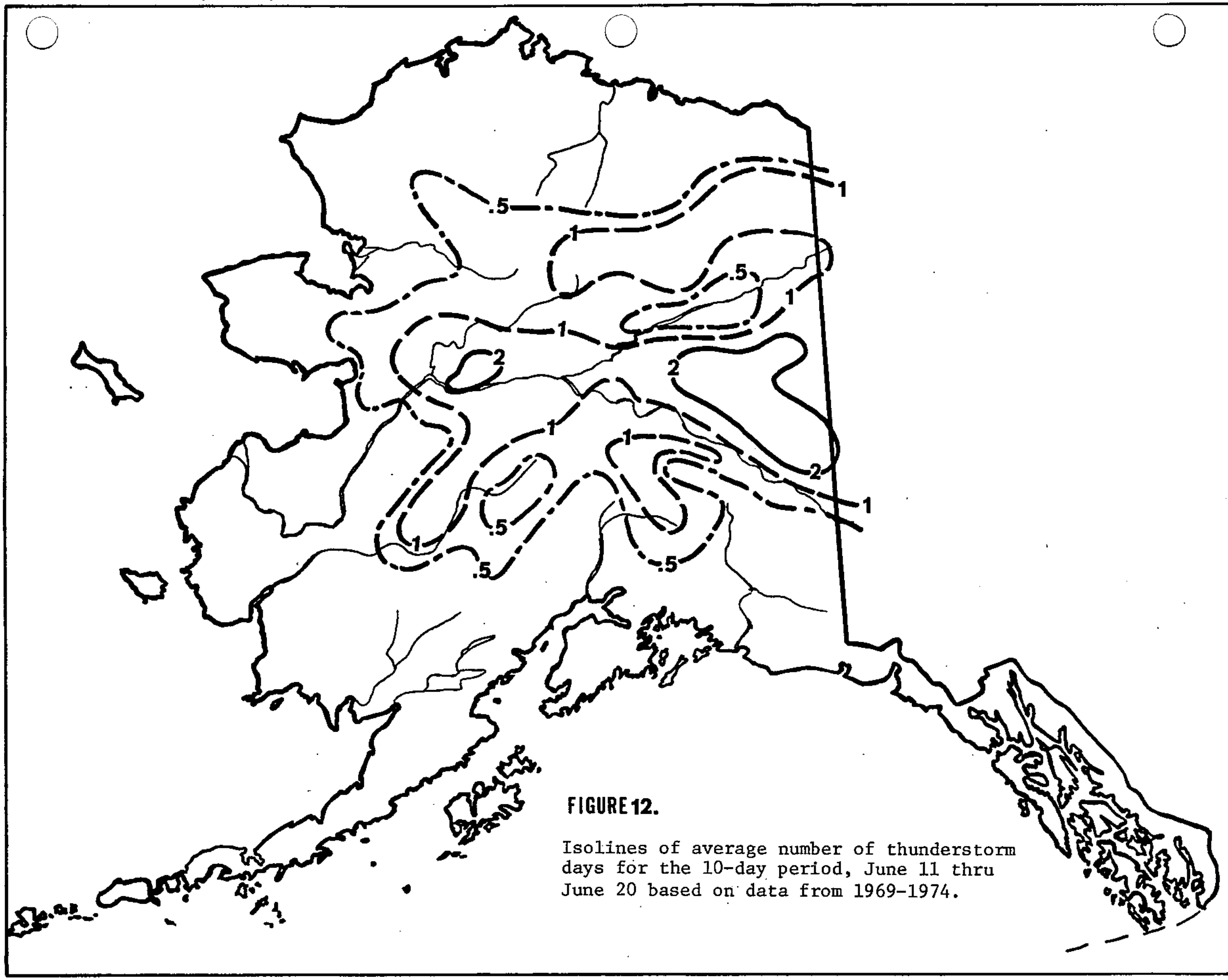

FIGURE 12.

Isolines of average number of thunderstorm days for the 10-day period, June 11 thru June 20 based on data from 1969-1974.

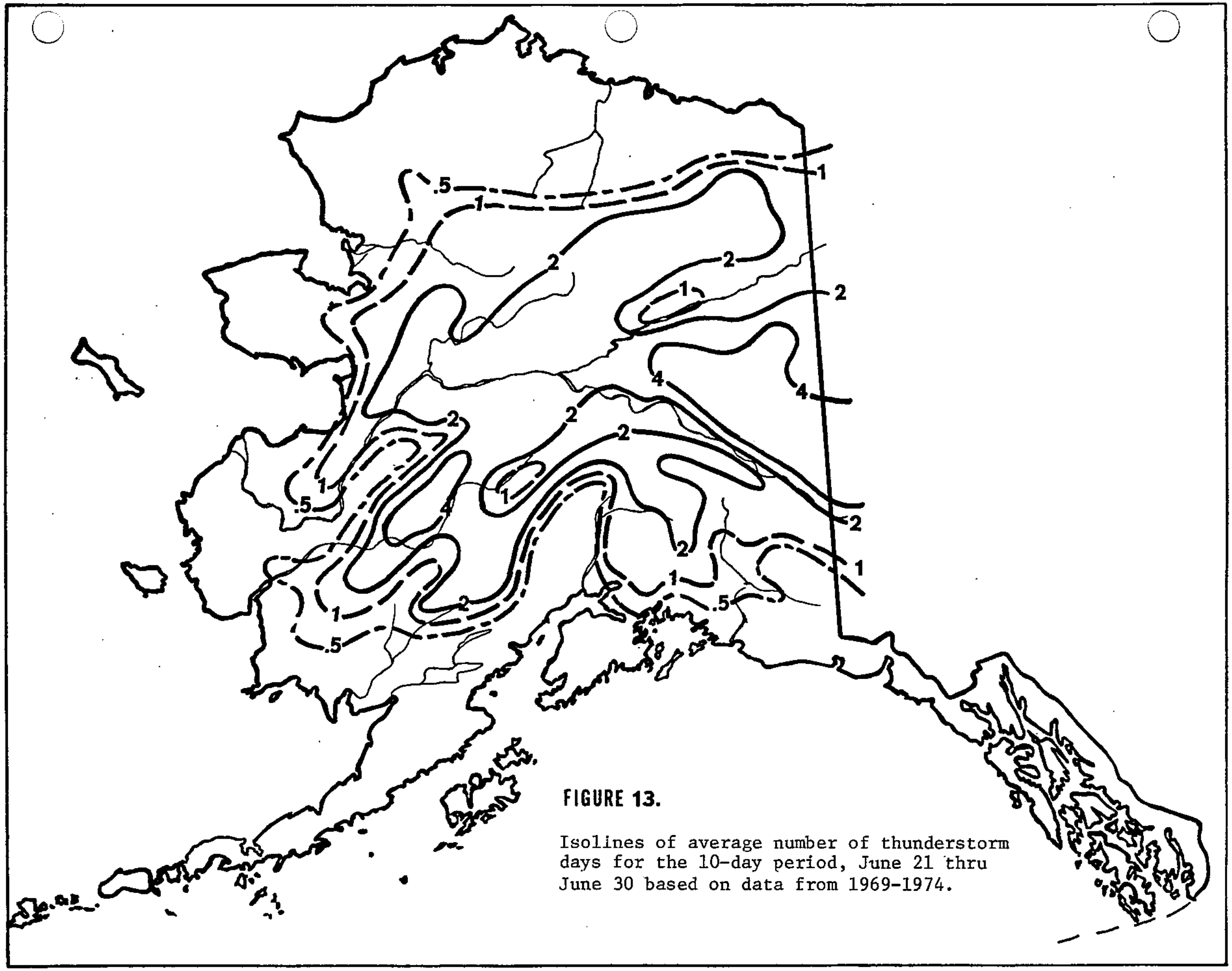

FIGURE 13.

