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HEADQUARTERS
QUARTERMASTER RESEARCH & DEVELOPMENT COMMAND

TECHNICAL REPORT
EP-25

FC

FREQUENCY OF COLD-WET CLIMATIC CONDITIONS
IN THE UNITED STATES



QUARTERMASTER RESEARCH & DEVELOPMENT CENTER
ENVIRONMENTAL PROTECTION RESEARCH DIVISION

JULY 1956

NATICK, MASSACHUSETTS

HEADQUARTERS QUARTERMASTER RESEARCH & DEVELOPMENT COMMAND
OFFICE OF THE COMMANDING GENERAL
NATICK, MASSACHUSETTS

20 July 1956


Major General Kester L. Hastings
The Quartermaster General
Washington 25, D C.

Dear General Hastings:

This study, the first of a series dealing with the frequency and distribution of cold-wet conditions in the cold regions of the Northern Hemisphere, is intended to provide Army planners with a knowledge of how often and where cold-wet conditions occur. This information will assist planners to provide for the protection and efficiency of United States troops operating in regions with cold-wet climates.

Sincerely yours,

1 Incl
EP-25


E. G. CALLOWAY
Brigadier General, USA
Commanding

HEADQUARTERS QUARTERMASTER RESEARCH & DEVELOPMENT COMMAND
Quartermaster Research & Development Center, US Army
Natick, Massachusetts

ENVIRONMENTAL PROTECTION RESEARCH DIVISION

Technical Report
EP-25

FREQUENCY OF COLD-WET CLIMATIC CONDITIONS
IN THE UNITED STATES

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Project Reference:
7-83-03-008B

July 1956

FOREWORD

Cold-wet climatic conditions are characterized by temperatures near freezing, precipitation, cloudiness, and wet or snow-covered ground. The occurrence of cold-wet conditions is of great concern to the soldier, for such conditions frequently result in one of the most serious problems encountered in the field: wet clothing.

Based on criteria developed by the Quartermaster Corps, the frequency of cold-wet conditions at 61 stations in the United States was tabulated by the United States Weather Bureau, Statistical Control Center, National Weather Records Center, Asheville, North Carolina. For convenience of the reader, data are presented in both tabular and map form.

This report is the first in a series presenting the frequency and distribution of cold-wet and cold-dry conditions in the Northern Hemisphere. Additional studies in progress will cover northern North America, Europe, and Asia.

AUSTIN HENSCHEL, Ph.D.
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Approved:

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Abstract

Cold-wet conditions occur most frequently in the extreme Pacific Northwest, with a second maximum in the Northeast from the Great Lakes to northern New England. The minimum occurrence is in southern Arizona, New Mexico, Texas, and Florida.

During the colder part of the year (from October through April), cold-wet conditions occur over 50 percent of the time in the two above-mentioned regions of maximum incidence, reaching 70 to 80 percent in January.

In summer (July and August), cold-wet conditions occur less than 10 percent of the time except in the far northeastern and Lake states and on the north Pacific coast. The Olympic Peninsula of Washington has more than 30 percent frequency all summer, the highest in the country during this season.

FREQUENCY OF COLD-WET CLIMATIC CONDITIONS IN THE UNITED STATES

1. Introduction

Among the most severe climatic conditions that soldiers face while operating in the field are those known as cold-wet. These are characterized by temperatures that are often near or below freezing (32°F), especially during the night, but that may be above freezing during the day; abundant precipitation, generally in the form of snow, sleet, or chilling rains; much cloudiness and some wind. Thus, cold-wet climatic conditions frequently cause one of the most serious and annoying problems encountered by soldiers-- wet clothing. Troops not only feel miserable when exposed to these conditions, with lowered morale and efficiency, they may also become cold-weather casualties.

Since cold-wet climatic conditions occur during much of the year over large parts of the land surface of the Northern Hemisphere, it is essential to the development and supply of items of clothing and equipment, and for the training and indoctrination of troops, that the nature and distribution of these conditions be known. The purpose of this paper is to present the total frequency of four types of cold-wet conditions at 61 stations in the United States during each month of the year. It is intended that this information not only provide some knowledge of where and how often cold-wet conditions occur in the United States, but that it also serve as a guide in selecting proper locations for testing items of clothing and equipment and for training troops.

2. Definition of Cold-wet

There are many combinations of conditions that could be considered cold-wet. Selection of cold-wet climatic criteria, as used in this report, is based on: (1) Studies conducted in the field and laboratory by physiologists and biophysicists of the Quartermaster Corps; (2) experience of other individuals living in the field and conducting tests under cold-wet conditions; (3) study of climatic conditions as they occur at typical cold-wet places on the earth, such as the Aleutian Islands; (4) examination and study of available literature, much of it based upon research by scientists of the Quartermaster Corps over a period of more than ten years; and (5) a prototype study performed by the Weather Bureau for the Quartermaster Corps using data from selected stations in the United States and Alaska. Criteria were similar to those used in this report.

The four mutually exclusive combinations of cold-wet conditions selected for use in this report are as follows:

- a. Observations with falling precipitation or fog at the time of observation, with temperatures from 23°F through 59°F.
- b. Observations with falling precipitation or fog at the time of observation with temperatures from 60°F through 67°F and wind of 5 mph or more.
- c. Observations with no falling precipitation or fog at time of observation with snow on ground and with temperatures from 23°F through 49°F.
- d. Observations with no falling precipitation or fog at the time of observation, with no snow on ground, with 6-10 tenths clouds, and with temperatures from 23°F through 49°F.

True cold-wet conditions cannot be defined by any one meteorological element, but rather result from two or more elements in combination. For example, snow on the ground cannot be considered as indicative of cold-wet conditions unless accompanied part of the time by air temperatures near or above freezing. The Arctic and subarctic have snow on the ground much of the winter, but since winter temperatures usually remain well below freezing in these regions, troops and equipment will operate in cold-dry rather than cold-wet conditions, an entirely different situation.

