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A DIGEST OF TECHNICAL INFORMATION

RADIOLOGICAL DEFENSE SERIES

FALLOUT AND THE WINDS

This is one of a series of technical bulletins on civil defense against the radiological effects of nuclear weapons.

Radioactive fallout is the surface deposition of radioactive material which has been explosively distributed in the atmosphere by the detonation of a nuclear weapon. When a bomb is detonated at heights which allow the fireball to come in contact with the ground, great quantities of pulverized and vaporized material are carried up in the atmosphere. The cloud then contains a vast amount of radioactive dust particles of all sizes, from submicroscopic specks to visible grains or flakes. The larger particles settle to the ground rapidly, the smaller more slowly. The particles of earth are not in themselves radioactive, but fragments of bomb materials adhere to them and fall to the ground. This is fallout. (See Fig. 1.)

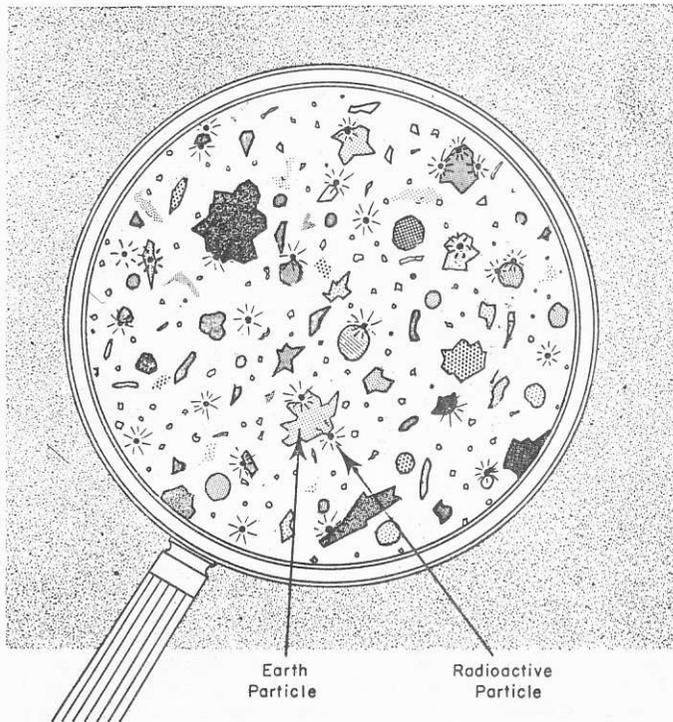


Figure 1. A portion of the mushroom cloud, magnified.

The radioactive particles formed from the bomb materials are themselves very small, and can remain in the air for a long time before settling to the ground. For this reason the cloud from a bomb detonated high in the air so that the fireball does not touch the ground, does not produce dangerous fallout.

Clouds produced by "A-bombs" of the type used in World War II generally do not rise above 50,000 feet. Photographs of the cloud produced by the first thermonuclear bomb at Eniwetok in November 1952 show that it reached a height of 25 miles, or about 130,000 feet. However, this does not mean that dangerous fallout comes from all altitudes up to the top of the cloud. It appears that the uppermost part may not contribute much to the overall hazard. Still, the evidence indicates that debris which rises to altitudes of at least 80,000 feet must be considered in attempting to explain the observed fallout from test detonations of the thermonuclear weapons. Figure 2 shows the comparative size of an A-bomb cloud, H-bomb cloud, and an ordinary thunderstorm cloud.

Rate of Fall of Particles

The particles carried up into the atmosphere by the detonation are acted upon by gravity and are carried by the winds. The wind directions and speeds usually vary from one level to another, so that each particle follows a constantly changing course, with changing speed, during its fall. The rate of fall depends upon the particle's size, shape, and weight, and the characteristics of the air. The stronger the winds in each layer, the farther the particles will be carried in that layer; but the faster the particle falls, the less influence the wind will have on it and the closer to ground zero it will land. The higher the altitude at which its begins to fall, the longer it will be carried by the wind, and under most conditions—when the winds at different altitudes do not oppose one another—the farther it will travel. Figure 3 shows the effects of various combinations of particle size and wind distribution.