Isolines of average number of thunderstorm days for the 10-day period, June 21 thru June 30 based on data from 1969-1974.

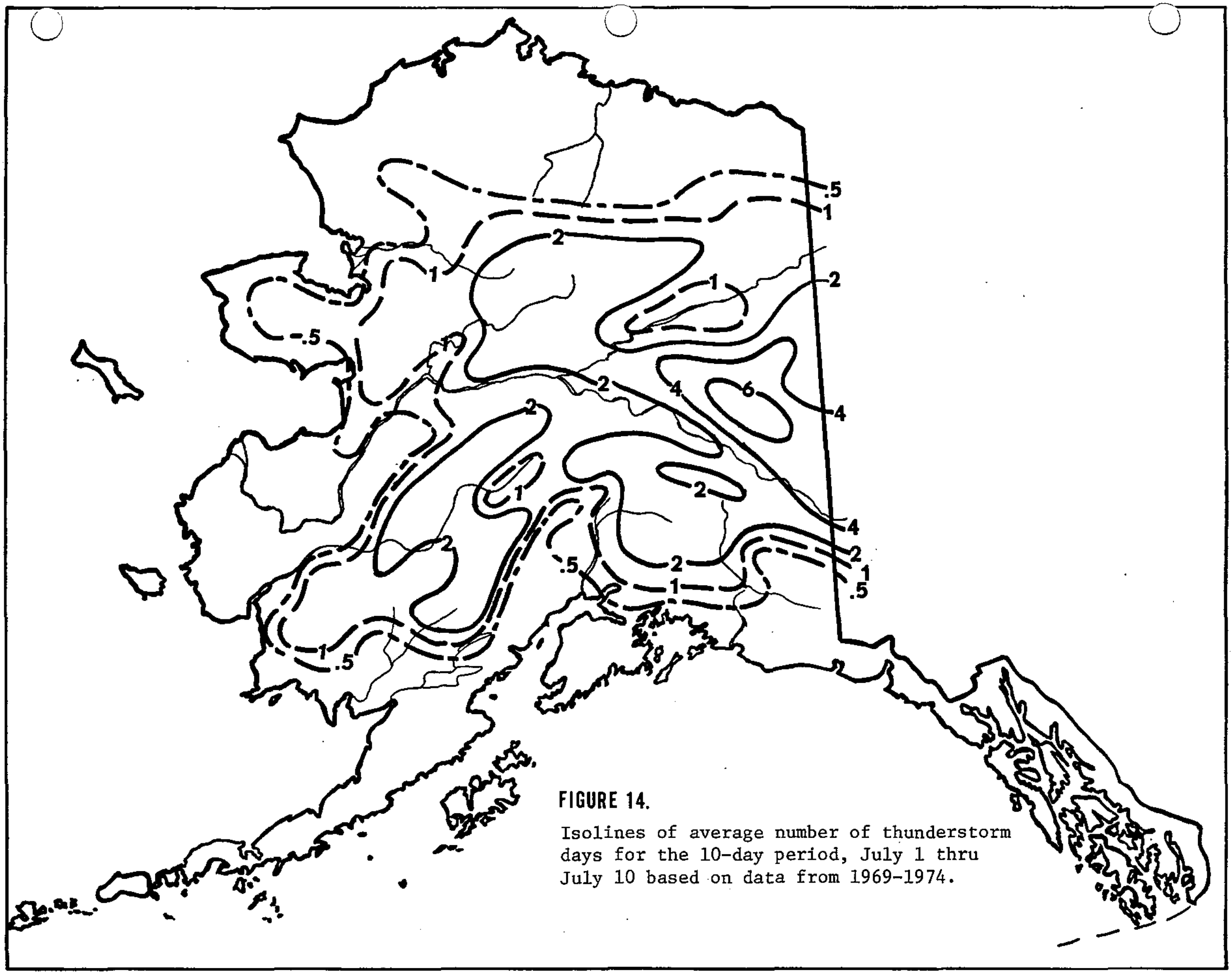

FIGURE 14.

Isolines of average number of thunderstorm days for the 10-day period, July 1 thru July 10 based on data from 1969-1974.