In considering the criteria presented above, it should be emphasized that they define cold-wet only in terms of climate; given criteria may or may not have application to specific physiological or biophysical problems involving the reaction of man to this climate. All the criteria have a bearing on some aspect of the logistics of the soldier, since external climatic conditions profoundly affect the clothing and equipment requirements of troops.

3. Data

Hourly data used in preparing this study were compiled by personnel of the United States Weather Bureau for 61 stations (Fig.1) in the United States, in accordance with the above criteria provided by the Environmental Protection Research Division, Quartermaster Research and Development Command. Tabulation was performed at the National Weather Records Center, Asheville, North Carolina, using data available on punched cards. The period of record was limited to five years (July 1948 through June 1953) since observations for "state of ground," required in determining the existence of a snow cover, were not available for the years prior to 1948.

Certain weather elements directly associated with cold-wet conditions are not included in the criteria because they were not available on punched cards. Two of the more important of these missing elements are radiation and relative humidity. An attempt has been made to compensate for this



Figure 1: Location of Stations

TABLE I

PERCENT OF FREQUENCY OF OCCURRENCE OF COLD-WET CONDITIONS AT STATIONS IN THE UNITED STATES

STATION	JAN.	FEB.	MAR.	APR.	MAY	JUNE	JUL.	AUG.	SEP.	OCT.	NOV.	DEC.
Phoenix, Arizona	18.5	10.5	7.4	2.7	0.5	0.0	0.0	0.0	0.1	1.0	4.1	13.7
Yuma, Arizona	10.2	3.4	2.2	0.6	0.1	0.0	0.0	0.0	0.0	0.6	1.7	7.3
Little Rock, Arkansas	47.0	37.1	29.4	12.7	7.5	0.5	0.1	0.1	3.5	10.0	23.8	40.7
Texarkana, Arkansas	38.1	32.6	22.8	10.9	6.1	0.7	0.0	0.1	2.3	7.2	21.0	35.9
Fresno, California	49.5	31.7	23.7	7.1	2.2	0.3	0.0	0.0	0.6	3.9	24.5	59.6
Sacramento, California	51.0	34.1	25.8	9.3	3.8	0.9	0.2	0.1	0.9	6.7	25.0	58.9
San Diego, California	20.1	18.4	9.4	9.2	4.5	2.6	3.4	2.6	5.5	9.2	14.5	16.1
San Francisco, California	41.5	34.0	24.3	14.9	8.5	7.1	6.0	7.8	5.9	11.5	20.5	37.8
Denver, Colorado	29.2	39.6	41.1	40.1	24.5	9.1	3.0	2.2	7.4	18.3	32.5	38.5
Washington, D.C.	56.7	51.2	43.4	27.2	15.2	4.7	0.0	0.7	7.0	15.2	38.1	55.1
Jacksonville, Florida	15.9	17.6	9.5	3.9	0.8	0.1	0.0	0.0	0.2	2.9	10.0	21.0
Miami, Florida	1.0	3.3	0.8	1.0	0.1	0.0	0.0	0.0	0.0	0.1	0.8	1.6
Atlanta, Georgia	38.9	35.3	31.7	14.1	4.2	0.7	0.2	1.4	4.7	12.9	28.4	50.2
Boise, Idaho	56.7	59.0	59.9	23.4	16.5	7.3	0.2	0.7	4.3	19.5	50.3	74.9
Pocatello, Idaho	50.3	51.7	59.8	27.3	25.0	8.3	0.6	0.9	6.4	24.8	53.2	64.3
Chicago, Illinois	59.0	61.5	59.6	47.3	16.6	4.4	2.2	3.8	7.5	20.7	54.3	51.5
Des Moines, Iowa	38.6	56.2	57.8	43.2	16.1	6.9	2.4	4.8	6.8	16.3	38.1	43.5
Louisville, Kentucky	63.1	52.9	46.0	32.5	12.8	2.6	0.5	1.5	6.6	18.8	42.2	54.6
Goodland, Kansas	28.0	37.9	40.0	36.5	22.0	8.3	5.4	6.9	10.7	17.7	34.5	34.5
Wichita, Kansas	33.7	42.6	38.5	26.9	10.8	3.6	1.6	2.2	6.3	9.8	28.6	37.7
New Orleans, Louisiana	18.3	22.2	14.2	6.9	0.8	0.0	0.0	0.0	0.0	2.8	13.9	24.3
Caribou, Maine	30.3	27.4	61.1	74.6	37.8	19.7	10.8	14.7	26.2	52.2	70.0	42.8
Portland, Maine	57.2	52.9	65.8	54.3	34.8	16.7	8.2	13.4	20.5	36.5	59.2	51.5
Boston, Massachusetts	64.0	65.6	61.9	45.8	29.1	7.7	4.8	5.6	9.4	21.3	46.6	51.9
Calumet, Michigan	26.9	31.4	49.8	69.8	39.4	21.2	11.5	12.4	26.3	52.9	70.3	40.7
Sault Ste. Marie, Mich.	38.7	38.2	58.9	57.6	35.7	22.6	14.5	18.4	32.5	57.2	77.6	54.1
Duluth, Minnesota	17.3	26.5	49.6	67.2	39.0	20.5	15.9	14.1	28.6	48.1	56.1	30.7
Minneapolis, Minnesota	25.9	44.9	58.3	50.0	18.6	7.6	3.4	6.0	12.6	26.8	50.8	36.1
Kansas City, Missouri	41.0	49.3	46.9	32.4	10.0	2.6	1.7	1.6	5.9	13.3	32.9	44.0
St. Louis, Missouri	53.7	52.5	46.0	33.5	9.6	2.3	0.7	1.4	6.4	15.4	40.1	52.0

TABLE I (Cont'd)