Source of Wind Data

High altitude wind observations are taken at many stations in the United States operated by the Weather Bureau, Army, Air Force, and Navy. At these stations, small lightweight radio transmitters attached to helium-filled bal-

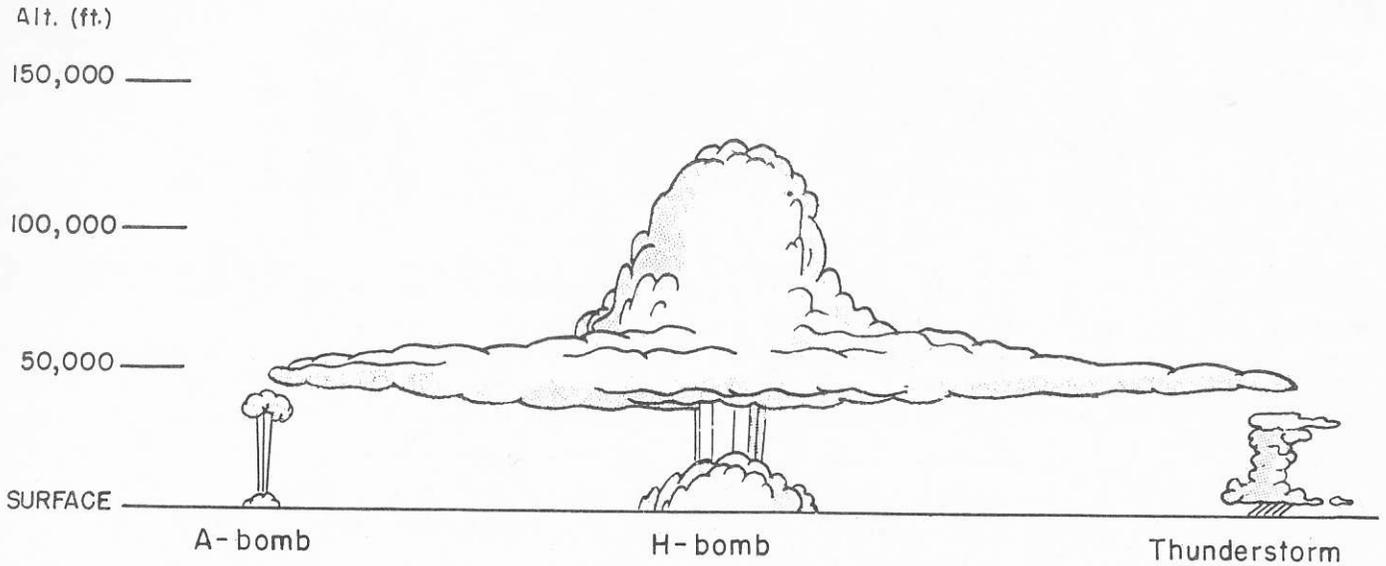


Figure 2. Comparative size of A-bomb mushroom, H-bomb mushroom, and ordinary thunderstorm cloud.