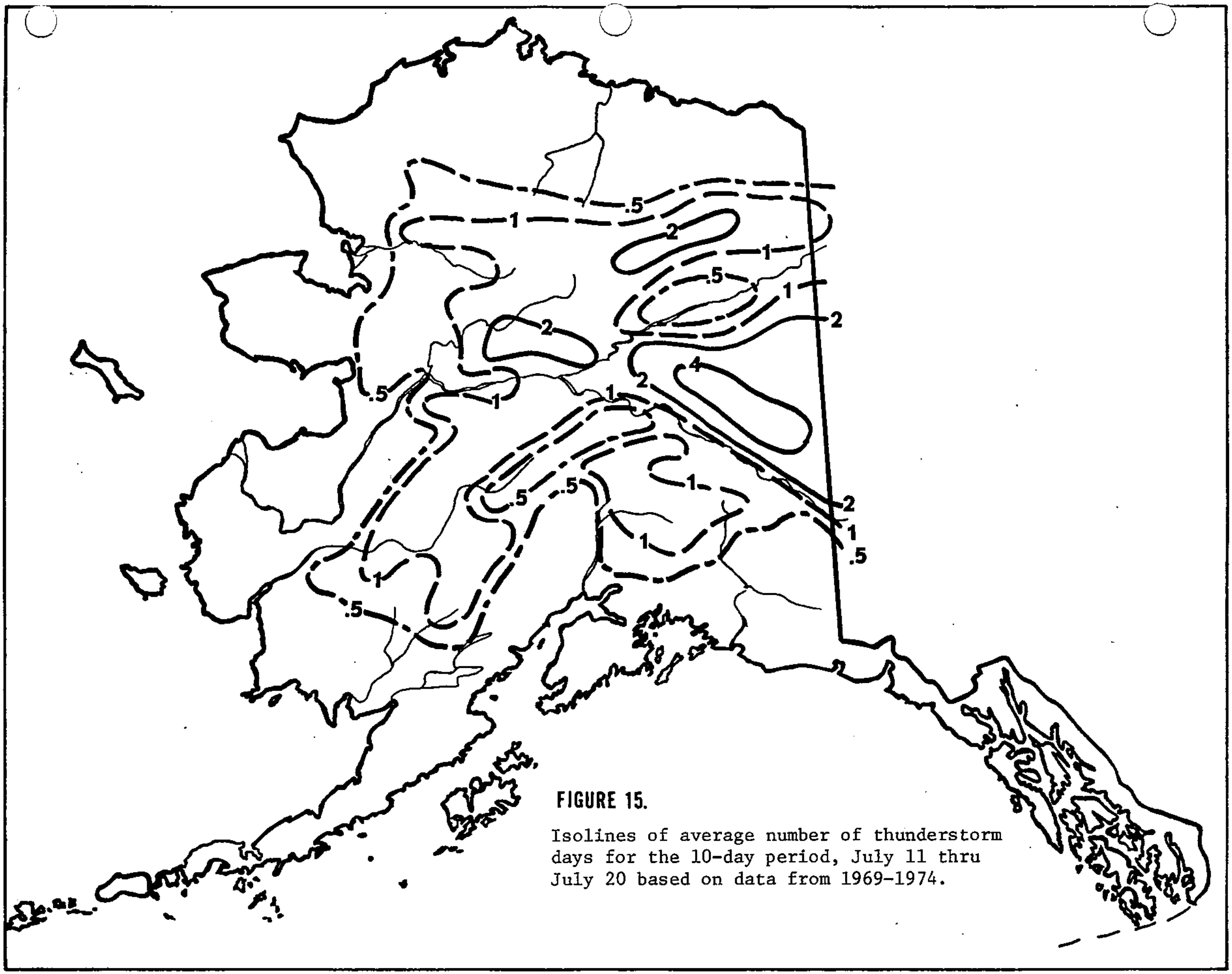

FIGURE 15.

Isolines of average number of thunderstorm days for the 10-day period, July 11 thru July 20 based on data from 1969-1974.

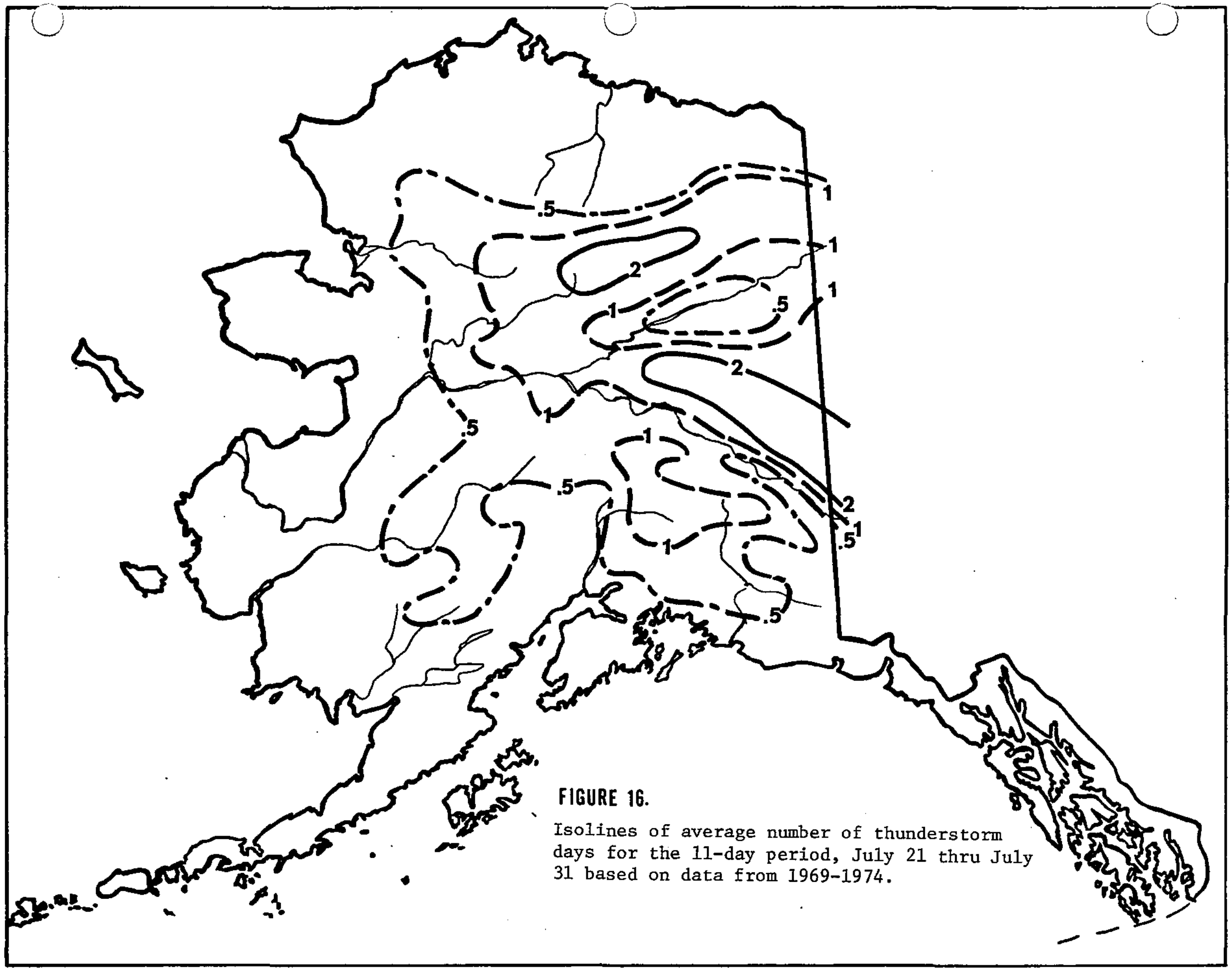

FIGURE 16.

Isolines of average number of thunderstorm days for the 11-day period, July 21 thru July 31 based on data from 1969-1974.