PERCENT OF FREQUENCY OF OCCURRENCE OF COLD-WET CONDITIONS AT STATIONS IN THE UNITED STATES

STATION	JAN.	FEB.	MAR.	APR.	MAY	JUNE	JUL.	AUG.	SEPT.	OCT.	NOV.	DEC.
Billings, Montana	37.9	56.8	45.5	39.3	24.9	14.4	4.1	3.4	17.3	31.5	50.0	50.1
Great Falls, Montana	40.9	50.5	48.4	40.0	29.5	19.5	5.4	5.7	18.7	30.4	52.1	47.9
Grand Island, Nebraska	36.8	45.7	47.6	39.9	17.8	6.3	4.5	4.5	7.6	18.5	40.2	40.5
Elko, Nevada	47.4	46.2	56.0	32.0	24.1	7.5	1.5	0.9	6.6	21.0	39.6	53.5
Las Vegas, Nevada	34.9	18.2	13.4	2.7	1.1	0.4	0.0	0.0	0.3	1.7	9.2	25.9
Reno, Nevada	47.0	39.9	44.0	21.0	16.4	4.6	0.5	1.2	5.6	13.6	26.0	50.5
New York City, N.Y.	63.6	53.4	55.2	35.1	21.4	6.7	1.5	0.9	5.1	12.6	37.8	54.0
Syracuse, N.Y.	65.4	65.3	65.5	53.8	24.4	6.5	3.3	6.3	18.2	39.5	67.3	64.2
Asheville, No. Carolina	50.1	43.1	39.6	25.3	13.3	5.8	3.4	8.3	20.9	29.7	38.1	49.2
Raleigh, No. Carolina	37.6	39.6	29.0	15.7	8.0	3.1	0.6	1.1	5.1	14.8	25.5	42.7
Bismarck, No. Dakota	11.0	25.6	44.7	48.0	26.0	11.5	3.9	5.8	15.6	35.0	40.0	21.6
Fargo, No. Dakota	8.9	27.2	49.7	47.8	23.6	9.6	4.2	6.0	13.7	35.0	46.8	23.8
Cleveland, Ohio	68.1	64.3	65.3	51.2	17.4	4.6	2.3	3.7	9.2	27.1	60.9	61.9
Dayton, Ohio	69.9	62.7	58.2	45.2	16.7	5.6	1.0	4.1	9.9	26.1	55.4	58.8
Oklahoma City, Oklahoma	34.2	38.9	27.0	18.5	9.3	1.6	0.7	0.5	3.1	8.1	21.4	32.6
Medford, Oregon	77.4	67.9	58.9	28.0	23.6	9.3	0.7	0.6	5.8	29.1	61.4	83.9
Portland, Oregon	74.5	75.2	74.6	36.2	23.4	11.7	3.2	3.0	15.1	43.2	69.3	83.3
Harrisburg, Penn.	70.2	60.6	55.5	39.8	18.8	5.4	1.0	1.3	10.1	23.8	54.6	65.4
Charleston, S. Carolina	23.3	23.0	18.5	8.6	2.3	0.2	0.0	0.1	2.4	9.1	14.6	33.6
Huron, So. Dakota	19.7	40.8	51.5	44.8	23.0	7.7	2.9	4.5	10.8	27.8	40.4	27.1
Rapid City, So. Dakota	30.3	40.0	45.0	42.7	27.2	10.4	4.6	4.3	12.3	27.0	39.7	33.7
Nashville, Tennessee	53.6	46.0	36.4	23.2	6.3	1.6	0.1	0.7	3.9	15.4	35.2	48.0
Amarillo, Texas	27.7	30.0	25.4	18.6	11.4	3.4	2.3	3.4	6.5	7.9	20.8	28.6
Brownsville, Texas	14.4	13.2	7.4	1.4	0.6	0.0	0.0	0.0	0.0	1.6	5.5	10.8
El Paso, Texas	22.5	14.9	8.4	5.3	1.0	0.3	0.7	0.4	1.1	2.6	10.2	18.9
Houston, Texas	27.9	29.1	12.7	8.3	3.3	0.2	0.0	0.1	0.1	6.3	19.0	25.5
Salt Lake City, Utah	51.3	47.7	54.2	23.3	16.5	3.9	0.5	0.7	3.4	17.1	45.0	71.4
Spokane, Washington	55.5	69.1	65.2	34.1	20.2	13.1	2.7	2.3	8.8	39.0	70.3	70.3
Tatoosh, Washington	81.8	80.3	80.3	66.1	40.9	32.3	32.3	34.7	33.7	39.8	66.5	82.1
Cheyenne, Wyoming	34.5	47.8	43.0	40.4	37.1	16.9	6.4	5.9	17.0	25.0	38.3	42.8
Sheridan, Wyoming	35.7	52.5	49.8	42.1	27.7	13.2	5.5	3.1	15.9	32.2	48.7	42.2

deficiency by including falling precipitation and cloudiness in the criteria. These elements are usually indicative of high relative humidities and low radiation values.

The 5-year period of record used in this study includes approximately 3,600 hourly observations for each station, a sample large enough to provide a representative picture of the situation.

State of ground, reported every 6 hours at U. S. Weather Bureau stations, was used to determine the presence or absence of a snow cover. If a six-hourly observation showed "snow-on-ground" in an amount greater than a trace, it was considered that the succeeding 5 hourly observations also had snow-on-ground. If no snow was on the ground at the time of the six-hourly observation, the succeeding 5 hourly observations were considered to have no snow-on-ground, except that if falling snow was reported on 2 consecutive hourly observations, the second and remaining observations within the 6-hour period were also considered as having snow on the ground.

Data were used only from lowlands and scattered stations in interior plateaus. No attempt is made to analyze mountain conditions since they vary considerably with slight differences in locations. Slope, altitude, exposure, and other factors strongly influence the climate in mountains, including the distribution and frequency of cold-wet conditions. In general, it may be expected that cold-wet conditions will occur earlier in fall and will last later in spring in mountains than in adjacent lowlands. At very high altitudes in some of the mountains of the western part of the country these conditions may persist throughout summer. During winter, at moderate to high altitudes, temperatures will usually be very low, and cold-dry rather than cold-wet conditions will occur.

