

FOG FREQUENCY IN THE UNITED STATES*

ARNOLD COURT AND RICHARD D. GERSTON

THIRTY years ago the *Geographical Review* published a map of fog distribution over the United States, by Robert G. Stone.¹ Five years later a map of "Average Annual Number of Days with Dense Fog" appeared as one of forty-six maps depicting climates of the United States in "Climate and Man," the 1941 *Yearbook of Agriculture*.² No other fog maps for the entire country have since appeared, and both Stone's map and the "Climate and Man" map have been widely reprinted and adapted.³ A new map showing fog distribution over the conterminous United States, based on averages at 251 first-order Weather Bureau stations through 1960, is presented here as Figure 1.

Stone's map (Fig. 2) was based on "mean values for the full period of record . . . (through 1931 or 1932) . . . for 410 stations in all, including many non-Weather Bureau observatories and about 100 stations outside the United States proper." His primary basic data were 30-year means, 1901-1930, for 108 United States stations and 26 Mexican stations; in addition, "data were obtained from about 500 lighthouses."⁴ The "Climate and Man" map (Fig. 3) was based on "200 first-order Weather Bureau stations, period 1899-1938."

* This paper is the outgrowth of a 1964 seminar report by Mr. Gerston, then a graduate student at San Fernando Valley State College.

¹ Robert G. Stone: Fog in the United States and Adjacent Regions, *Geogr. Rev.*, Vol. 26, 1936, pp. 111-134; map on p. 112 (Fig. 1).

² "Climate and Man," *Yearbook of Agriculture 1941*, U. S. Dept. of Agriculture, Washington, D. C., 1941, p. 737.

³ Stone's map has appeared, for example, in J. J. George: Fog: Its Causes and Forecasting with Special Reference to Eastern and Southern United States (I), *Bull. Amer. Meteorol. Soc.*, Vol. 21, 1940, pp. 135-148, reference on p. 142; Helmut Landsberg: Physical Climatology (State College, Pa., 1941), p. 102; and Sverre Pettersen: Introduction to Meteorology (New York, 1941), p. 93 (2nd edit. 1958, p. 143). The "Climate and Man" map has appeared in various later publications of the Weather Bureau and also in B. C. Haynes: Meteorology for Pilots, *U. S. Dept. of Commerce, Civil Aeronautics Administration, Civil Aeronautics Bull. No. 25*, Washington, 1940, p. 109; Glenn T. Trewartha: An Introduction to Weather and Climate (2nd edit.; New York and London, 1943), p. 159; E. Wendell Hewson and Richmond W. Longley: Meteorology Theoretical and Applied (New York and London, 1944), p. 341; George F. Taylor: Elementary Meteorology (New York, 1954), p. 185; Glenn T. Trewartha: An Introduction to Climate (3rd edit.; New York, Toronto, London, 1954), p. 124; Stephen Sargent Visser: Climatic Atlas of the United States (Cambridge, Mass., 1954), p. 181 (Map 444); George H. T. Kimble: Our American Weather (New York, Toronto, London, 1955), p. 264; and Clarence E. Koeppel and George G. De Long: Weather and Climate (New York, Toronto, London, 1958), p. 69.

⁴ Stone, *op. cit.* [see footnote 1 above], pp. 124-125.

➤ DR. COURT is professor of climatology in the Department of Geography at San Fernando Valley State College, Northridge, California. MR. GERSTON teaches in the Madrone School, Thousand Oaks, California.