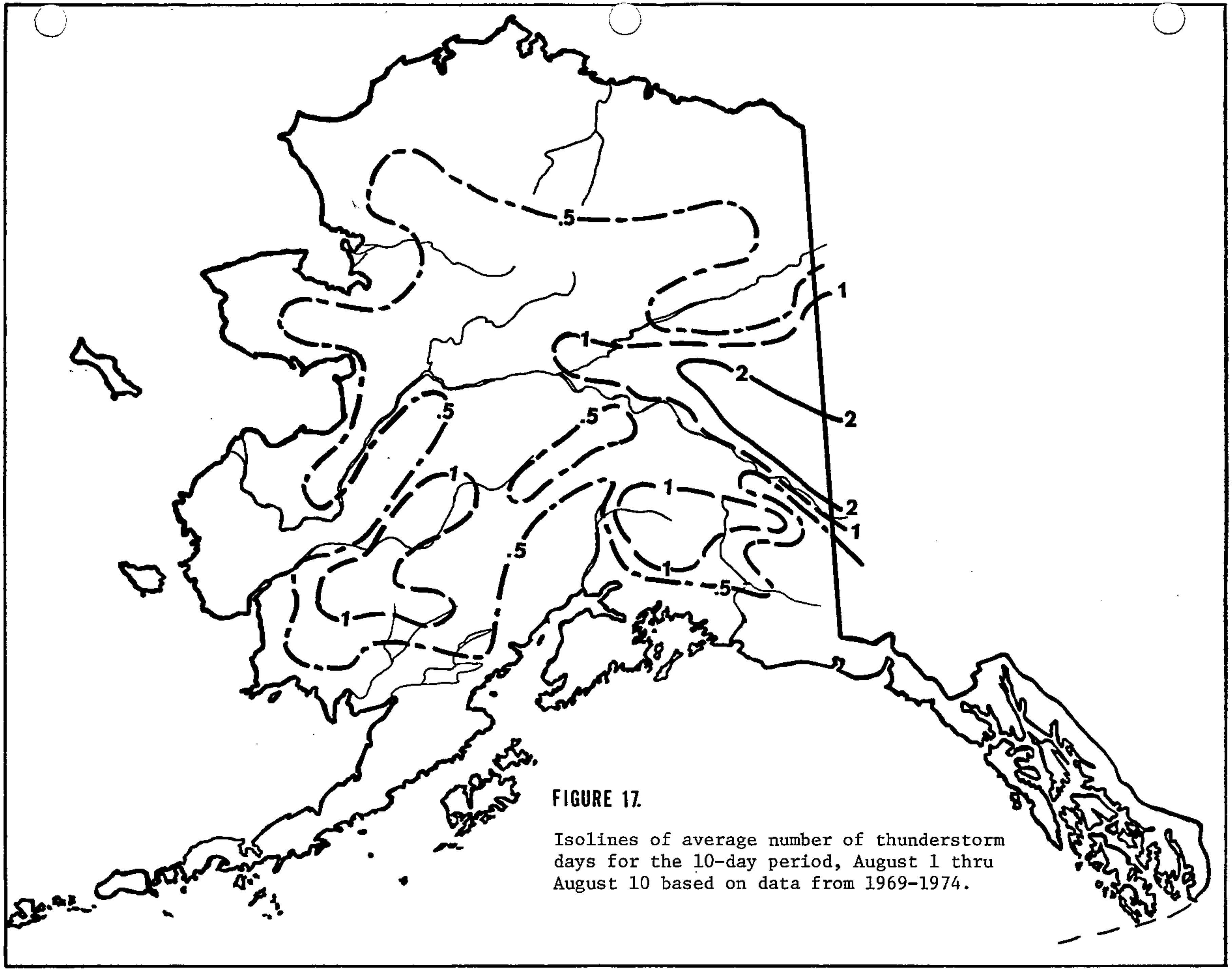

FIGURE 17.

Isolines of average number of thunderstorm days for the 10-day period, August 1 thru August 10 based on data from 1969-1974.

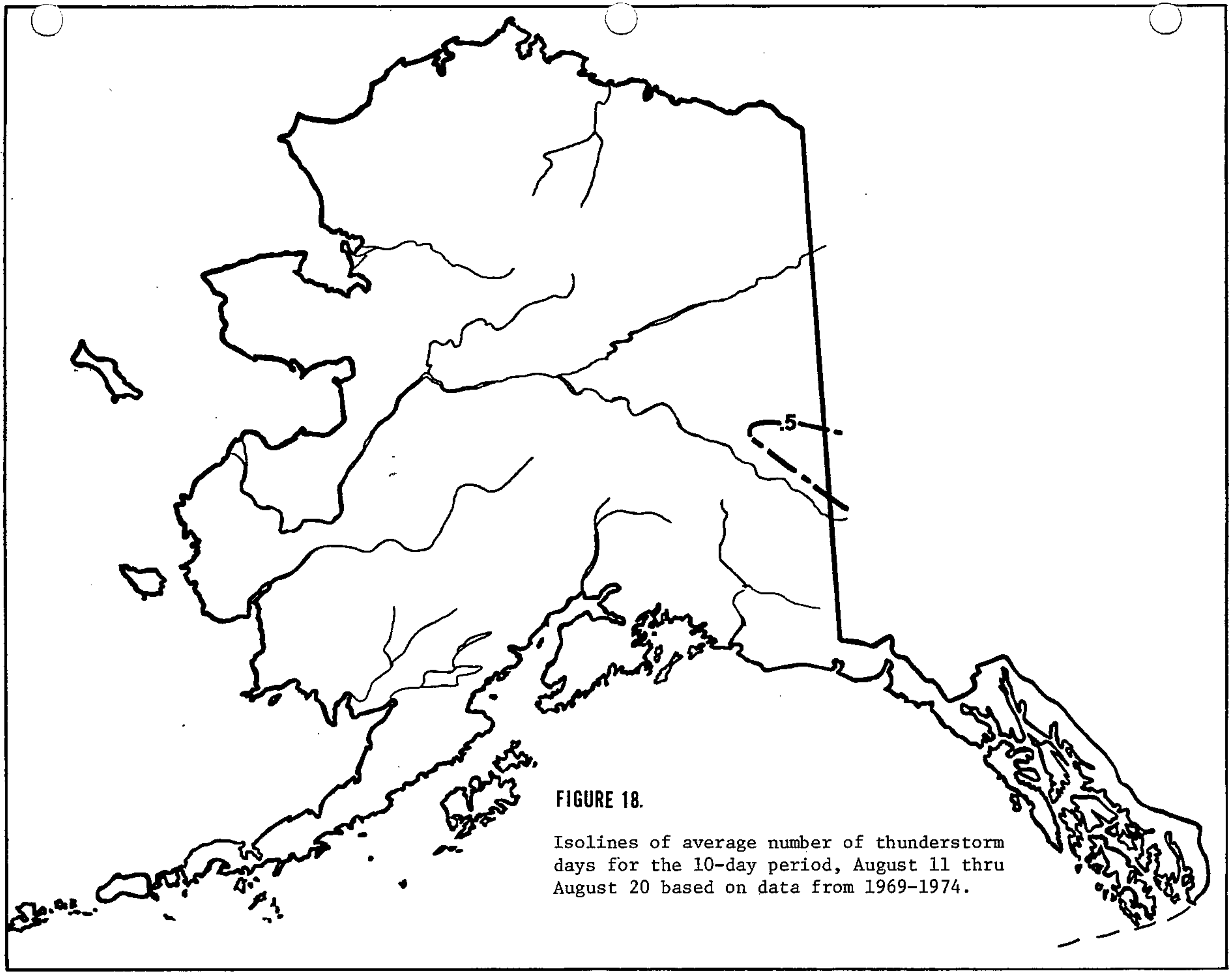

FIGURE 18.

Isolines of average number of thunderstorm days for the 10-day period, August 11 thru August 20 based on data from 1969-1974.