4. Monthly Frequencies

The total frequency of occurrence (in percent) of all four criteria combined for each of the 61 stations used, for each month of the year, is given in Table I.

Figures 2 through 13 show isarithms drawn for 10-percent intervals for each of the twelve months. These maps show the distribution and frequency of cold-wet conditions during any month. It should be recognized that the isarithms are not sharp lines of discontinuity between one region and another, but simply represent values in a gradual transition between greater and lesser frequencies. In some areas, such as mountains, the zones of transition are more abrupt than in lowland areas, but there is still a gradation.

a. September through April The greatest frequency and extent of cold-wet conditions in the United States occurs during the period from October



FIGURE 2: FREQUENCY (PERCENT) OF COLD-WET CONDITIONS DURING SEPTEMBER



FIGURE 3: FREQUENCY (PERCENT) OF COLD-WET CONDITIONS DURING OCTOBER

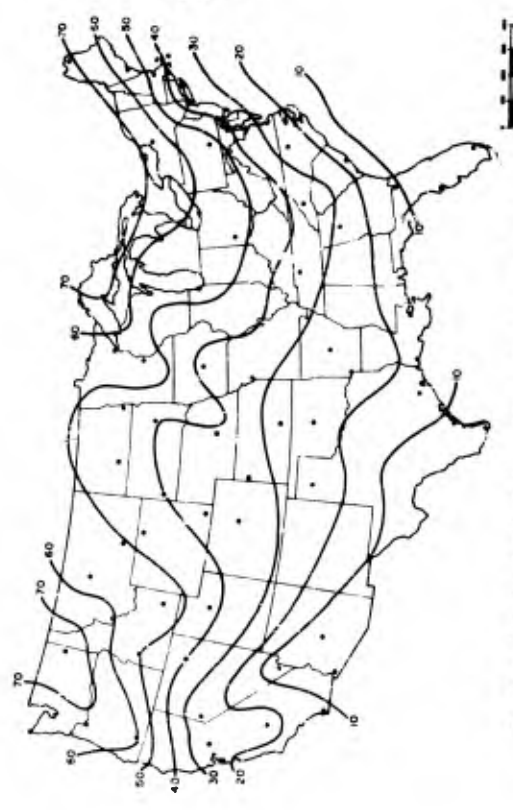


FIGURE 4: FREQUENCY (PERCENT) OF COLD-WET CONDITIONS DURING NOVEMBER

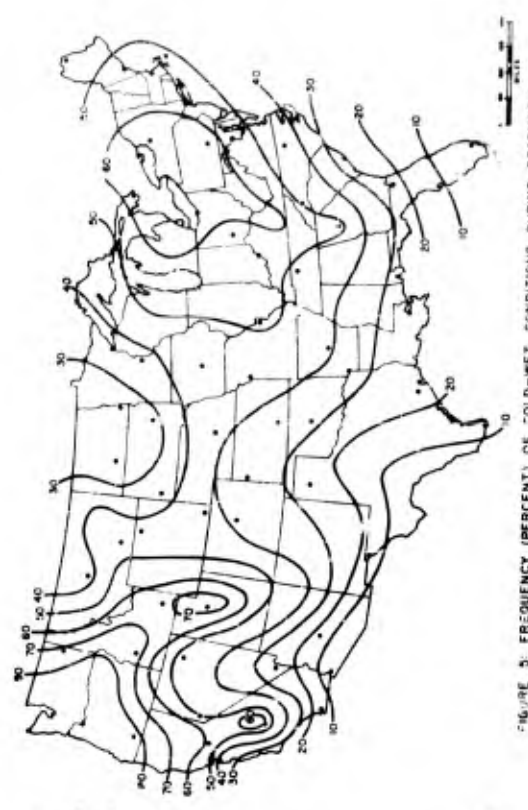


FIGURE 5: FREQUENCY (PERCENT) OF COLD-WET CONDITIONS DURING DECEMBER



FIGURE 6: FREQUENCY (PERCENT) OF COLD-WET CONDITIONS DURING JANUARY

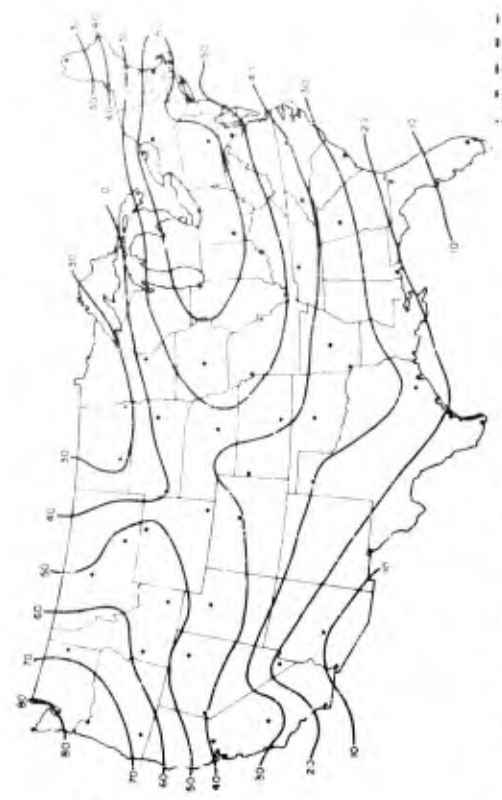


FIGURE 7: FREQUENCY (PERCENT) OF COLD-WET CONDITIONS DURING FEBRUARY

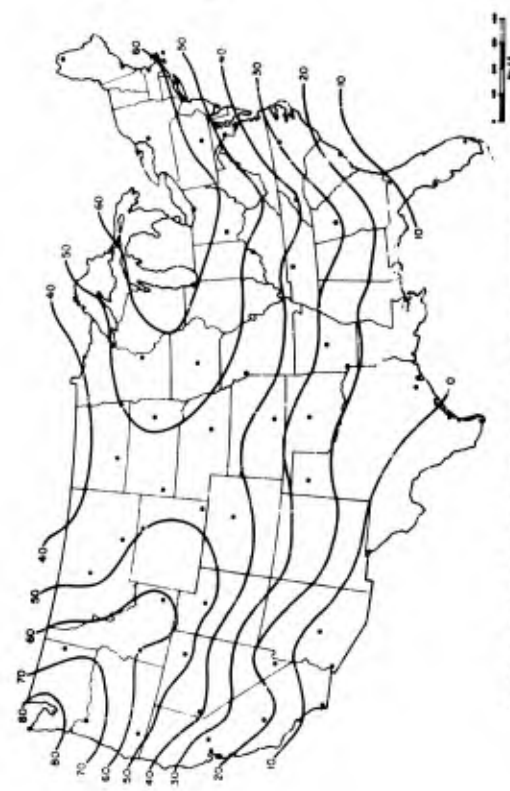


FIGURE 8: FREQUENCY (PERCENT) OF COLD-WET CONDITIONS DURING MARCH

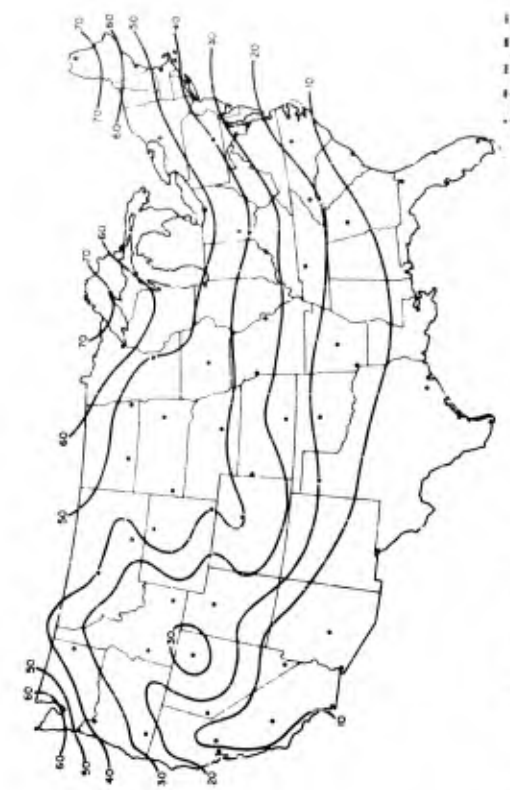


FIGURE 9: FREQUENCY (PERCENT) OF COLD-WET CONDITIONS DURING APRIL



FIGURE 10: FREQUENCY (PERCENT) OF COLD-WET CONDITIONS DURING MAY



FIGURE 11: FREQUENCY (PERCENT) OF COLD-WET CONDITIONS DURING JUNE



FIGURE 12: FREQUENCY (PERCENT) OF COLD-WET CONDITIONS DURING JULY



FIGURE 13: FREQUENCY (PERCENT) OF COLD-WET CONDITIONS DURING AUGUST

through April. For purposes of discussion, September is included in this period, for during this month the frequency and extent of cold-wet conditions first begin to increase throughout the country after the relatively infrequent occurrence during summer. The frequency of cold-wet conditions does not increase to a winter maximum in all parts of the country and then decrease in spring. This is true for some parts of the country, but in areas such as the North Central States midwinter is too cold to be wet.

In September (Fig. 2) only the Appalachians and the extreme northern part of the United States, especially the northwestern part of Washington, show frequencies of cold-wet conditions of 20 percent or greater. Most of the United States has less than 10 percent occurrence during this month.