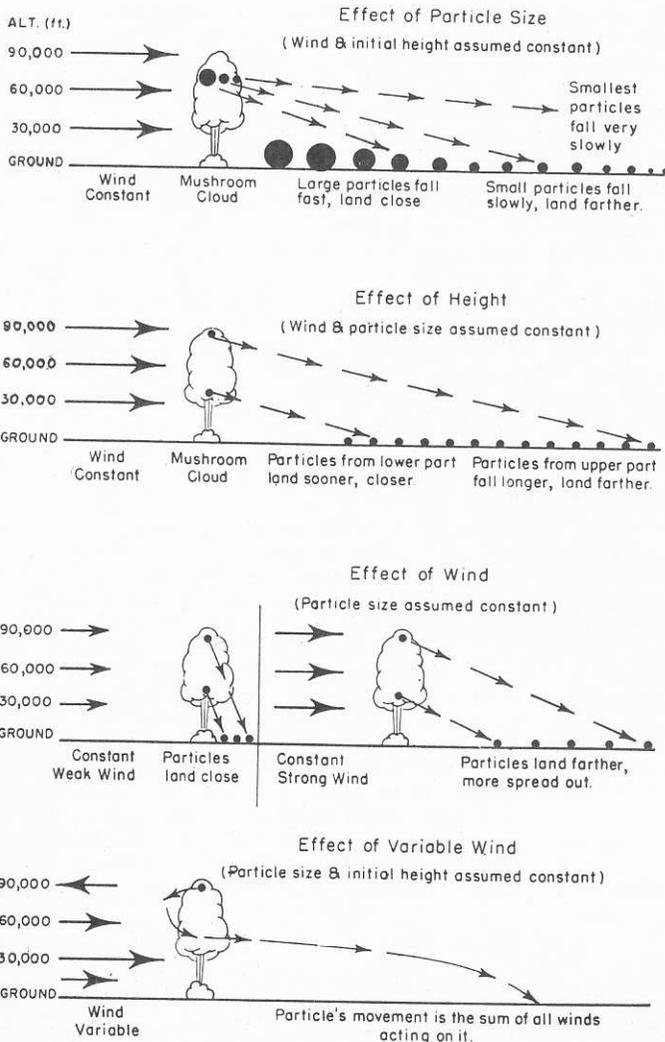


Figure 3. Factors affecting distribution of radioactive particles.

loons are sent aloft several times daily and their positions recorded at frequent intervals by direction-finding receivers. Altitudes of 80,000 feet or more are frequently reached. The wind data for each station at observation time are transmitted by teletype to all weather forecasting offices. Figure 4 indicates the locations of the high altitude wind reporting stations in the United States.

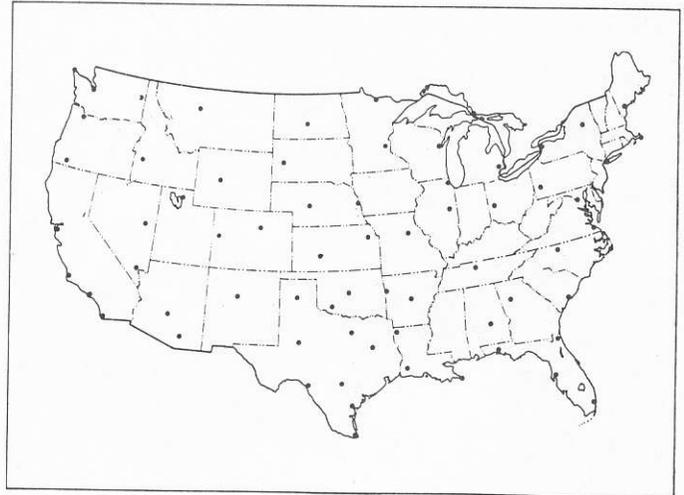


Figure 4. High altitude wind reporting stations in the United States.

Prediction of Fallout Areas

Weather Bureau reports can be used to predict probable areas of fallout from a nuclear bomb. The observed or predicted wind in each layer of the atmosphere can be translated into a definite horizontal movement for each size of particle. The horizontal movements imparted to the falling particles in all layers of the atmosphere can be added together to predict their total travel. Although particle sizes and altitudes will not be known in advance of an attack, a useful estimate can be made of the direction and rate of spread of the fallout under existing wind conditions. Figure 5 is a simplified drawing indicating the

sector of fallout from the stem and top portion of the cloud from all levels 5,000 feet to 80,000 feet.

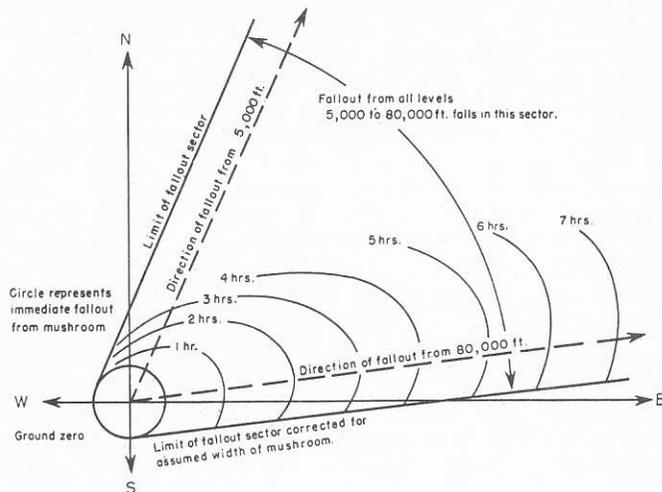


Figure 5. Sector of fallout from stem of cloud.

