Hailstorms

OF THE UNITED STATES

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To the many thousand co-operative observers of the country who, serving without pay, faithfully recorded hailstorms in their respective communities over the years, and to my associates of the United States Weather Bureau and the American Meteorological Society for their unfailing courtesy in furnishing the data and information that made this book possible.

The Reason for a Book on Hail

Hail is more destructive than tornadoes. A single hailstorm, striking a city during business hours, can in a few minutes result in a loss of a million dollars or more to parked automobiles alone. Wichita, Kansas, in a period of twenty-four months had two violent hail and wind storms that caused losses of nine to fourteen million dollars each. In many parts of the High Plains between the 100th Meridian and the Rocky Mountains hail destroys, on the average, 8 to 10 per cent of all crops annually. Hailstorms constitute one of the major risks in aviation.

With the value per acre of crops rising steadily and with more and more automobiles and buildings as targets, losses from hail damage will increase correspondingly. Since hailstorms occur throughout the United States and over most of the world’s land surface, hail is a matter of crucial importance to a great many people.

United States Weather Bureau publications give innumerable records of hailstorm damage, and discussions of the various aspects of hail, including its cause, have appeared from time to time in scientific journals and in textbooks, but as yet no comprehensive treatise on the subject has been published. Thirty-two years of experience in compiling and studying hailstorm reports while serving as section director of the Weather Bureau for Kansas, where hail damage is excessive, has impressed the author with the need for a book dealing comprehensively with the problem of hail. This book is intended for the general reader. It is not a technical treatise for professional meteorologists. The theories advanced are those held by authorities on the subject, and all data used have been obtained from official sources, unless otherwise specified.

I wish to give credit here to the many persons who have furnished facts and figures used in this book, especially to Mr. Richard J. Roth, secretary, Crop-Hail Insurance Actuarial Association, Chicago, for detailed information regarding crop-hail insurance; to other insurance organizations for details on insurance of other property against the same peril; and to Mr. H. T. Harrison, superintendent of Weather Service, United Air Lines, Denver, for information concerning the hail hazard to airplanes.

I am deeply appreciative of the information so freely afforded me by Weather Bureau officials over the country, including those of the Central Office of the Weather Bureau, Washington, D. C., who made available much scientific data from the files of the Central Office Library, the most complete meteorological library in the world.

Snowden D. Flora

Topeka, Kansas
September 21, 1956

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Hailstorms of the United States

I. Hail: The White Plague

More property damage is caused by hail throughout the United States than by tornadoes, and in some years hail damage comes surprisingly close to that of hurricanes. In the decade ending with 1953 hail losses of the country averaged $53,277,840 annually, according to reports compiled by the United States Weather Bureau (Table I). Annual tornado losses for the same period, which includes the record-breaking tornado year of 1953, averaged $45,061,909, about 15 per cent less than the losses from hail. It is generally agreed that the hundreds of small hail losses not reported to the Weather Bureau, together with those for which no estimates could be obtained, would materially increase the total hail damage.

Damage to crops comprised almost 79 per cent of all hail losses reported over that same ten-year period. In 1951, the most disastrous hail year on record, losses totaled $75,432,200, of which $49,015,800 was to crops. Kansas suffered a crop loss that year of $14,975,450, almost a third of the nation’s total.

No section of the United States is immune to hailstorms, although they are more frequent and more severe in some sections than in others. Thousands of farmers have had the experience of looking over a flourishing crop, one day almost ready for harvest, the next day wiped out completely, and with little or no warning. With the exception of droughts and freezes, hail is the greatest menace to crops of the Middle

West. Entire districts have had crops completely ruined by it. Tobacco growers in Eastern states and commercial fruit growers from New York to California have suffered staggering losses from hail damage.

Windows are an ordinary casualty of hailstorms. Heavy hailscreen will usually protect glass, but not always. Greenhouses have been left with every pane shattered and tender plants destroyed. At Denver, Colorado, twenty carloads of glass were required to replace losses after a severe hailstorm on May 30, 1948. Windshields and windows of automobiles exposed to hail can suffer heavy damage, and since it is impractical to use metal heavy enough to withstand hail damage, the tops, hoods, and fenders of automobiles are often dented and punctured beyond repair.

TABLE I

Hail Damage in the United States, 1944-53

(Compiled by the U. S. Weather Bureau.)