During October (Fig. 3) there is a considerable increase (over September) in cold-wet conditions in the northern part of the country, especially in New England and in the vicinity of the Great Lakes where increases of about 20 percent occur. During this month approximately the northern quarter of the country has cold-wet conditions at least 30 percent of the time. In the extreme northern part of the Great Lakes area (represented by Calumet and Sault Ste. Marie) and in Caribou, Maine, these conditions occur over 50 percent of the time; secondary centers occur in the extreme Northwest (Tatoosh Island, Washington, and Portland, Oregon) and in the Appalachians as far south as North Carolina. The southern part of the country has cold-wet conditions less than 10 percent of the time, with Miami, Florida, recording less than 1 percent.

The sudden increase that occurs from September to October continues into the month of November (Fig. 4). Northeastern United States, the Great Lakes area, and the Pacific Northwest have cold-wet conditions from 50 to over 70 percent of the time. The southern part of the country shows increases of between 20 and 30 percent, and only southern Arizona, Texas, and Florida have cold-wet less than 10 percent of the time.

Only a slight rise (10 or 15 percent) occurs in the north central part of the country, owing to the increase of very cold weather during this month.

In December (Fig. 5), cold-wet frequencies actually decrease in the northern part of the country, except in the Pacific Northwest. The greatest increases occur in California and at the intermontane stations of western United States where cold-wet conditions occur as far south as northern Arizona and New Mexico as much as 30 to 40 percent of the time.

In the north central part of the country the pronounced influence of very cold weather is now evident. Marked decreases in cold-wet frequency, on the order of 15 to 25 percent, occur in Minnesota, North and South Dakota,

and parts of adjoining states. During December, and also during January and February, these states are dominated by very cold dry polar continental air which has its source in interior, snow-covered Canada. Temperatures are usually much too low for cold-wet conditions to occur. The decrease also occurs in northern Maine, and to a lesser extent, near the Great Lakes. To the south, slight increases of about 5 to 10 percent are noted in Texas, Oklahoma, Kansas, Colorado, and Nebraska. In these states the frequency of cold-wet conditions is probably limited by weather that is either too warm, too dry, or too cold.