The U. S. Weather Bureau issues forecasts twice daily for all critical target areas of fallout direction, distance, and arrival time. On February 1, 1956, the service was expanded to cover all areas of the country. This information provides to local, State, regional, and national civil defense, the data necessary for the construction of fallout plots. Details of the program are described in FCDA (OCDM) Advisory Bulletin No. 188, dated May 25, 1955, and Supplements Nos. 1, 2, and 3, dated August 16, September 27, 1955, and January 26, 1956. Instructions are included for constructing fallout plots from the Weather Bureau forecasts.

These fallout predictions are useful for civil defense planning, but limitations must be recognized. Forecasts are released only twice a day. Therefore, at certain times the fallout plots will be based on wind measurements more than 12 hours old.

Prediction of Radiation Levels

Wind data alone, of course, do not indicate the levels of radiation to be expected. Levels would depend on such things as altitude of the burst, amount of energy released, the nature of the ground surface, height to which the cloud rises, and the bomb design. These things could not be known before the attack—making it difficult to predict accurately the radiation levels that would result.

Data for forecasting levels of fallout radiation from a given weapon are limited. However, some information was obtained from the Pacific "H-bomb" tests of the Atomic Energy Commission. According to the AEC, "... it is estimated that following the test explosion on March 1, 1954, there was sufficient radioactivity in the downwind belt about 140 miles in length and of varying widths up to 20 miles to have seriously threatened the lives of nearly all persons in the area who did not take protective measures." The device that produced this pattern was in the multimegaton range. However, it cannot be expected that other bombs of the same power would necessarily produce the same fallout pattern or radiation levels. The Bikini "cigar-shaped" pattern is only an example of what is possible. Even with exactly the same type, power, and altitude of detonation, different wind conditions would have produced a different fallout pattern, possibly of irregular shape.

The speed and vertical shear of the upper air winds will affect the concentration of radioactivity on the ground. A fallout pattern under conditions of strong winds aloft would differ from that of weak winds in two ways. The strong wind would spread the material over a larger area, tending to reduce the concentration close to the source, and at a given distance the fallout would arrive sooner and would have had less time to decay. Therefore, the area of dangerous contamination would likely extend farther from the source in stronger winds.

Obviously, the length of time required for the bulk of dangerously radioactive dust to be deposited on the ground will depend on the yield of the bomb and the size of the particles. Referring again to the March 1, 1954, Bikini test, it appears that hazardous material continued to fall in some areas for at least 12 hours after the burst. In some instances, it might continue for 24 hours.

Precipitation in a fallout area will affect the radioactive deposition. Raindrops and snowflakes collect a large proportion of the atmospheric impurities in their paths. Particles of radioactive debris are "washed" or "scrubbed" out of the air by precipitation. The result is that contaminated material, which would be spread over a much larger area by the slower dry weather fallout process, is rapidly brought down in local rain or snow areas. It is conceivable that hazardous concentrations can occur in rain areas where ordinary fallout estimates might indicate a safe condition. This scrubbing reduces the amount of contamination left in the air to fall out farther downwind.

Terrain features will cause a variation in degree of deposition. Hills, valleys, and slopes of a few hundreds of feet would probably not have a great effect on the fallout radiation levels. By receiving more fallout on the side facing the surface wind, large mountains or ridges could cause significant variation in deposition. This is true for both dry weather fallout and "rainout."

Climate and Wind Considerations

It is highly questionable whether the Bikini fallout pattern should be applied to regions not in the tropics. The climate and winds of the United States are generally different from those of Bikini. The United States has a variety of upper air winds. However, wind conditions similar to those accompanying the Bikini test do occur in the United States, particularly in the summer months. During the winter, spring, and fall seasons, the United States winds are primarily the "prevailing westerlies." By this it is meant that the winds over the United States blow more frequently from the western quarter than from any other quarter of the compass. The westerlies in the middle latitudes become increasingly predominant with increasing height up to about 40,000 feet. At 5,000 feet the winds are from the western quadrant about half the time; while at 30 to 40 thousand feet, they are from that quadrant about three-fourths of the time. Above 40,000 feet, the percentage of westerly winds again decreases.

It is implied in the above paragraph that predominance of westerly wind direction changes with the seasons. Upper winds blow from the west more often during winter than during summer. The increase in frequency of other directions in the summer is more pronounced in the southeastern portion of the country, where directions become variable at all levels. Along the Pacific Coast, the winds blow less constantly from the west than in other sections of the country. Southwesterly and northwesterly winds are more common. Above 60,000 feet, easterly winds occur frequently in all seasons and are the rule in summer over most of the United States. Figure 6 indicates the percentage of time that winds blow from the western quadrant at 40,000 feet over the United States in the winter and summer seasons.