Year	*Property (exclusive of crops)*	*Crops*	*Total*
1944	$ 9,061,000	$ 49,987,900	$ 59,048,900
1945	3,608,200	31,513,400	35,121,600
1946	9,783,800	30,382,000	40,165,800
1947	3,829,300	54,348,900	58,178,200
1948	12,163,200	56,180,800	68,344,000
1949	6,336,400	41,646,600	47,983,000
1950	21,072,800	28,094,500	49,167,300
1951	26,416,400	49,015,800	75,432,200
1952	9,454,400	40,094,300	49,548,700

1953	11,457,800	38,330,900	49,788,700
Totals	$113,183,300	$419,595,100	$532,778,400
Averages	11,318,330	41,959,510	53,277,840

"Like a thousand triphammers suddenly let loose," hail can pound shingle and composition roofs to pieces, exposing interiors and contents to heavy rain that commonly accompanies hail. Shingles and roll roofing on buildings are easily damaged by hail, especially if the pitch of the roof is slight. Steep-pitched roofs are not as susceptible because the hailstones strike them with glancing blows. Roofs of asbestos shingles fare better than other types of shingles, since they overlap each other and are generally laid on roofs of a fairly steep pitch. Tile roofs are hail resistant to some extent but hail can be heavy enough to crack tiles.

Metal roofs of heavy tin or sheet iron withstand hail to a marked degree but they can be damaged if they are not laid on a base of heavy boards. Aluminum roofs, being softer than those of iron, are very likely to be punctured or dented by hail. About the only kind of roof that seems to be immune is one of concrete slab, commonly used on commercial buildings but rarely on residences. The heavy asbestos laid over the concrete to prevent water from seeping through may be damaged to some extent. In addition to roof damage, hail often mars the paint on the wooden siding of houses, and it can even split the siding itself.

Hail is one of the most serious hazards a pilot can face. Planes have been so badly damaged in a ten- to twenty-minute encounter with hail that their condition warranted scrapping. Airplanes are especially vulnerable to hail in several respects.

One is the speed at which they meet the impact of bail. Another is the exposure of glass and light metal to the force of the hailstones. So far as is known, no large plane has crashed because of hail damage alone but there is always the possibility that it could happen. Controls could be damaged beyond use or the pilots themselves could be seriously injured by shattering glass.

Hailstones ranging from three to five inches in diameter have been known to kill small animals and in some instances even horses and cattle. Numerous reports tell of persons who have been seriously injured by large hailstones. In some countries people have been killed by them. Only one death in the United States has been officially attributed to hail. This occurred about thirty miles northwest of Lubbock, Texas, on May 13, 1930. A farmer, thirty-nine years of age, working in a distant field in the open country common to this region, was caught in a sudden hailstorm and before he could reach shelter he was so violently beaten by the hailstones that he died within a few hours. Fatalities are rare in this country because shelter is so readily available in most instances, and when hail begins to fall, man’s instinct is to run for the nearest building or cover of any sort.

The largest hailstones officially recorded fell on July 6, 1928, in Potter, Nebraska. This is in Cheyenne County, where a number of very severe hailstorms have occurred. These hailstones fell sparsely, ten to fifteen feet apart, some measuring four and one-half and even five and one-half inches in diameter. The largest one was seventeen inches in circumference and weighed twenty-four ounces—a pound and a half. Cut open, it disclosed a structure of concentric rings that proved it to be an individual stone, not two or more stones frozen together. As they fell they made a peculiar hissing sound, an indication of great speed. They struck with such impact that in many places they were found completely buried. No persons were reported injured in this storm, but hailstones of that size could have caused serious injury to anyone caught without shelter.

II. Oddities of Hail and Hail Damage

Hailstones are usually spherical in shape, or nearly so, with more or less concentric layers of compact snow and solid ice about a nucleus of partially melted snow or possibly a large raindrop in which freezing has already begun.

There are many variations to the pattern. Botley, who made an intensive study of the subject, says that shapes of hailstones are often “fantastic.”[1] Some are like pyramids with flattened bases, while others, according to his description, resemble “fruit jellies.” Still others may be covered with spikes from a quarter of an inch to almost an inch in length projecting from a central core. Some are in the form of a disk or lens. Stones that fell in Italy in 1872 had shapes exactly like quartz crystals.

Sometimes an irregular mass of ice is mistaken for a true hailstone, but examination discloses two or more hailstones frozen together. It is generally believed that this freezing of smaller stones into one large mass takes place after they reach the ground, but it could possibly happen while they are falling. Hailstones sometimes contain foreign matter such as pebbles, leaves, twigs, nuts, and insects. This extraneous material is evidently carried up by powerful winds in the area and frozen into the ice as the hail is forming. Some hailstones contain small air bubbles.

Reed tells of a freak fall of “dry hailstones” which occurred in northern Iowa and caused serious damage in the hot, dry summer of 1936.[2] This hail descended through a screen of dry air with no rain apparent. An unusual storm was reported near Rich Valley, Indiana, on July 2, 1924, in which snow covered a twenty-foot square of ground to a depth of eight inches with a heavy fall of hail all around it. The actuality of this snow was verified by a snowball made from it and displayed in a near-by town.