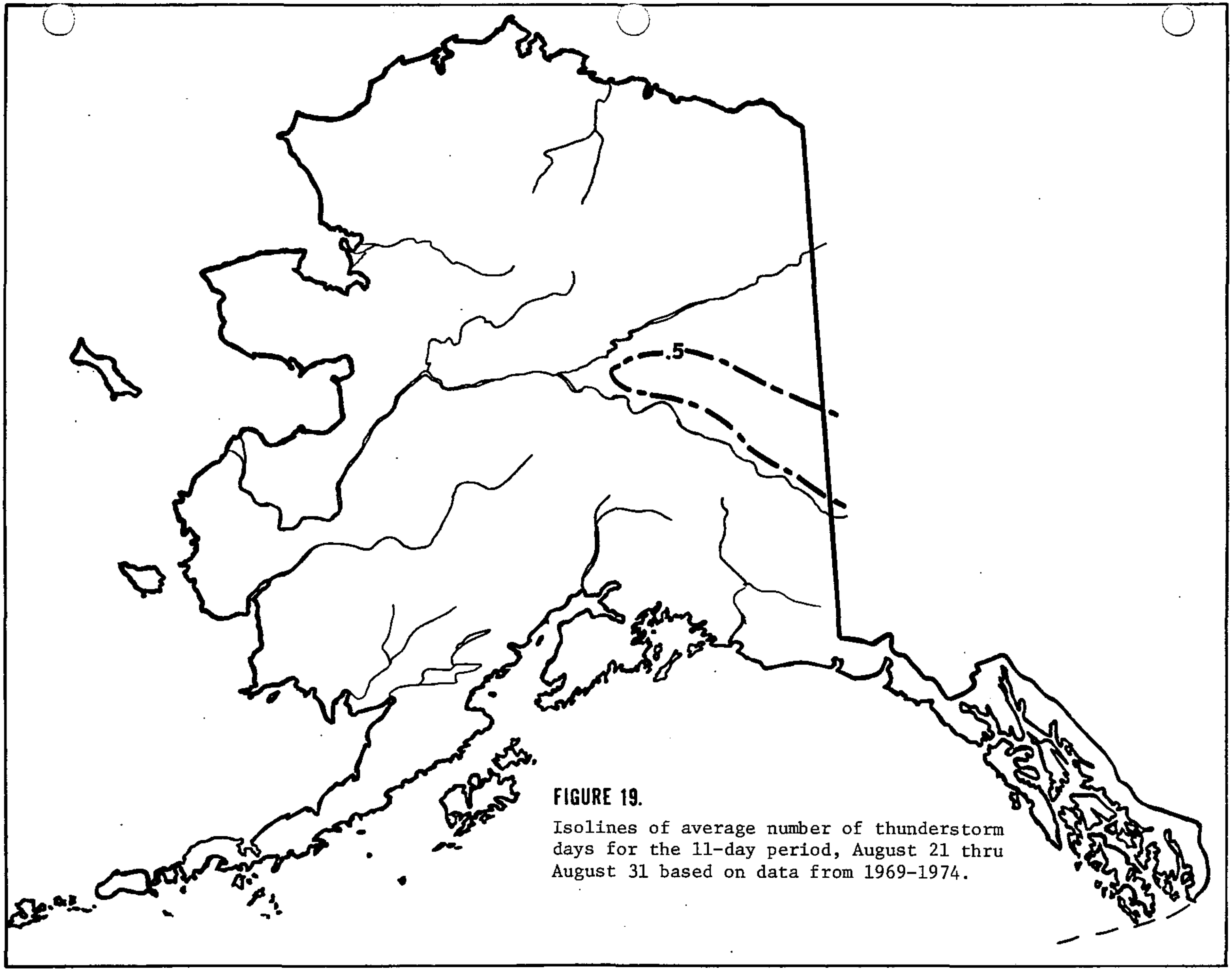

FIGURE 19.

Isolines of average number of thunderstorm days for the 11-day period, August 21 thru August 31 based on data from 1969-1974.

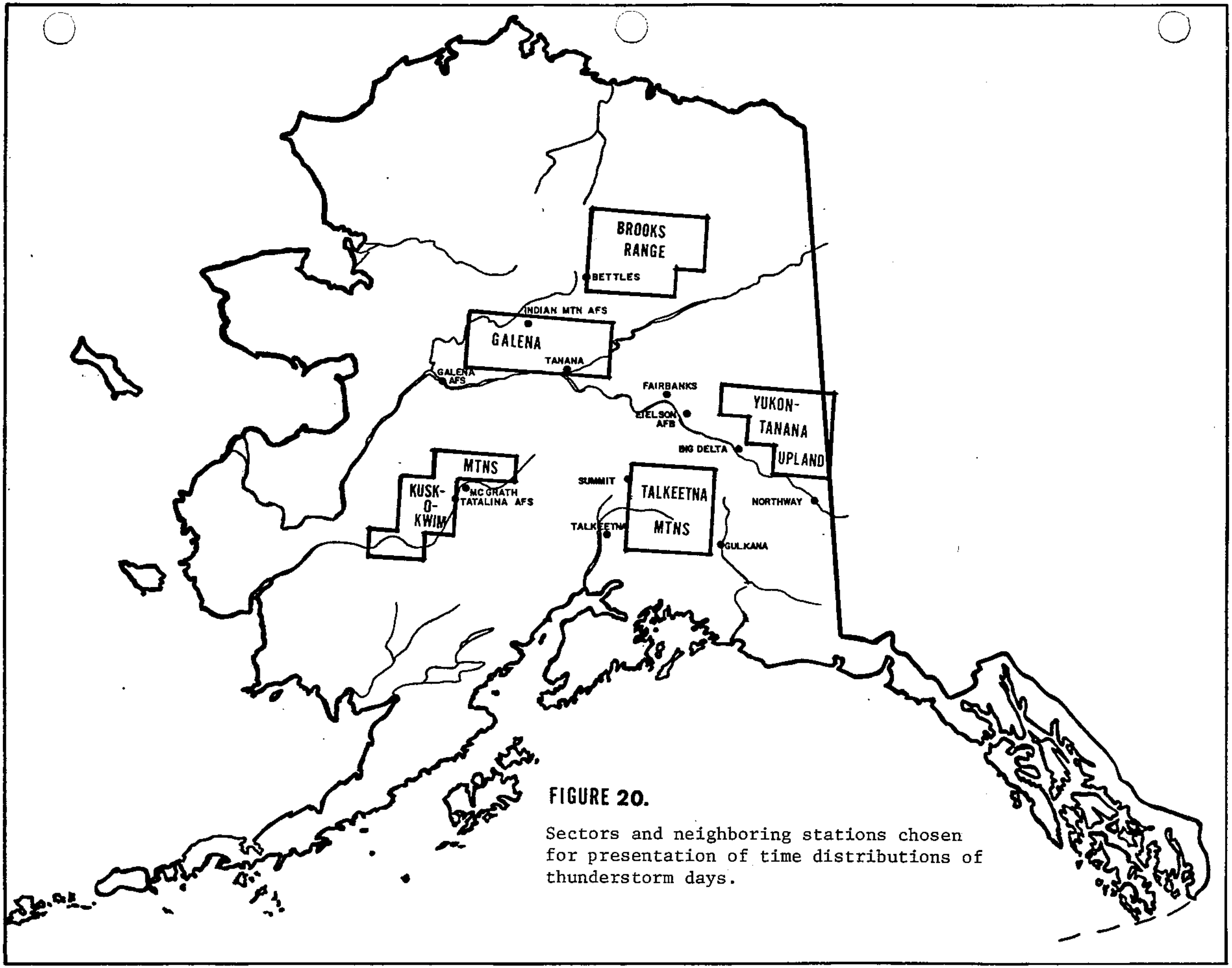

FIGURE 20.