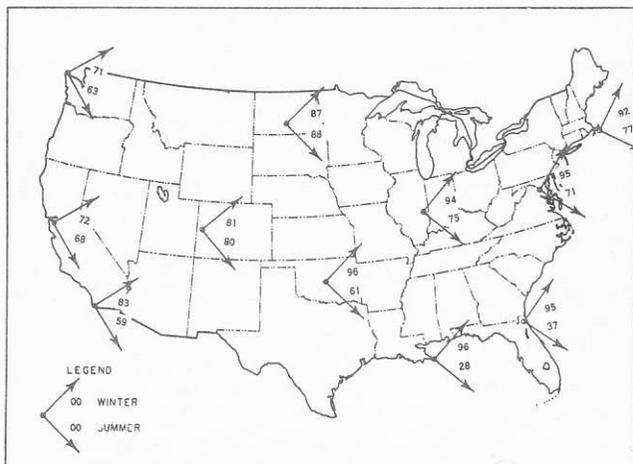


Figure 6. Percentage of time with westerly winds at 40,000 feet.

In describing direction of fallout from the point of detonation (GZ—Ground Zero), the terms "upwind" and "downwind" are often used. The downwind direction is the direction toward which the wind blows. "Upwind" means against the wind, just as "upstream" and "downstream" are related to river currents. When applied to fallout, the terms "upwind" and "downwind" will apply to the resultant or total effect of all the winds through which the particles have fallen. An upwind component results from the very rapid expansion of the cloud in all directions immediately after detonation. The disturbances at the time of the explosion will deposit radioactive material in upwind and crosswind directions for relatively short distances from ground zero.

All civil defense personnel should be cautioned against using surface wind directions as an indication of direction of flow at levels high in the atmosphere. The direction of fallout is determined by winds up to at least 80,000 feet above the surface. Winds in the upper air frequently are different from those at the surface. It is not at all uncommon to have east, south, or north winds at the surface and westerly winds aloft. There is no correlation between the two.

It has been pointed out that, in considering the possible area of fallout, wind speed is as important as wind direction. The direction determines the sector to which particles are carried, and the speed governs how far they will travel before coming to earth. The average wind speed at different heights over the United States is shown in the accompanying table.

Average Wind Speeds Over The United States

Height (ft.)	Winter (mph)	Summer (mph)
5,000	25	15
10,000	35	19
20,000	55	25
40,000	80	45
80,000	30	20

Wind speeds over the United States generally are less in summer than in winter at all heights and above all areas. The only exceptions would be during the passage of hurricanes or tornadoes which produce very strong surface winds in the warm season. This difference between seasons is greatest in the southeastern portion of the country, where winds become particularly light and variable in the summer. During the winter, upper winds along the Pacific Coast generally have lower speed than in any other section of the United States. Winds increase with altitude from the surface up to a level between 30,000 and 40,000 feet. Above this level they usually decrease in speed until, at 60,000 to 80,000 feet they become relatively light. Figure 7 indicates the variation of wind direction and speed in the United States at 40,000, 50,000, 60,000, and 80,000 feet.

The winds of greatest speed usually occur between 30,000 and 40,000 feet, winds exceeding 50 mph being the rule all over the country in winter and in the northeast in summer. In this layer, winds greater than 100 mph are at times experienced over all areas of the United States, but have been observed most often over the northeast, where they are found about 25 percent of the time. In this northeastern area, winds of 200 mph occur frequently and even speeds of 300 mph are observed on rare occasions. The high speed winds usually occur in narrow meandering currents within the broad belt of middle-latitude westerly winds, and are called "jet streams." Figures 8 and 9 indicate the percentage frequency of occurrence of winds greater than 50 knots (58 mph) and greater than 100 knots (115 mph) for the United States by seasons.

The strongest winds encountered by a falling particle have the greatest proportional influence on its total movement. The strongest winds are usually at altitudes in the vicinity of 40,000 feet. These winds would determine largely the general direction and length of the fallout area, although all the winds up to more than twice that height could be effective.