The enormous accumulation of hail from a severe storm is sometimes hardly credible to people who have never seen it happen. On June 23, 1951, in southern Kansas, hailstones accumulated to a depth of twelve inches in the northern part of El Dorado in Butler County. In Washington County, Iowa, on September 1, 1897, drifts of hailstones were six feet deep. In another Iowa storm on August 6, 1890, from Adair County to Union County, hail fell to a depth of four inches in places and drifted into heaps six feet deep, Where it remained, protected by debris, for twenty-six days. Several days after the storm Mr. Henry C. Wallace of Orient, Iowa, visited the scene and gathered up enough hail to freeze a gallon of ice cream.

During a violent hailstorm in Nodaway County, Missouri, on September 5, 1898, in which hundreds of small animals were killed, chunks of ice went entirely through the roofs of houses. One house was completely stripped of its board siding on the exposed side. Another, built of second-grade lumber, had all the knots in the board siding beaten out, leaving only gaping holes. One man claimed that he had to cut the ice out of his stovepipe before he could build a fire. In one locality it was impossible to get through a lane two weeks after the storm because of the depth of ice in it. Some of this hail remained for fifty-two days.

Reports of the size of hailstones and the force with which they strike are many and varied. There are, of course, unauthenticated reports such as the story of a hailstone in India that weighed seven and one-half pounds, and a chunk of ice "as big as a millstone" that was reported to Father Huc, a French missionary. Undoubtedly these were masses of ice that had frozen together on the ground.

The most deadly hailstorm of record occurred in India on April 30, 1888. This hailstorm killed 230 people at Moradabad, about one hundred miles east of Delhi, and 16 others died at Bareilly. The following day 12 were killed near Ghaziabad by stones "as large as cricket balls." Two more persons were killed and a large number wounded at Tilhar. In 1936 "jagged lumps of ice" caused the death of 19 persons in the Northern Transvaal of South Africa. On June 13, 1930, hail killed 22 people in the Siatista district of Greek Macedonia, and on July 16, 1930, 7 persons in southern Bulgaria. There are authentic records of death from hail in Russia, Siberia, and Romania. Two hundred were reported killed in a severe hailstorm that occurred in western Honan Province, China, on June 19, 1932.

At Topeka, Kansas, on June 24, 1897, horses were knocked down by hail, while others hitched to vehicles became panic-stricken and ran away. On July 5, 1891, in Rapid City, South Dakota, hail killed sixteen horses and injured others so seriously that they had to be shot. Some were even blinded. In other Iowa and Nebraska storms, cattle, horses, and smaller animals were reported killed, and people attempting to save the livestock sustained serious injuries, in some instances to the extent of broken bones.

The amount of crop damage by hail in any part of the country depends upon the frequency and severity of hailstorms and upon the nature of the crops grown. Damage to wheat and corn exceeds that to any other crops, partly because of the immense acreage involved and partly because they are chiefly produced in a section of the country where hail is often severe during the growing season. This is the region known as “the breadbasket of the nation”—the Mississippi Valley and the High Plains east of the Rockies.