Sectors and neighboring stations chosen for presentation of time distributions of thunderstorm days.

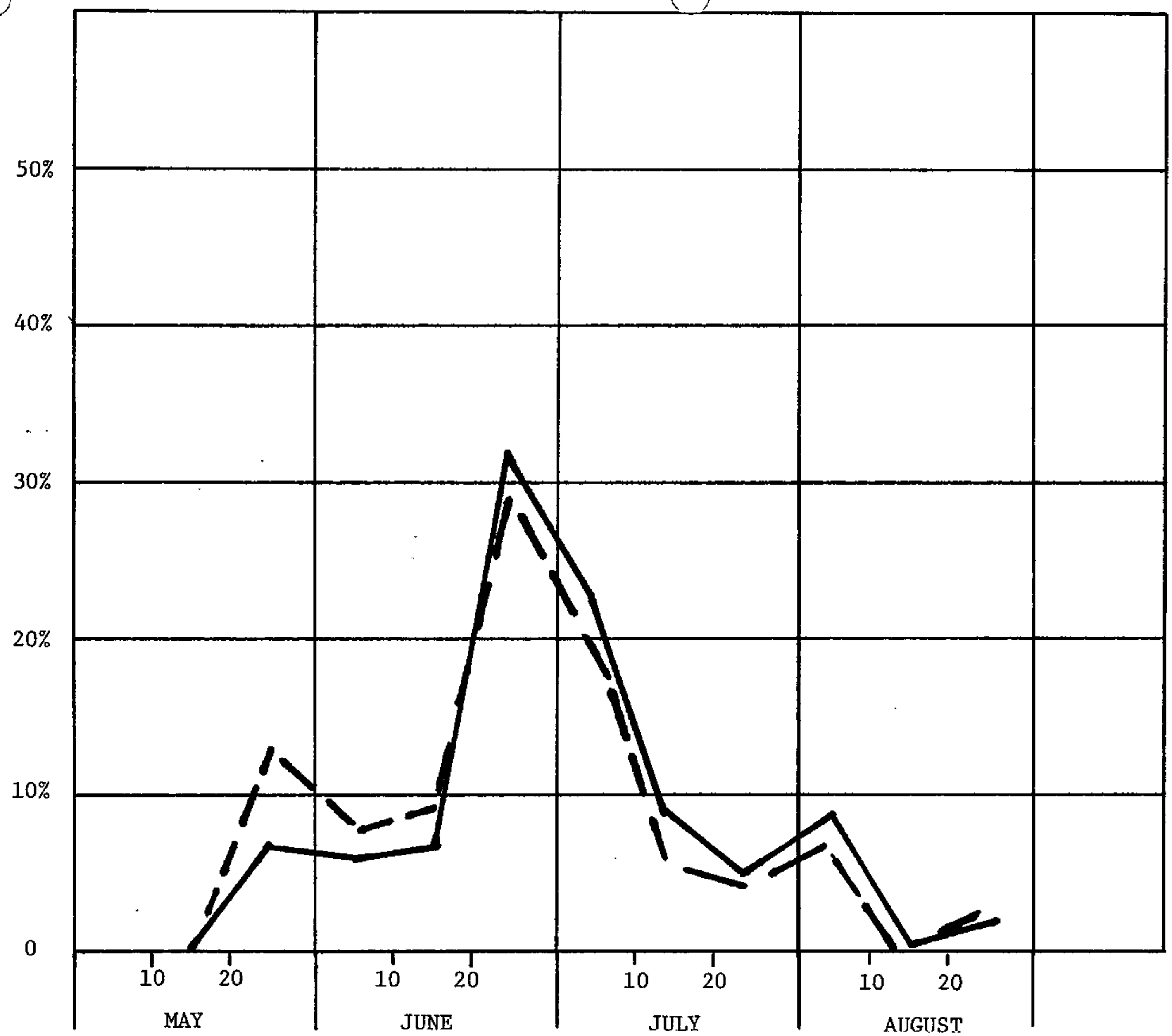

FIGURE 21. Percentage frequency of thunderstorm days for Kuskokwim Mountains Sector (solid line) and neighboring stations: McGrath and Tatalina AFS (broken line).