The increased frequency of cold-wet conditions is particularly noticeable in the far western part of the country--California, Oregon, and Washington--where the winter rains, accompanied by cloudiness and lower temperatures, now prevail. In central and northern California these conditions occur 60 to over 80 percent of the time in December. Of considerable interest is the fact that the frequency in central and northern California is comparable to that of the Great Lakes and New England. Southern Florida, with 2 percent at Miami, continues to show the lowest frequency of cold-wet conditions.

In January (Fig. 6) the decrease in frequency of cold-wet conditions in North and South Dakota continues with the frequency decreasing to between 10 and 30 percent. A slight decrease occurs in California, Oregon, and Maine, and a slight increase is evidenced in Ohio and Pennsylvania, but with these exceptions conditions remain much the same as in December.

February (Fig. 7) shows an increase in frequency in the North Central States, with slight decrease south of the Great Lakes, in Oregon, and in California. The increase noted in North and South Dakota is due to the rise in temperature following the coldest month of the year, January. In this month Miami has its greatest frequency, approximately 3 percent.

During March (Fig. 8) the only significant changes in the frequency of cold-wet conditions are in Minnesota, North and South Dakota, Montana (10 to 15 percent increase), and Maine (20 to 30 percent increase), where continued warming is evidenced in the more frequent occurrence of these conditions. The extreme Pacific Northwest (Olympic Peninsula) continues to have the greatest frequency, 80 percent.

In April (Fig. 9), with the retreat of the polar front and cold air masses, a sharp increase is seen in the northern Great Lakes, North Central States, and northern Maine. Considerable decreases are apparent in the southern part of the country, California, and the Pacific Northwest. During this month northwestern Washington relinquishes its lead (for the only time) to the northern Great Lakes and Maine which have 70 to 75 percent occurrence.

b. May through August During this period cold-wet conditions occur less than 20 to 30 percent of the time throughout the country, with the following exceptions: (1) the Olympic Peninsula of Washington which has over 30 percent frequency all summer, and (2) in May (Fig. 10), all the northern states, which have 25 to 40 percent occurrence. During June, July, and August (Figs. 11 to 13), cold-wet conditions occur 10 percent of the time or more only in the far northern fringe of the country.

5. Cold-Wet Regions

From the preceding discussion and from examination of the monthly maps, it is apparent that the greatest frequency of occurrence of cold-wet conditions is concentrated in two parts of the country: (1) the Pacific Northwest, and (2) the states bordering the Great Lakes, especially those east and south of the Lakes. These regions may be designated as the "cores" of cold-wet conditions; that is, they are the places where the greatest frequency exists, in terms of the defined criteria. Away from these two regions there is a gradual decrease in the frequency of cold-wet conditions.

The data for the year and for the cold season, presented in Table II and plotted on maps (Figs. 14 and 15), show the two major cold-wet cores on a generalized basis.

The average annual frequency of cold-wet conditions (Fig. 14) shows that the northern two-thirds of the country has these conditions about 20 percent of the time or more. The Pacific Northwest shows a frequency of 40 to 50 percent, and the states bordering the Great Lakes, particularly Michigan, northern Ohio, northwestern Pennsylvania, and northern New York, have 35 to 40 percent. A slight extension into extreme northern Vermont, New Hampshire, and Maine may also be observed.

6. Comparisons of Frequency of Occurrence of Each of the Criteria

Table III presents the frequency of occurrence of each of the four cold-wet climatic criteria at four selected stations during January, April, July, and October. Two stations, Duluth, Minn., and Tatoosh Island, Wash., are in the core regions previously discussed. Nashville, Tenn., and Boston, Mass., are representative of the transition to the areas of less frequent cold-wet conditions of eastern and southern United States.

Table III shows that with few exceptions Criteria A (cold with precipitation) and D (cold and cloudy) occur most frequently at each station and Criterion B (mild, wet, and windy) is least frequent.

In January, at Tatoosh Island, Boston, and Nashville, Criteria A and D occur more than 50 percent of the time (67.6 percent at Tatoosh), and Criterion C (cold

TABLE II

AVERAGE PERCENT PER MONTH OF COLD-WET CONDITIONS AT STATIONS IN THE UNITED STATES

<u>STATION</u>	<u>Annual</u>	<u>Oct-Apr</u>	<u>STATION</u>	<u>Annual</u>	<u>Oct-Apr</u>
Phoenix, Arizona	4.9	8.3	Great Falls, Montana	32.4	44.3
Yuma, Arizona	2.2	2.2	Grand Island, Nebraska	25.8	38.5
Little Rock, Arkansas	17.7	28.7	Elko, Nevada	28.0	42.2
Texarkana, Arkansas	14.8	24.1	Las Vegas, Nevada	9.0	15.1
Fresno, California	16.9	28.6	Reno, Nevada	22.5	34.6
Sacramento, California	18.1	30.1	New York City, N.Y.	28.9	44.5
San Diego, California	9.6	13.8	Syracuse, N.Y.	40.0	60.1
San Francisco, California	18.3	26.4	Asheville, No. Carolina	27.2	39.3
Denver, Colorado	23.8	34.2	Raleigh, No. Carolina	18.6	29.3
Washington, D.C.	26.2	41.0	Bismarck, No. Dakota	24.1	32.3
Jacksonville, Florida	6.8	9.0	Fargo, No. Dakota	24.7	34.2
Miami, Florida	0.7	1.2	Cleveland, Ohio	36.3	57.0
Atlanta, Georgia	18.6	30.2	Dayton, Ohio	34.5	53.8
Boise, Idaho	31.1	49.1	Oklahoma City, Oklahoma	16.3	25.8
Pocatello, Idaho	31.0	47.3	Medford, Oregon	37.2	58.1
Chicago, Illinois	32.4	50.6	Portland, Oregon	42.7	65.2
Des Moines, Iowa	27.6	42.0	Harrisburg, Penn.	33.9	52.8
Louisville, Kentucky	27.8	44.3	Charleston, S. Carolina	11.3	18.7
Goodland, Kansas	25.2	32.2	Huron, So. Dakota	25.1	36.0
Wichita, Kansas	20.2	31.1	Rapid City, So. Dakota	26.4	36.9
New Orleans, Louisiana	8.6	14.7	Nashville, Tennessee	22.5	36.8
Caribou, Maine	39.0	51.2	Amarillo, Texas	15.5	22.7
Portland, Maine	39.2	53.9	Brownsville, Texas	4.6	7.8
Boston, Massachusetts	34.5	51.0	El Paso, Texas	7.2	11.8
Calumet, Michigan	37.7	48.8	Houston, Texas	11.0	18.4
Sault Ste. Marie, Mich.	42.2	54.6	Salt Lake City, Utah	27.9	44.3
Duluth, Minnesota	34.5	42.2	Spokane, Washington	37.6	57.6
Minneapolis, Minnesota	28.4	41.8	Tatoosh Island, Wash.	55.9	71.0
Kansas City, Missouri	23.5	37.1	Cheyenne, Wyoming	29.6	38.8
St. Louis, Missouri	26.1	41.9	Sheridan, Wyoming	30.7	43.3
Billings, Montana	31.3	44.4			