TABLE II

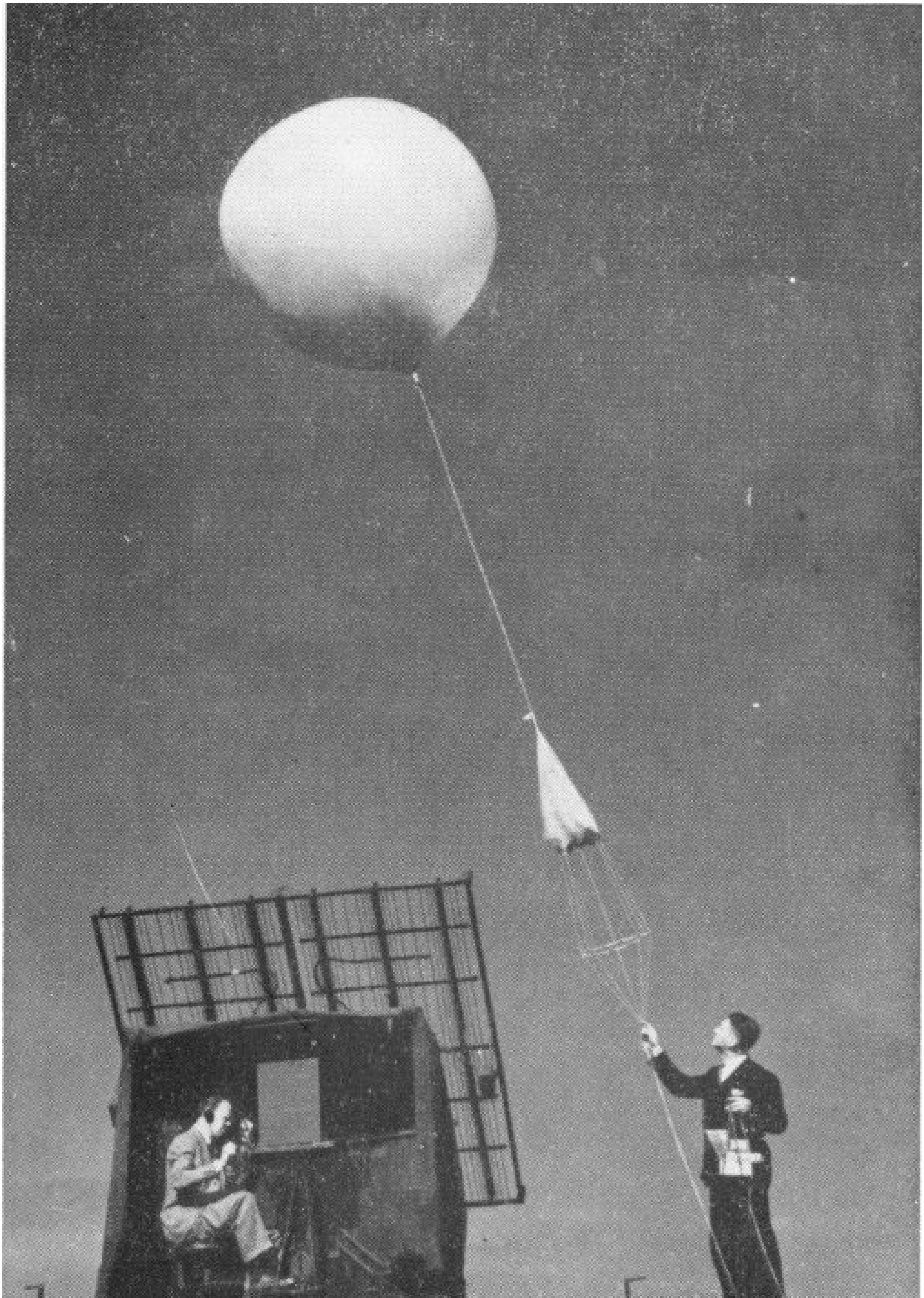
States Having the Greatest Hail Damage, 1944-53

(Includes damage both to crops and to other property. Compiled from records of the U. S. Weather Bureau.)

State	***Damage***
Kansas	$101,877,900
Nebraska	67,643,400
Montana	61,225,170
Iowa	60,171,212
North Dakota	34,434,000
Texas	31,858,275
North Carolina	31,715,516
Colorado	31,152,976
Oklahoma	29,256,725
Illinois	10,226,120
Missouri	9,377,450
Minnesota	9,807,800
South Dakota	5,297,100

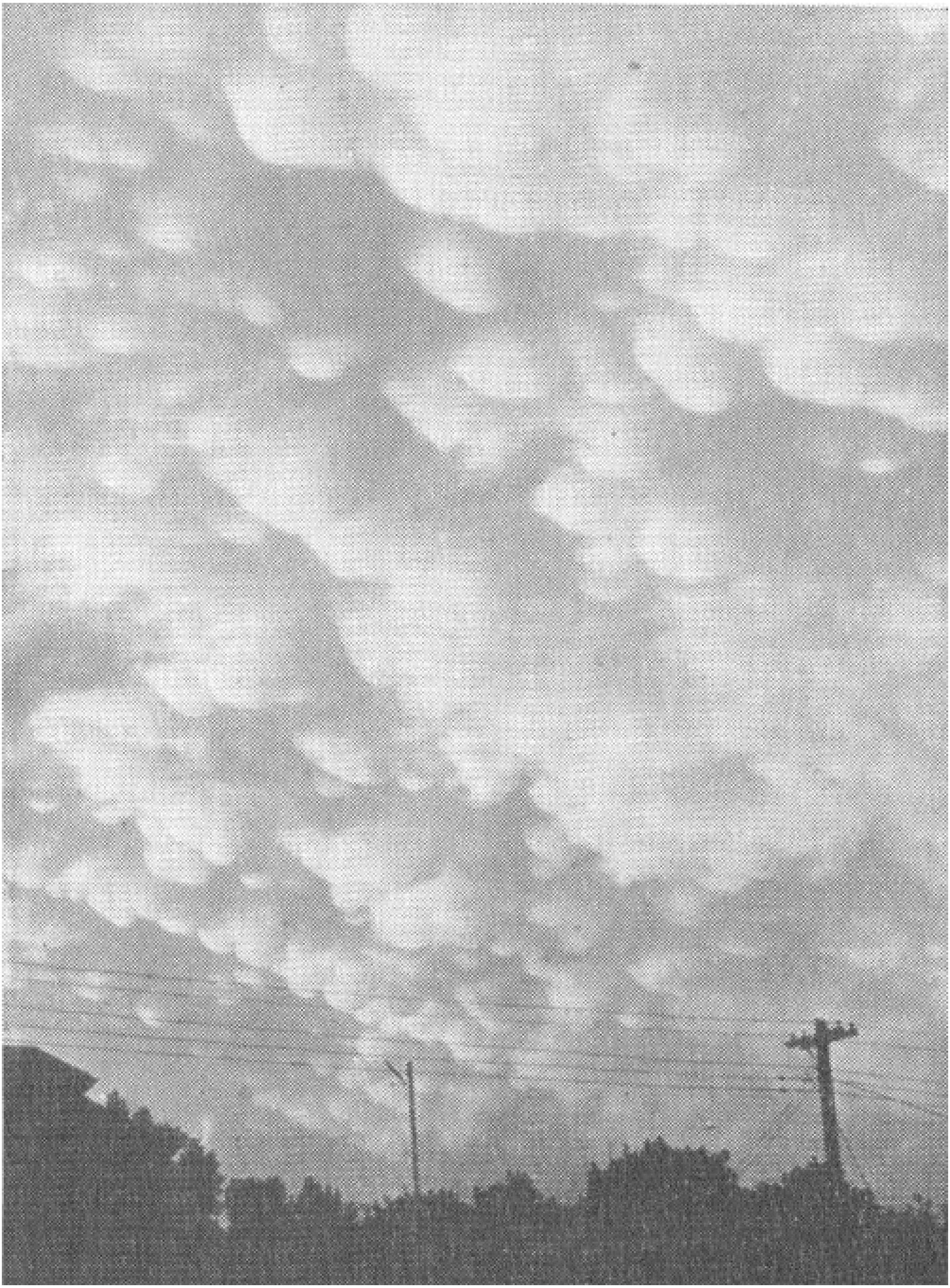
Tennessee	4,542,000
New Mexico	4,061,100
Arkansas	3,811,700