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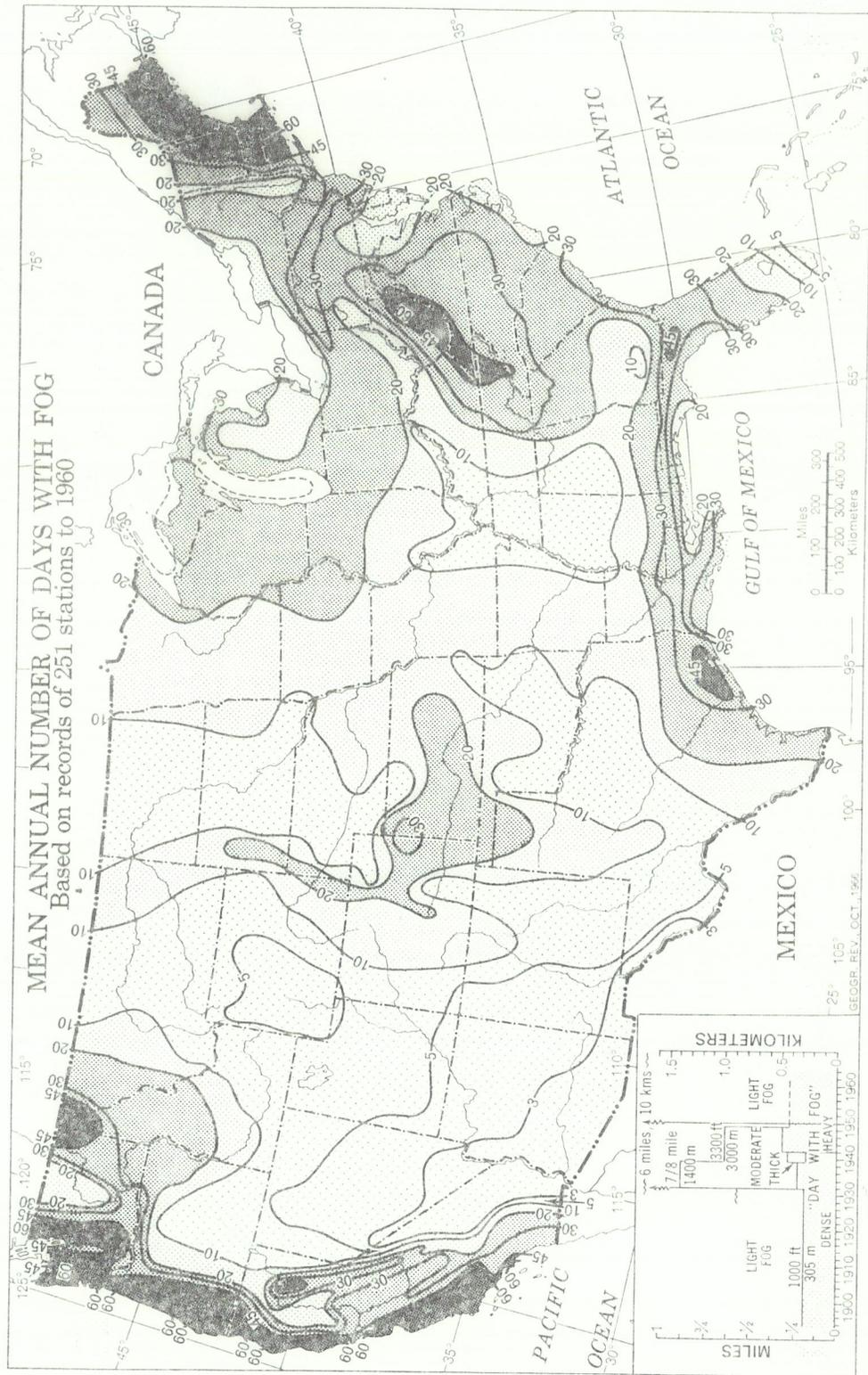


FIG. 1—A new map of fog frequency in the United States.

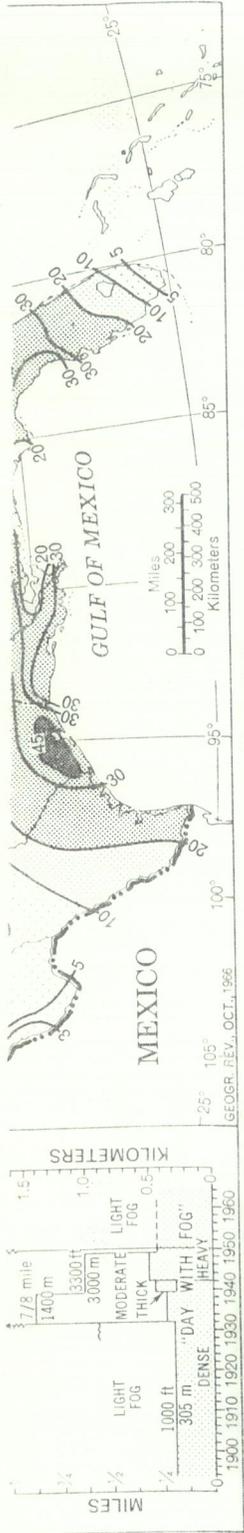


Fig. 1—A new map of fog frequency in the United States. GEOGR. REV., OCT., 1966



Fig. 2—Robert G. Stone's fog-distribution map from the *Geographical Review* (see text footnote 1 for reference).