Fallout patterns over the United States, as has been stated, would probably differ in shape and extent from Bikini patterns. In the northern half of the country considerably longer patterns would be expected, spreading toward the east because of the strong upper air westerly winds. The passage of low pressure areas would cause shifts from a more northeasterly to a more southeasterly spread of the fallout pattern from one day to another. In the summer, particularly in the southern part of the country, a great variety of patterns might be expected with a broad irregular spreading in all directions in some cases, and elongated streaks in others. It should be remembered also, that in an area where several target cities are situated within a few hundred miles of one another, fallout from more than one detonation might occur at the same place.

Variation of the winds by day and night has little effect on factors that determine fallout patterns. Winds a few hundred feet above the ground frequently change, from night to day, but those higher up, which have the greatest effect on the fallout pattern, do not follow a daily cycle. Cloudiness or fog alone are not believed to have a marked effect on fallout, although the combination of fallout particles with cloud droplets may result in a faster rate of fall. Some cloud types also have upward and downward air currents. The downward currents might tend to bring some of the radioactive debris down more rapidly than it would otherwise settle.

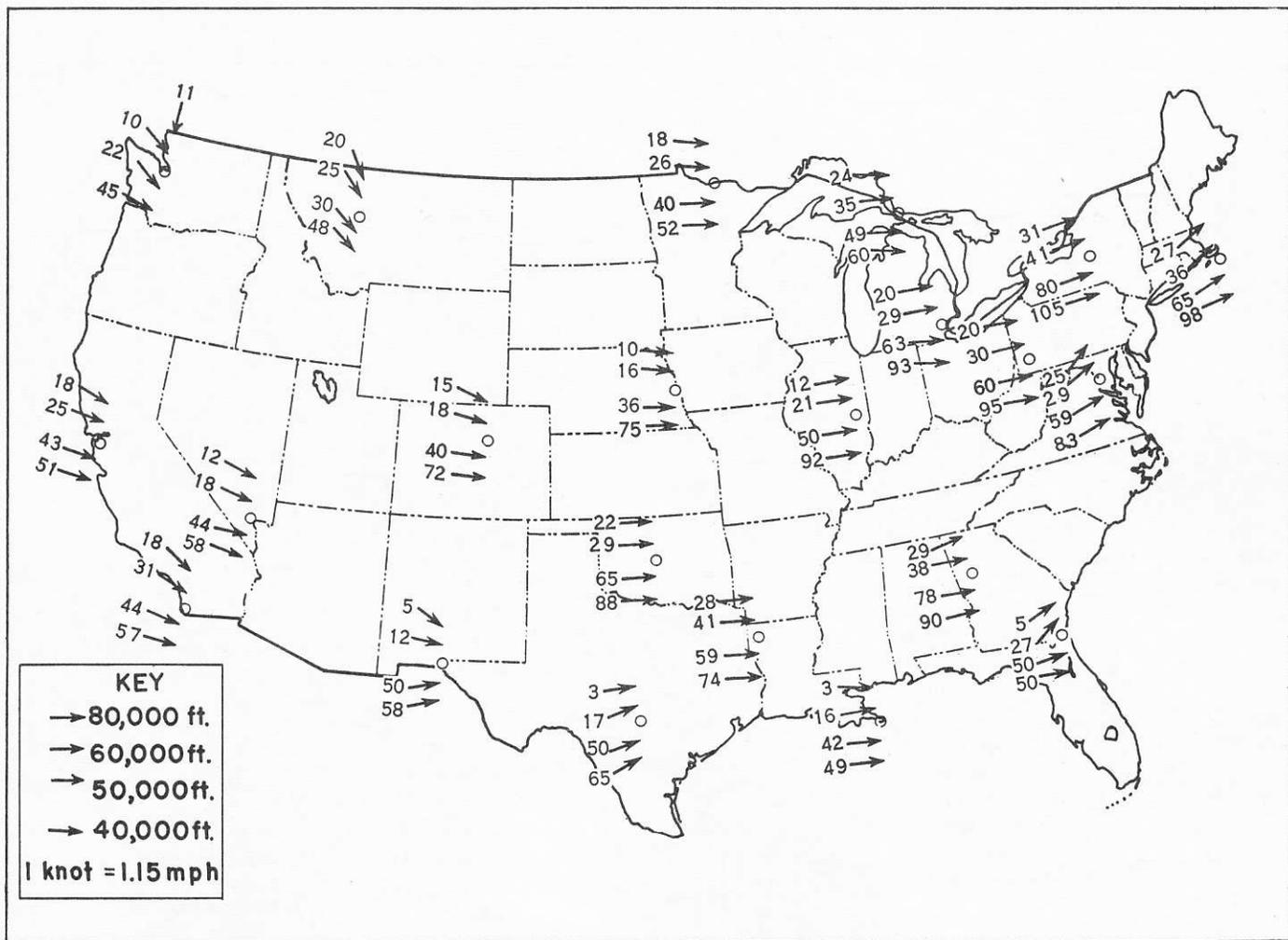


Figure 7.—Average wind direction and velocity for January. (Based on 5 years of data).

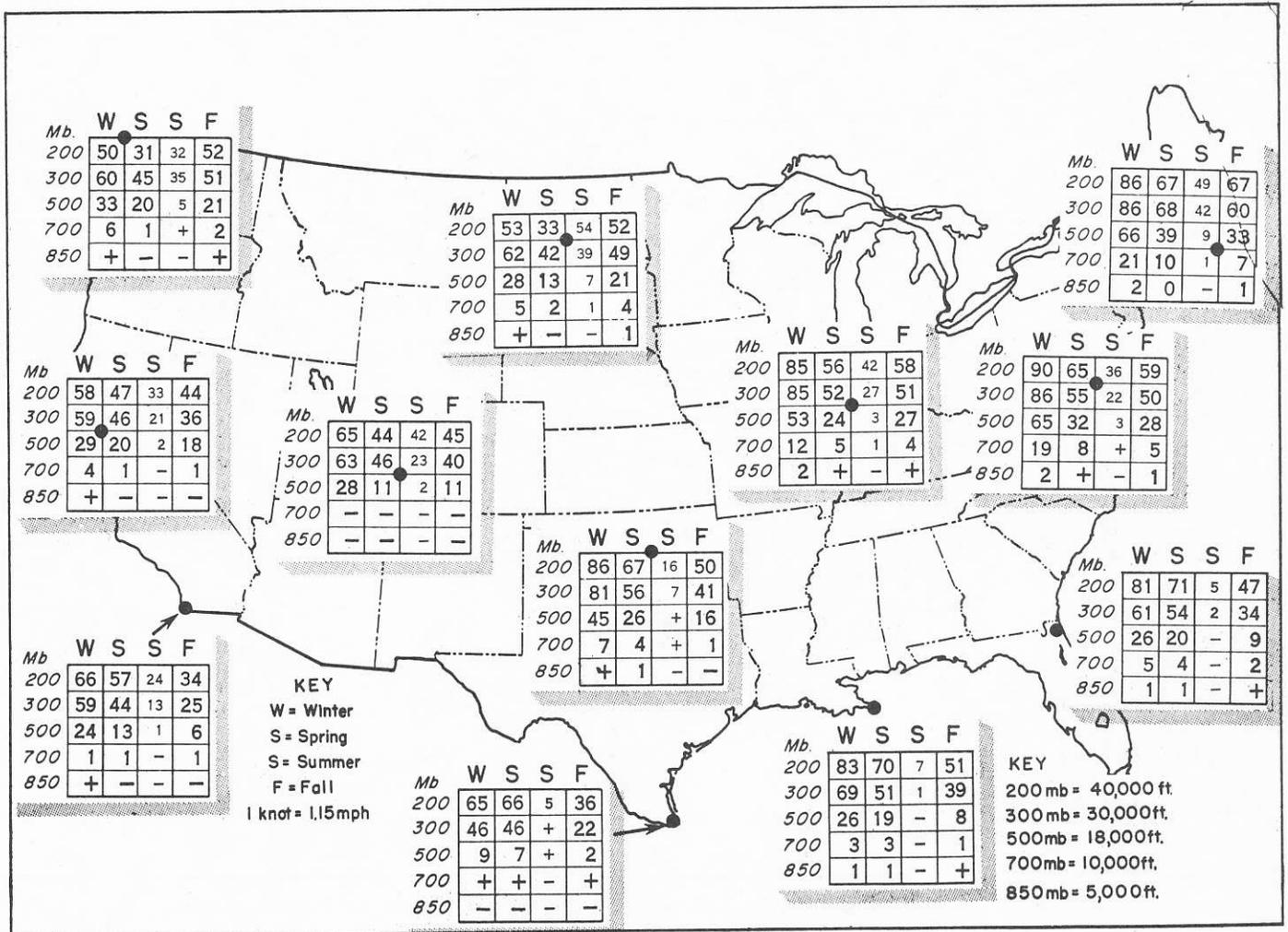


Figure 8. Percentage frequency of winds over 50 knots (58 mph).