Forecast of Storms to Come



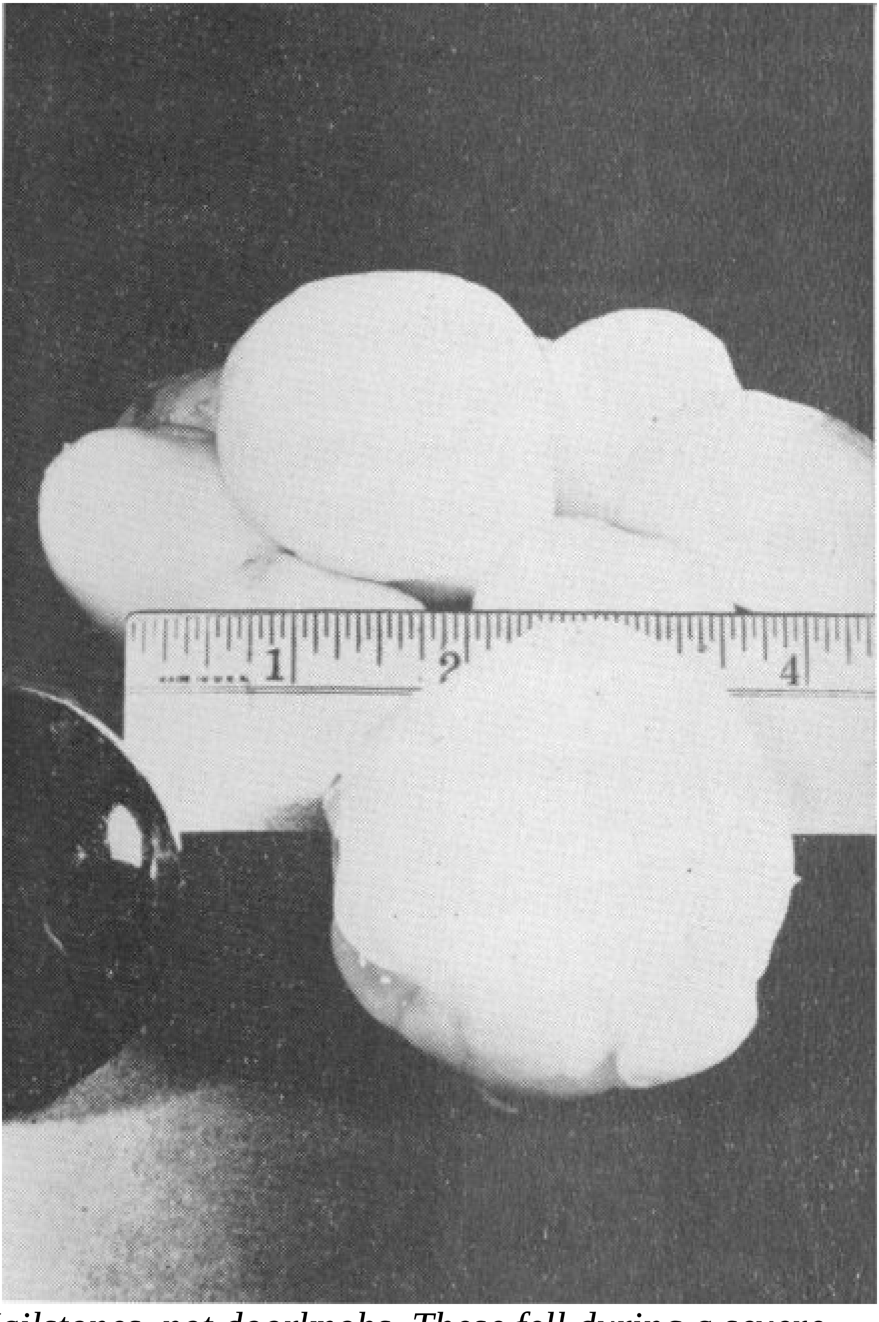
Launching a radiosonde. This instrument is used by the Weather Bureau, the Air Force, and the Navy to obtain data which make possible the forecasting of hailstorms. It registers and transmits pressure, humidity, and temperature aloft as the balloon rises to great heights. Courtesy U. S. Weather Bureau.