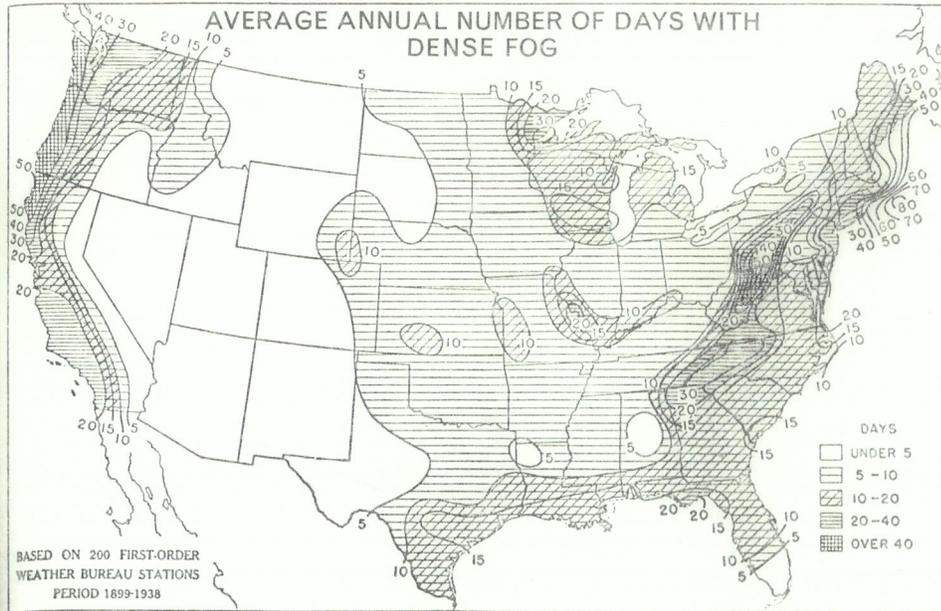


Fig. 3—The "Climate and Man" fog-distribution map (see text footnote 2 for reference).

Use of fewer stations, for a slightly later period, may have caused the "Climate and Man" map, though in general similar to Stone's, to differ from it in several details. These differences, and the availability of data for an additional two or three decades, prompted the preparation of Figure 1.

DEFINITIONS

"Days with dense or heavy fog" is the climatic quantity mapped here, as it was on both the preceding maps. But the definitions of such days, and of "dense" and "heavy," have changed repeatedly.⁵

In 1892, two years after the Weather Bureau was organized, a *foggy day* was one "on which fog surrounds the station for one hour or more, and is dense enough to obscure objects at a distance of 1,000 feet." In 1906 two classes of fog were defined: *dense*, when visibility was less than 1000 feet; *light*, when it was greater, with no upper limit.

Airways observations, begun in 1928, retained *dense* when visibility was less than 1000 feet. Because reportable visibilities were 1/8, 1/4, 1/2, 3/4, and 1 mile or more up to 10 miles, in practice *dense* fog was recorded when objects or lights could not be distinguished at 1/4 mile (1320 feet), and *light* fog, nominally when "visibility of only about one-half mile is present," was recorded when visibility was 1/4 mile or more. More flexibility in visibility reports was provided in the 1932 revision of airways reporting procedures, which introduced a third fog category: *moderate*, when "visibility is over 1/5 mile but not more than 3/4 mile." Fog was *light* when visibility was greater (no upper limit), and *dense* when visibility was "less than 1/5 mile (1000 feet)," though 1/5 mile is actually 1056 feet.

A fourth category was introduced in 1939: *thick* fog, when "objects are visible at 1/5 mile but not at 5/16. Visibility to be reported as 1/4 or 1/5 mile." *Dense* fog was to be reported only when "objects are not visible at 1/5 mile," visibility to be reported at 1/8 or 0 mile. Limits for *moderate* fog were narrowed slightly: "when objects are visible at 5/16 mile but not at 5/8 mile, visibility to be reported as 1/2 mile."