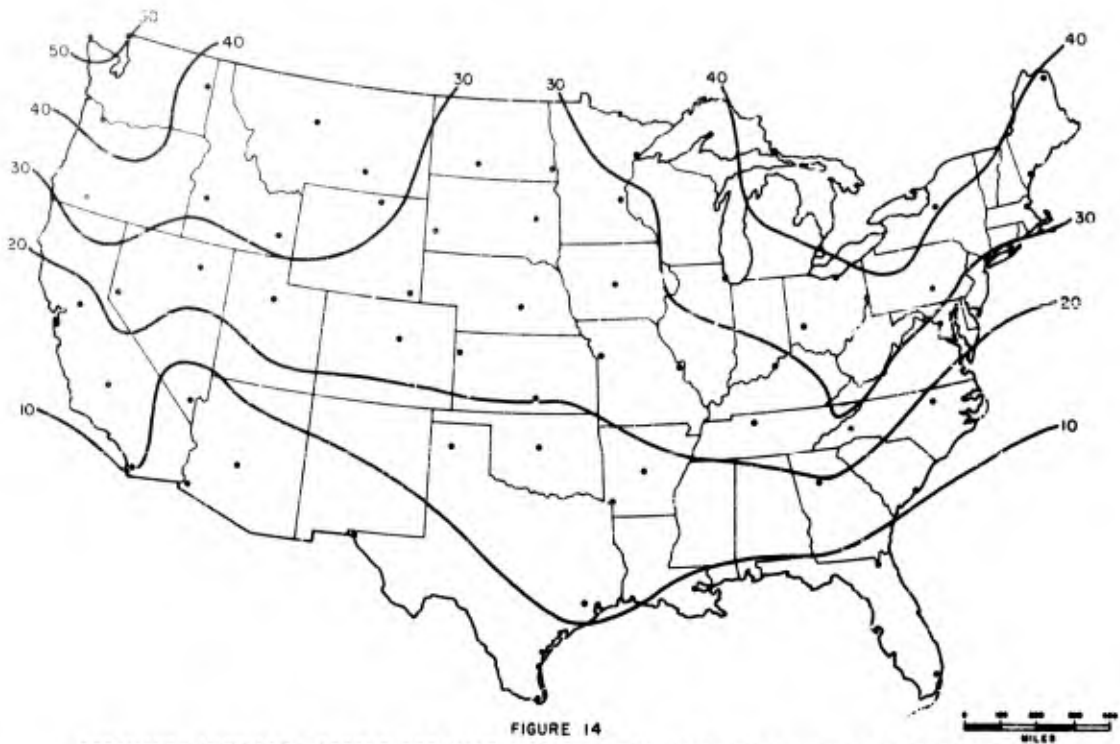


FIGURE 14
 FREQUENCY (AVERAGE PERCENT PER MONTH) OF COLD-WET CONDITIONS, JANUARY-DECEMBER
 (PERIOD OF RECORD, 1948-1953)