The Hail Cloud and What It Portends



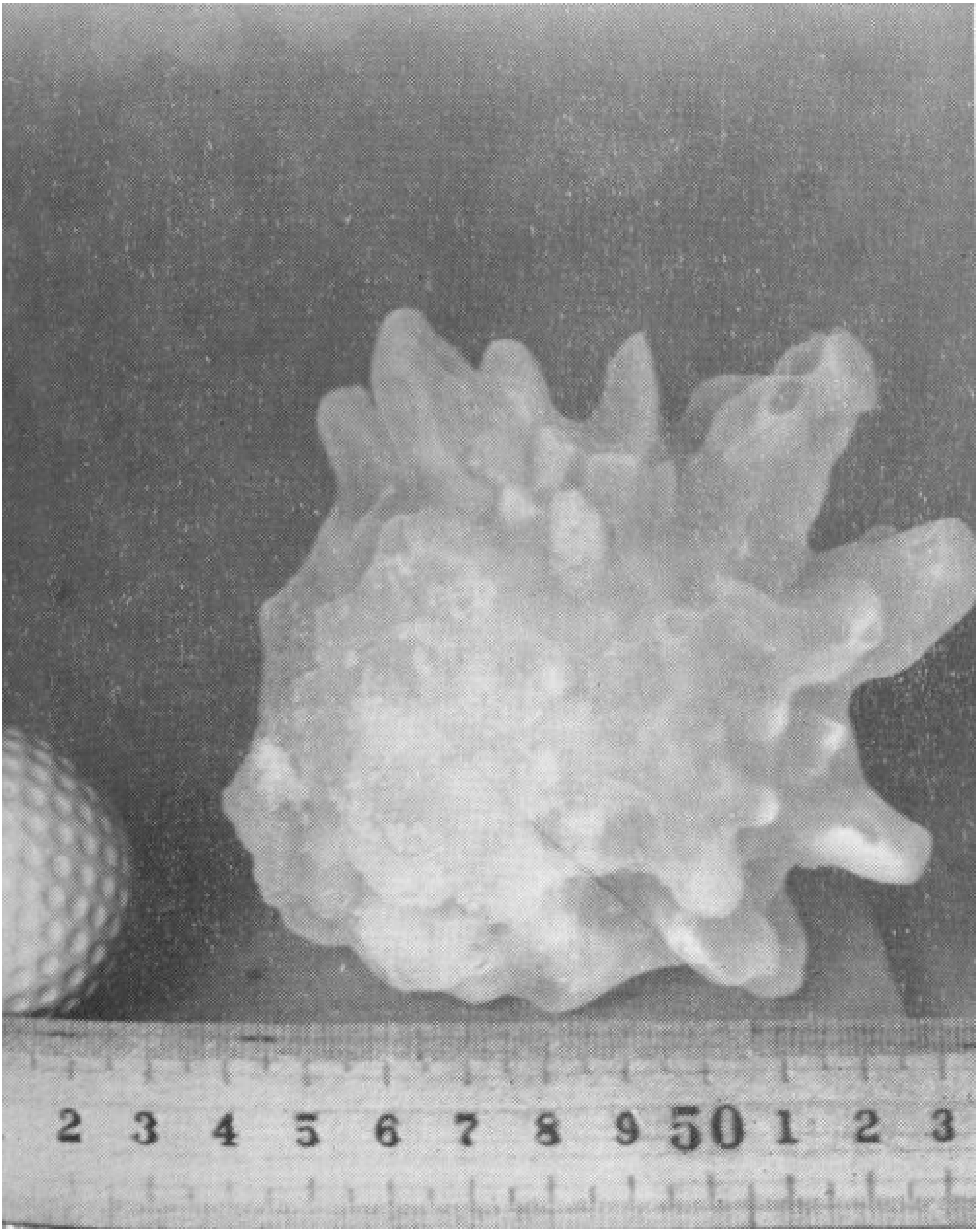
Mammatocumulus clouds, St. Joseph, Missouri, June 20, 1934. Indicating extreme turbulence aloft, clouds of this *kind are nearly always associated with hailstorms or tornadoes. Heavy hail fell shortly after this formation was seen.* Courtesy W. S. Belden.