In 1943 *thick* and *dense* fogs were merged to form *heavy* fog, in which objects could not be seen at 5/16 mile, or 1650 feet; definitions of *moderate* and *light* fog were unchanged. Six years later, on January 1, 1949, *moderate* fog was combined with *light* fog, in which objects could be seen at 5/16 mile

⁵ See M. D. Baliles: History of Observational Instructions on Fog, *Key to Meteorol. Records Documentation No. 3.031*, U. S. Weather Bureau, 1959. The history of fog definitions in the present paper was carefully checked by J. H. Hagarty and W. A. Joos of the Environmental Data Services, Environmental Science Services Administration (formerly the Office of Climatology, United States Weather Bureau), whose invaluable assistance is gratefully acknowledged.

but not at 7 miles, and *moderate* was abolished as a term; *heavy fog* was retained without change. Four months later, on May 1, all descriptive terms were abolished, and *fog* was reported whenever visibility was less than 7 miles unless the restriction was caused by smoke or haze.

Climatic summaries, such as those used for the map offered here, usually list only days with *heavy fog*, including *dense fog* (as it was called until 1943) and *thick fog* (1939–1942). Hence the hydrometeor mapped here is one that obscured objects at distances of 1000 feet until 1928, of 1320 feet from 1928 to 1932, of 1000 feet from 1932 to 1939, and of 1650 feet from 1939 to 1949; these limits are shown graphically in the inset to Figure 1. Since the elimination of descriptive terms in 1949, summaries have been generally for *heavy fog* with visibility of 1/4 mile (1320 feet) or less.

OBSERVATIONS

Fog is the most variable, in spatial distribution, of all the major climatic elements. The boundaries of its areas of occurrence, both instantaneously and in the mean, are much sharper than those of sunshine or precipitation. Detectable only by the human eye or by sophisticated substitutes such as the transmissometer, fog rarely is recorded completely. Precipitation can be trapped, wind is chronicled by broken branches, lightning is reported by thunder. But fog must be seen to be recorded, and not only must it be seen, it must be sought.

A reasonably true account of fog occurrence can be attained only through a continuous and conscientious watch of the weather, such as has been maintained at an increasing number of airports during the past thirty years. The pilot's paramount need for seeing the runway makes the visual range (vertically the "ceiling," horizontally the "visibility") the most important part of the aviation weather report. Hence fog occurrence is well documented at airports. Likewise, ship logs usually record fog occurrence, and some lighthouse and harbor records also are fairly complete.

But at other United States weather stations, especially before the needs of aviation forced a reorganization in weather reporting, fog was reported only if the observer was sure it had occurred and had lasted for at least an hour. In principle, observers were expected to keep track of the weather twenty-four hours a day, but in actuality stations were manned only during normal office hours, and for regular observations.

The number of observations⁶ has increased from two per day (at 8 a.m.

⁶J. H. Hagarty: History of Weather Bureau Climatological Record Forms for Surface Synoptic and Airway Observations, *Key to Meteorol. Records Documentation No. 2.211*, U. S. Weather Bureau, 1964.

and 8 p.m. EST) to three per day (a noon, local time, observation was added in 1918, discontinued in 1948) to four or five per day (1 a.m. and 1 p.m. EST observations were added in 1938). Observations at airport stations, begun

TABLE I—NUMBER OF DAYS WITH DENSE FOG*

STATION	STONE	CLIMATE AND MAN	CURRENT
Blue Canyon, Calif.	10-15	5-10	68
Cheyenne, Wyo.	5-10	10-15	25
Colorado Springs, Colo.	1-5	0-5	23
Daytona Beach, Fla.	1-5	10-15	34
Santa Maria, Calif.	40-50	20-30	88
St. Louis, Mo.	5-10	20-?	8
Wilmington, Del.	15-20	10-15	44

* Since ranges are given here, the table does not everywhere agree with the map, specifically at Blue Canyon and Wilmington.

about 1930, are made hourly or oftener; these stations superseded downtown offices as the principal observatories in 1939.

Hence the chances that a dense or heavy fog will be reported if it lasts only an hour or two during the night have increased markedly in the past two or three decades. As far as the climatic data go, the country is becoming foggier—just as increased awareness, closer networks, and better rural communications have increased the number of tornadoes recorded.