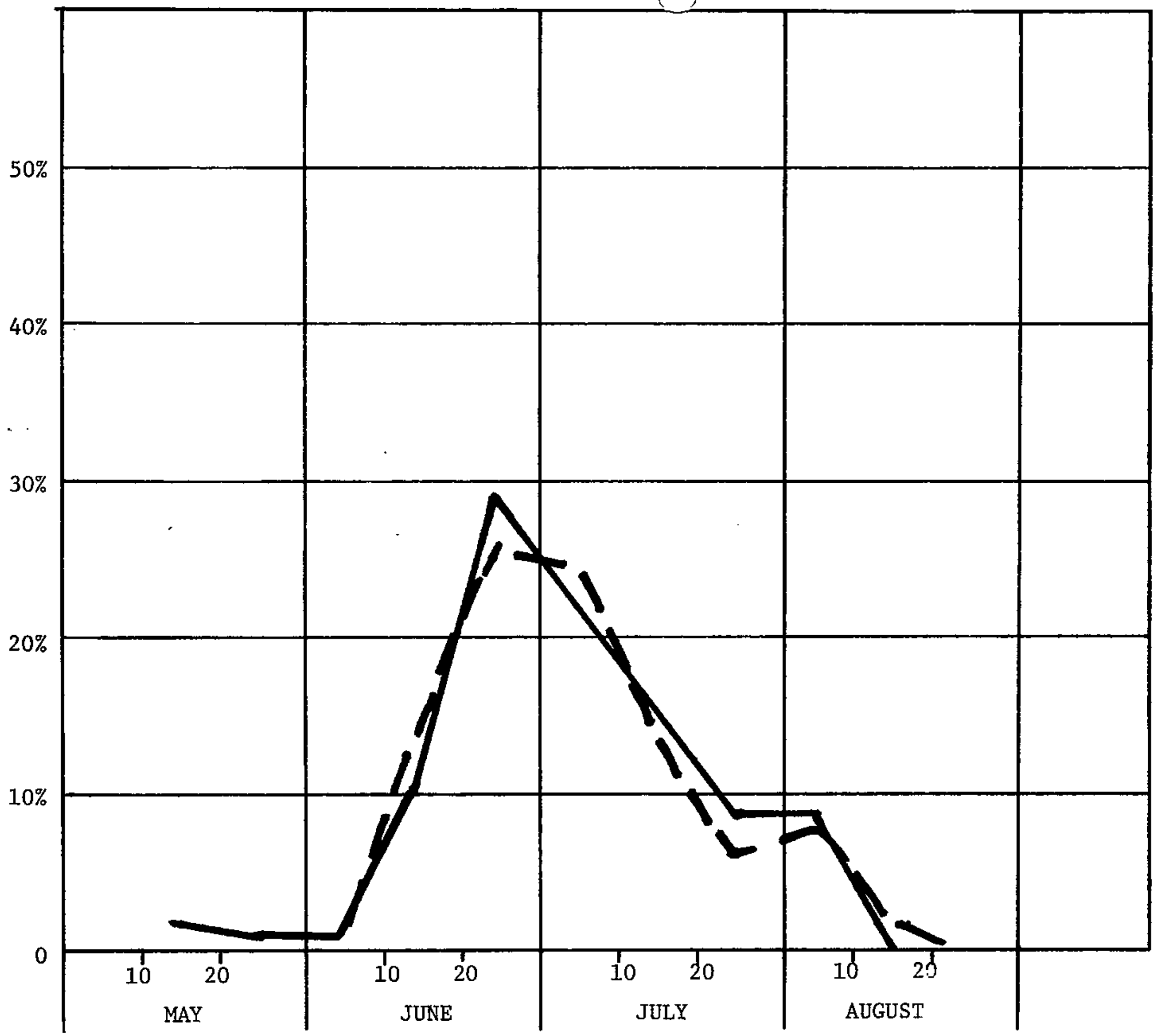

FIGURE 22. Percentage frequency of thunderstorm days for Galena Sector (solid line) and neighboring stations: Galena AFS, Indian Mountain AFS and Tanana (broken line).

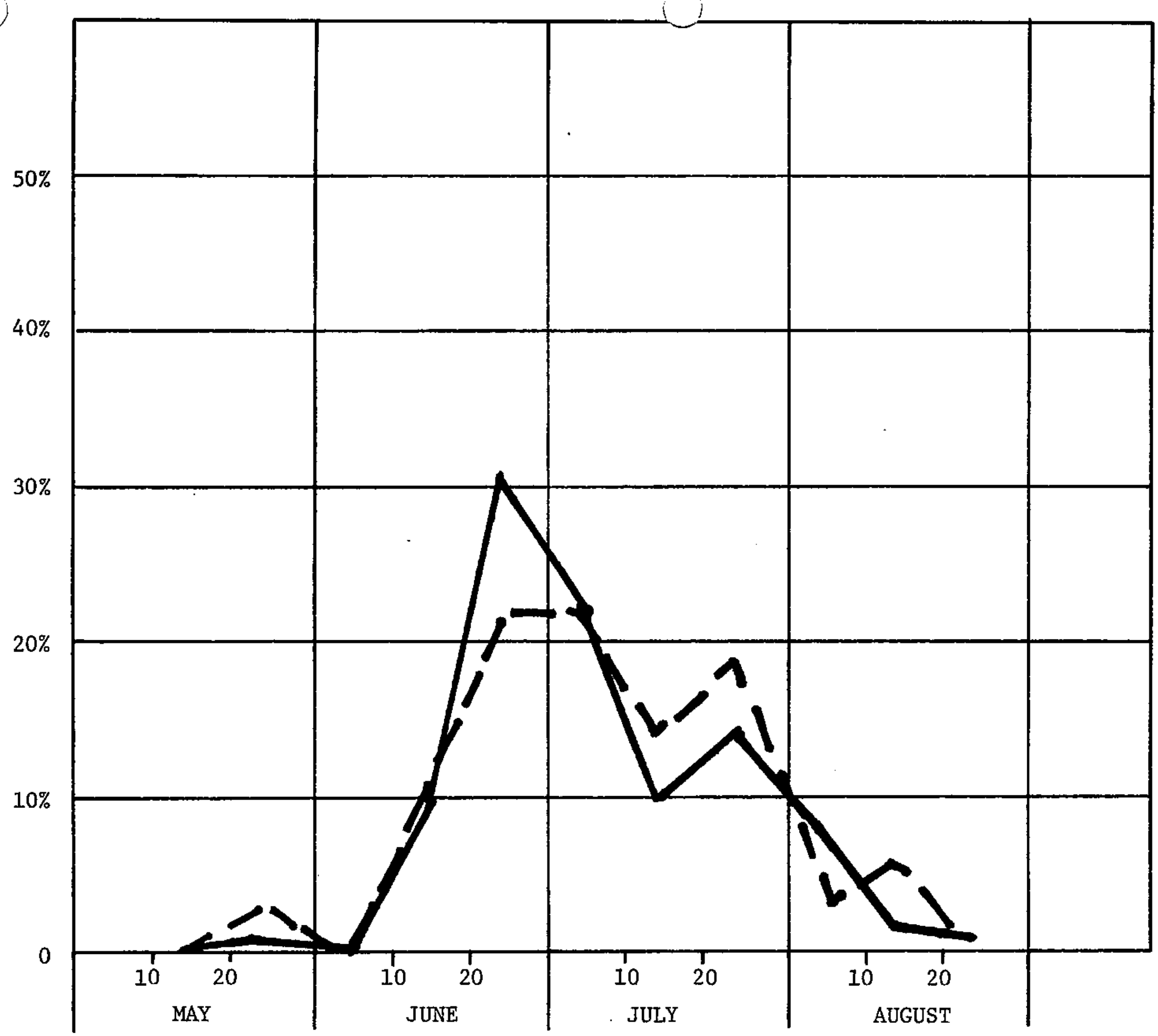

FIGURE 23. Percentage frequency of thunderstorm days for the Yukon-Tanana Upland Sector (solid line) and neighboring stations: Fairbanks, Eilson AFB, Big Delta, and Northway (broken line).