A hail and thunderstorm cloud moving in on Pueblo, Colorado. More than ten thousand window panes were broken and two thousand roofs severely damaged. Courtesy "United Press Photo."



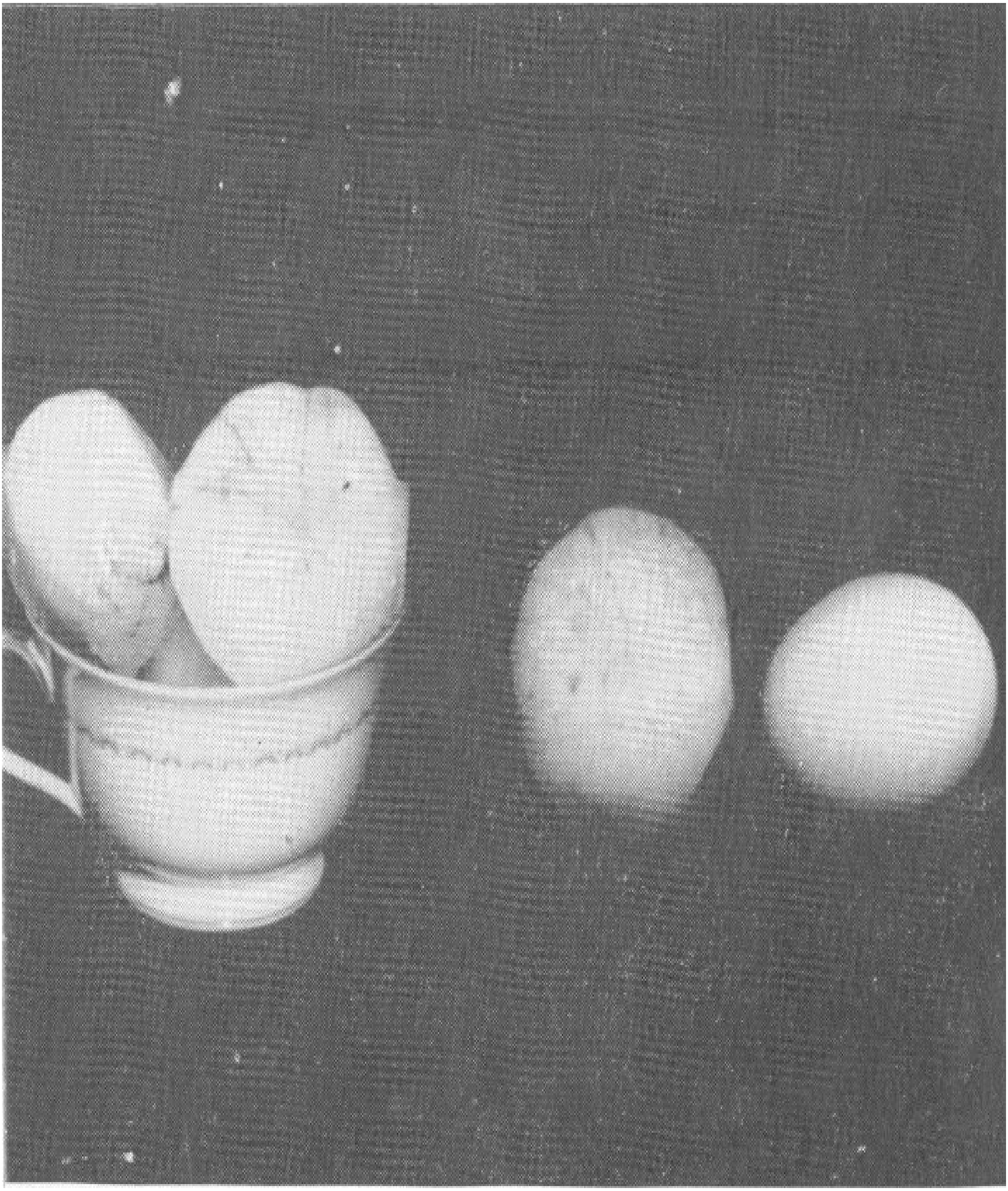
Hailstones, not doorknobs. These fell during a severe storm in the vicinity of Duncan, Oklahoma, May 13, 1938. This picture, taken an hour after the storm, indicates the size of the stones in comparison with the doorknob at left.

Courtesy “Acme Photo.”