These considerations of the definition of "day with fog," and of the likelihood that such a day would be recorded, are necessary for proper interpretation of the map presented here. It is based on the averages, for the entire period of record, of 251 United States Weather Bureau stations as given in the *Local Climatological Data: Annual Summary* for 1960. The Weather Bureau has not yet adopted the international thirty-year period, 1931-1960, for elements other than temperature and precipitation, and it gives averages only for the "period of record," from 1891 onward. Thus at the older stations the means combine observations of many sorts, from two per day in the early years to the continuous watch of recent times.

COMPARISONS

Of the two previous maps, that in "Climate and Man" is much more generalized than Stone's. It shows fewer than five foggy days annually throughout the Great Basin and Rocky Mountain region (except ten around Cheyenne) and twenty to thirty foggy days on the south and central coasts of California; in both regions the current figures for several stations are much higher. On the other hand, ten to twenty foggy days are indicated in the

lower Missouri and Ohio Valleys, but more recent figures are only six days in Cairo, Illinois, with heavy or light fog, and eight days in St. Louis. The Stone map accounts much more accurately for fog in major mountain areas and

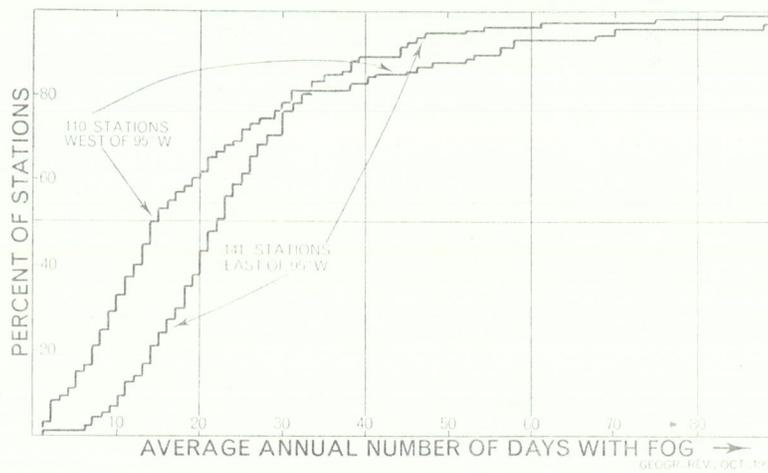


FIG. 4

over water bodies but gives little attention to localized fog east of the Rockies. A few examples of the number of days with dense fog, as estimated from the isopleths on the two maps and compared with recent Weather Bureau figures, are given in Table I.

West of the Continental Divide fogs occur most frequently over elevated, exposed, west-facing terrain. Radiation fogs occur, especially in winter, in the intercoastal and interior valleys, where clear, cold, calm air permits drainage, usually resulting in low-lying ground fog. Similar radiation fogs generally occur east of the Rockies, most frequently in winter in Appalachian valleys. Frontal and air-mass fogs are most common in the Deep South, north of the Gulf of Mexico (except for southern Texas and southern Florida), along the New England coast, and around Lakes Superior and Huron. Other fogs occur in the high plains of Colorado and Wyoming, an area of frequent prefrontal lifting, and on adjacent mountains.

Of the 251 stations available for this study, 110 were west of 95°W , and 141 east of it (Fig. 4). The western stations have the extremes; that is, more stations with few foggy days, and more stations with many foggy days. In each area 82 percent of the stations have fewer than thirty-three foggy days per year. Half of the 251 stations have nineteen or fewer days with fog annually.

The four foggiest eastern stations are all in New England; the least foggy is Key West, Florida, with less than one day per year, the only eastern station with fewer than six foggy days annually. The eight foggiest western stations are all on west-facing Pacific slopes. Although fourteen western stations have averages of fewer than six days with fog per year, Bishop, California, is the only one, like Key West, with an average of only a trace. Mount Washington, New Hampshire (303), and Tatoosh Island, Washington (251), have the highest frequencies in the conterminous United States. Neither Stone's map nor the "Climate and Man" map shows Mount Washington specifically; they suggest only twenty or fifteen days there, respectively. Stone's Table I gives 318 foggy days in 1933 as the only available data.

The new map presented here, though still inadequate because of the sparseness, inhomogeneity, and possible nonrepresentativeness of the basic data, is nevertheless offered as the best available synthesis of available information for the conterminous United States of the annual distribution of days with fog.