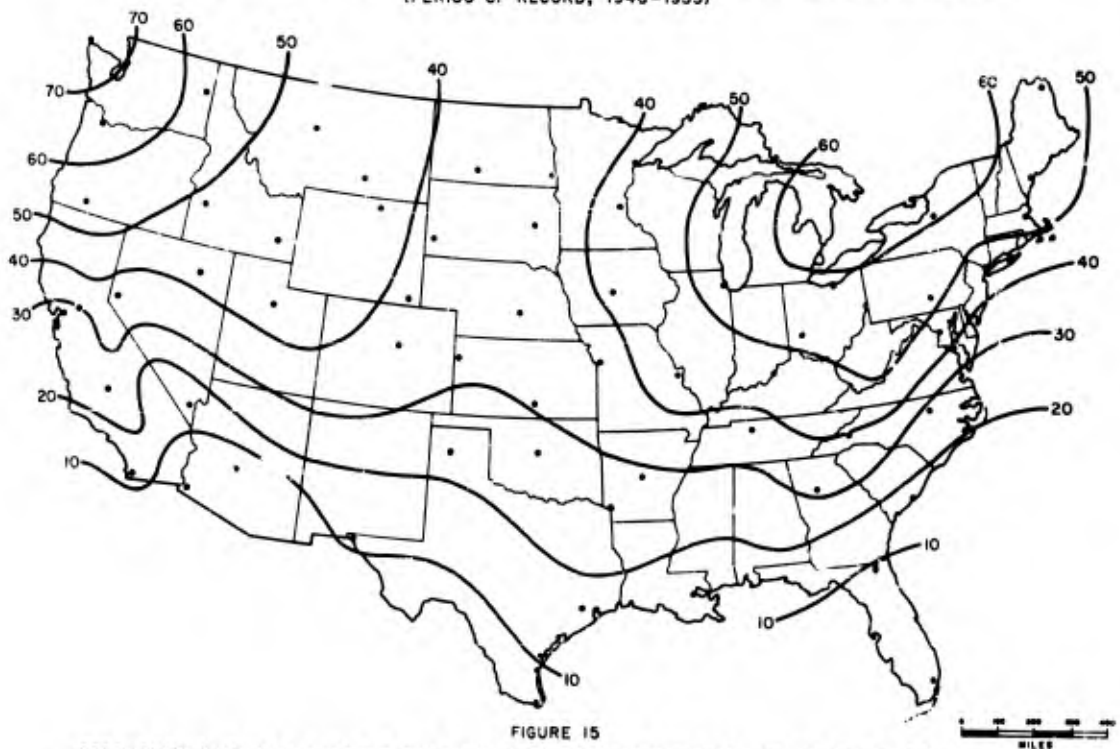


FIGURE 15
 FREQUENCY (AVERAGE PERCENT PER MONTH) OF COLD-WET CONDITIONS, OCTOBER-APRIL
 (PERIOD OF RECORD, 1948-1953)

TABLE III: FREQUENCY PERCENT OF SEPARATE COLD-WET CRITERIA*
(FOR FOUR SAMPLE STATIONS)

Station	Criteria				Criteria			
	A	B	C	D	A	B	C	D
		<u>January</u>				<u>April</u>		
Tatoosh Island, Wash.	38.6	0.0	14.2	29.0	22.8	0.0	0.0	43.2
Duluth, Minn.	7.4	0.0	9.7	0.1	21.9	0.0	34.4	10.9
Boston, Mass.	24.8	0.0	13.7	25.6	21.5	0.6	0.6	23.2
Nashville, Tenn.	27.3	1.9	1.0	23.4	10.4	1.8	0.0	11.2
		<u>July</u>				<u>October</u>		
Tatoosh Island, Wash.	32.1	0.1	0.0	0.0	28.5	0.0	0.0	11.3
Duluth, Minn.	10.2	5.2	0.0	0.5	18.3	0.1	1.2	28.6
Boston, Mass.	0.3	4.5	0.0	0.0	10.8	4.7	0.0	5.8
Nashville, Tenn.	0.0	0.1	0.0	0.0	10.7	2.3	0.0	2.4

* Criterion A - Observations with falling precipitation or fog at time of observation with temperatures from 23°F through 59°F.

Criterion B - Observations with falling precipitation or fog at time of observation with temperatures from 60°F through 67°F and wind of 5 mph or more.

Criterion C - Observations with falling precipitation or fog at time of observation with snow on ground and temperatures from 23°F through 49°F.

Criterion D - Observations with no falling precipitation or fog at time of observation with no snow on ground, with 6-10 tenths clouds, and with temperatures from 23°F through 49°F.

with snow on ground) appears as a secondary maximum at Tatoosh (14.2 percent) and Boston (13.7 percent). The extensive occurrence of cold-wet climatic conditions during January is due to the low temperatures which occur throughout the country. The complete absence of Criterion B, (except at Nashville which shows 1.9 percent) is attributed to temperatures being at or below 60°F at most places.

In April, the most noticeable changes are the increased occurrence of Criterion D at Tatoosh Island, the significant increase of cold-wet at Duluth (especially of Criterion C), and the decrease in all types of cold-wet conditions at Nashville. The large increase in Criterion D at Tatoosh Island indicates the continuation of winter cloudiness (18 days are cloudy) accompanied by a sharp decrease in frequency of precipitation from January to April. The increase at Duluth is due to warmer spring weather, with temperatures rising into the cold-wet range, and also to the persistence of a snow cover. At Nashville, temperatures are above the limit of the cold-wet range (67°F) a greater proportion of the time, thereby reducing the frequency of occurrence.

In July, only Tatoosh Island and Duluth (32.2 and 15.9 percent, respectively) have significant amounts of these conditions. The relatively low temperatures (mean daily minimum temperature during July is 51.5°F at Tatoosh Island and 54.5°F at Duluth) are accompanied by a summer maximum of precipitation frequency at Duluth, and by prevailing cloudiness (16 days of the month) at Tatoosh Island. Throughout most of the country, however, summer temperatures are too high, or precipitation and cloudiness too small, for cold-wet conditions to occur.

During October there is a considerable increase in cold-wet conditions at each of the four stations. Of greatest significance for this increase are the lower temperatures occurring throughout the country. Colder weather is accompanied by increases in cloudiness and precipitation at Tatoosh Island, and by increased cloudiness at Duluth.

7. Conclusions

a. The Pacific Northwest, especially the western part of the Olympic Peninsula in the state of Washington, has the greatest frequency of cold-wet conditions in the United States. In this region, such conditions occur 20 to 30 percent of the time in summer, and may be expected nearly 80 percent of the time from December through March.

b. There is a secondary center of cold-wet conditions in the northeastern part of the country, from the Great Lakes to New England. In this area, cold-wet conditions persist from 40 to over 70 percent of the time from October through April.

c. Cold-wet conditions are most frequent throughout the country during the period October through April except in the North Central States (Minnesota, North and South Dakota, and Montana), during winter.

d. In winter (December through February) climatic conditions in North and South Dakota are similar to those usually found in the Arctic and subarctic during early spring and late fall, with cold-wet conditions alternating with cold-dry.

e. Of the four criteria used, Criteria A and D occur most frequently, and Criterion B least frequently.

8. Acknowledgements

The authors are indebted to personnel of the Climatological Services Division, United States Weather Bureau, and especially to Mr. Harold Crutcher, for technical advice and guidance given during the original planning for the tabulation of data used in this study, and for supervision of the data extraction. Cartography was by Mr. Roland Frodigh.

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