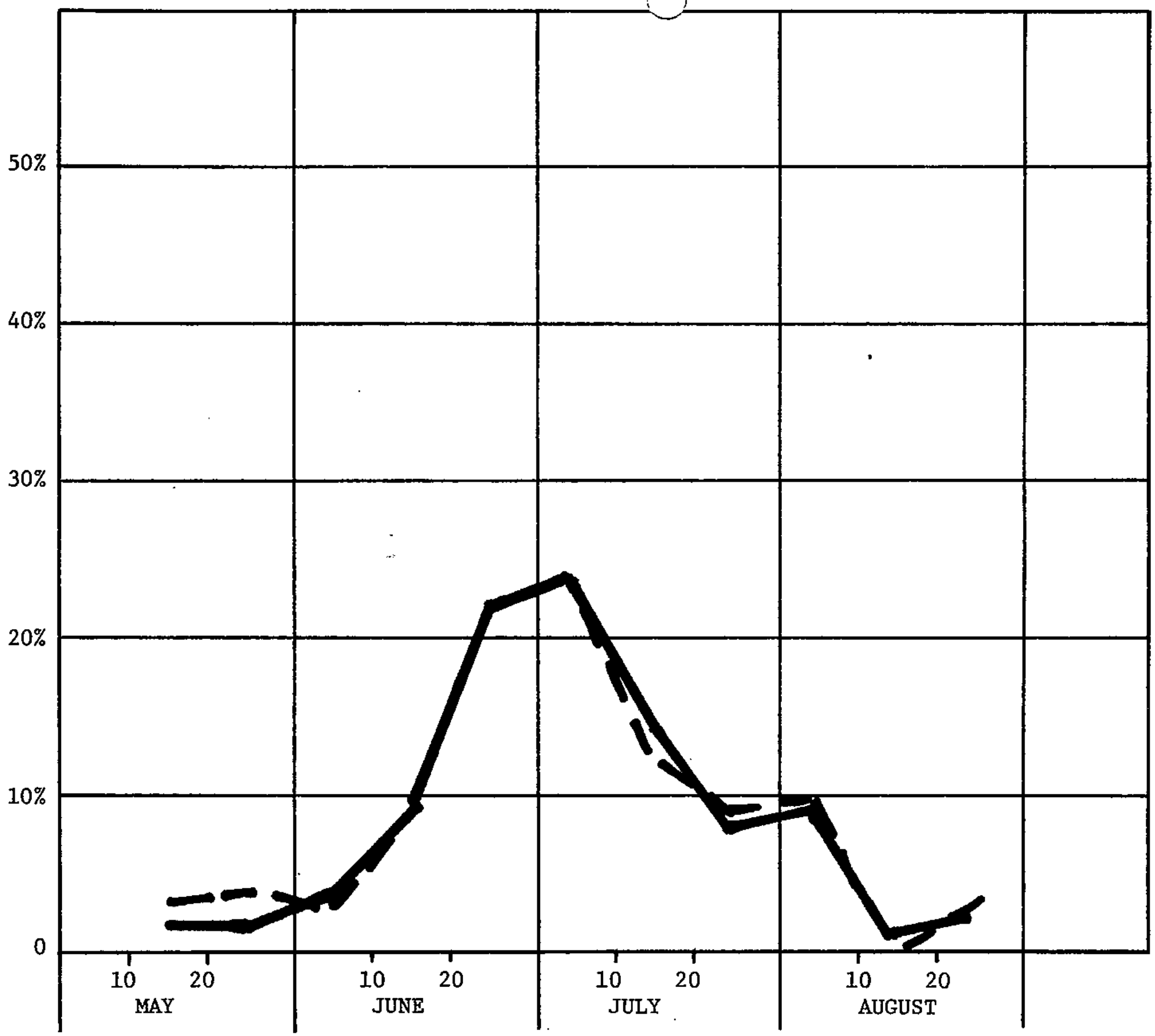

FIGURE 24. Percentage frequency of thunderstorm days for Brooks Range Sector (solid line) and nearby station, Bettles (broken line).

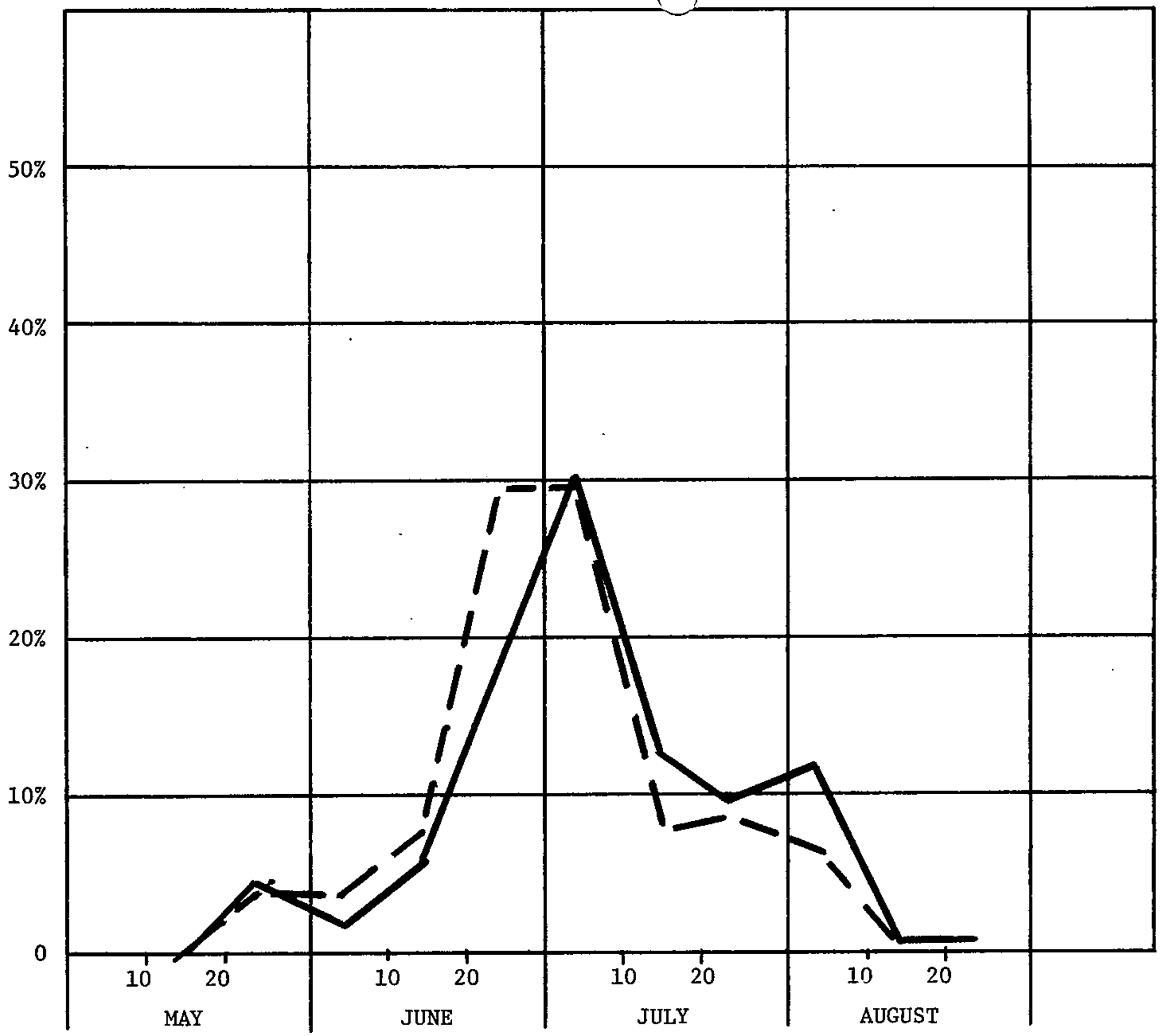

FIGURE 25. Percentage frequency of thunderstorm days for the Talkeetna Mountains Sector (solid line) and neighboring stations: Gulkana, Summit and Talkeetna (broken line).