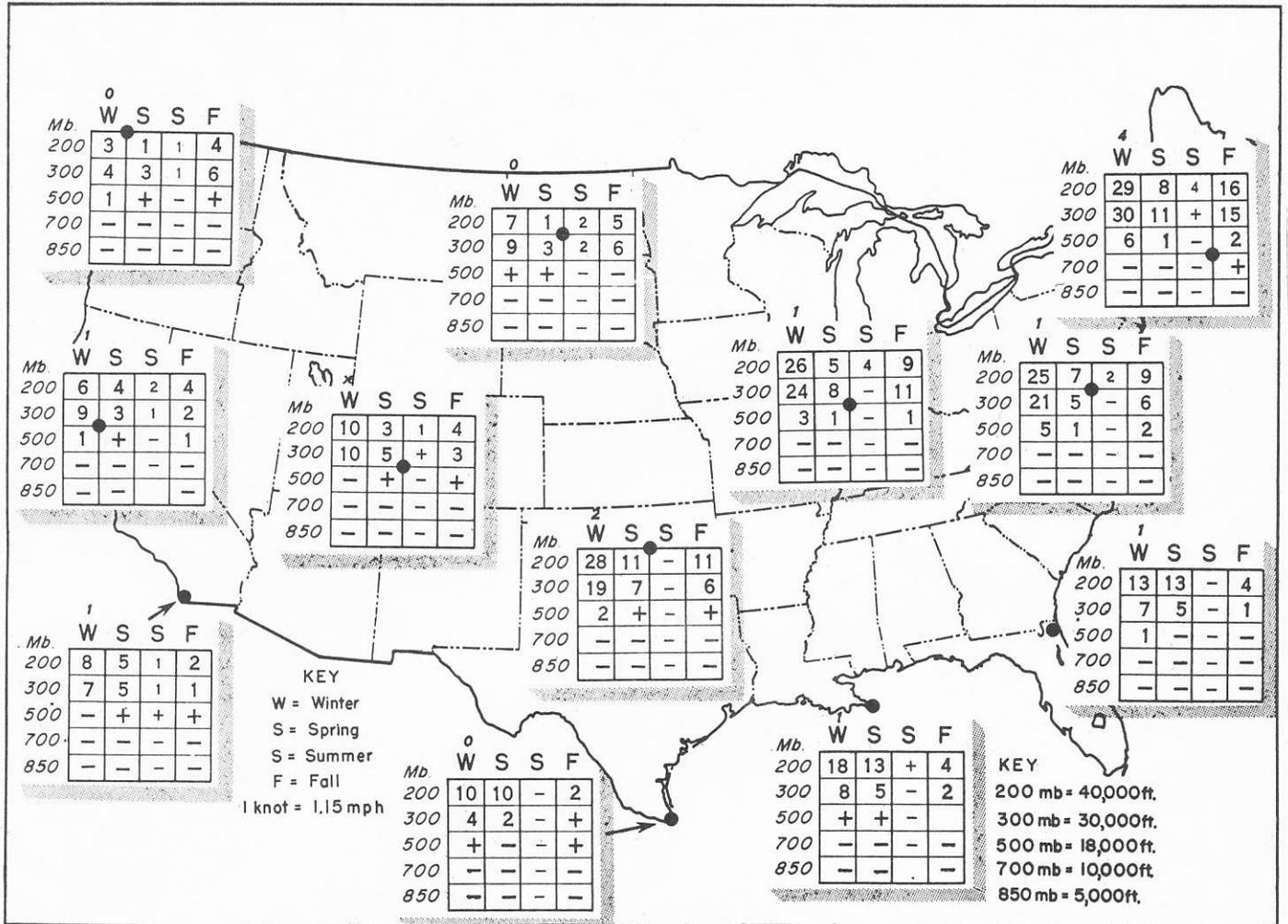


Figure 9. Percentage frequency of winds over 100 knots (115 mph).