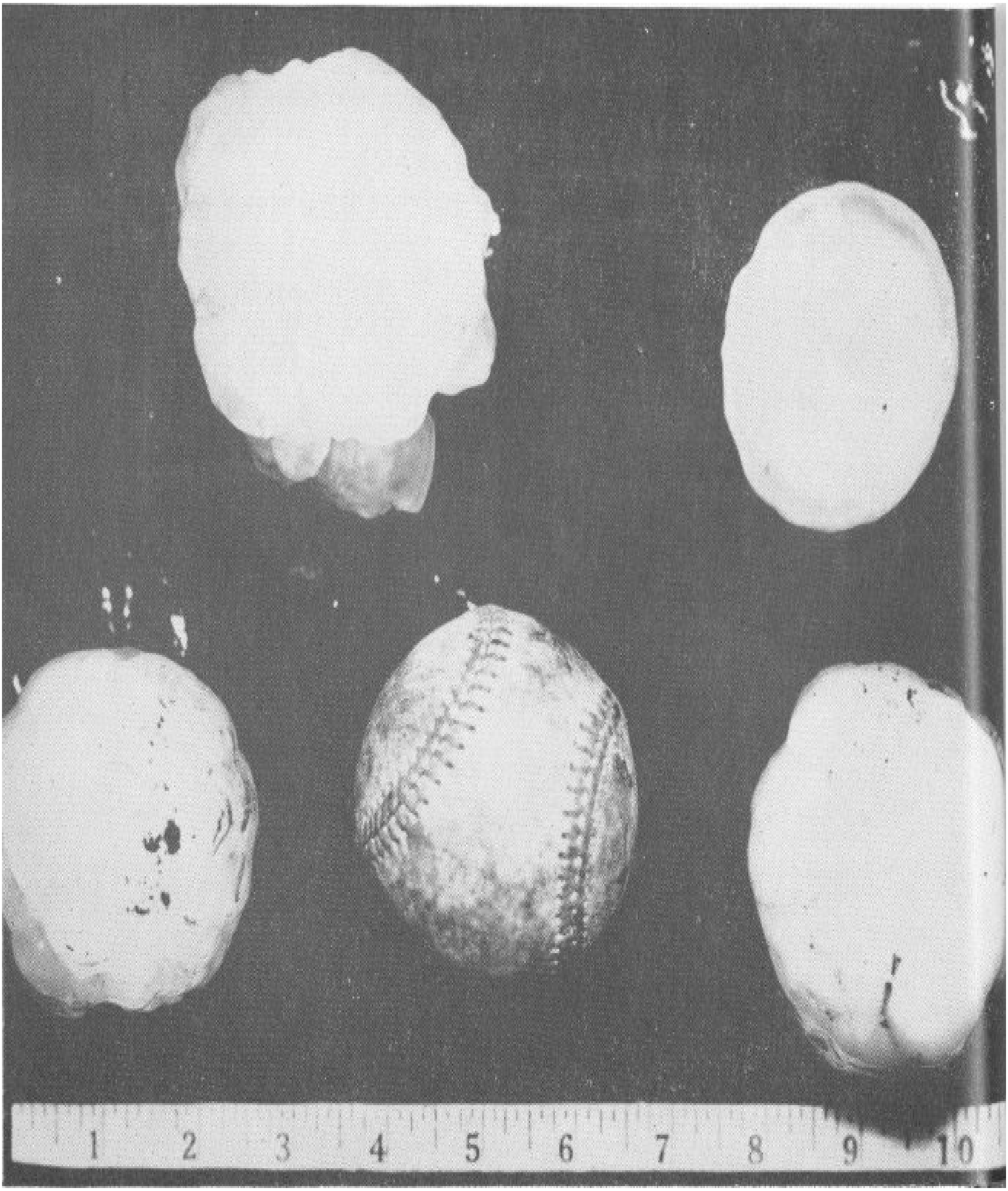
A hailstone that fell at Washington, D. C., May 26, 1953. This stone was four inches in diameter and weighed seven *ounces. The prongs are believed to have been formed by rotation of the hailstone as it fell.* Courtesy U. S. Weather Bureau.

Super hailstone that fell at Troy, New York, April 15, 1949. John Kolenburg displays the pellet which measured *five by five and one-half inches and weighed about four pounds.* Courtesy "United Press Photo."



Hailstones at Iowa City, Iowa, June 8, 1940. The hen egg at right gives an indication of the size of these hailstones.

Courtesy of the Iowa Press-Citizen.



Hailstones the size of a baseball. Fairfax, Atchison County, Missouri, November 16, 1942. Note the irregular projections on the hailstones. Courtesy W. S. Belden.

Kansas, the greatest wheat-producing state, with its western counties extending well into the High Plains area, has a bigger hail damage than any other state, with annual losses for a ten-year period exceeding $10,000,000. Next in order is Nebraska, followed by Montana and Iowa (Table II). Illinois, with its great corn production, but far enough east to escape the region of high probability of hail, ranks tenth in respect to crop damage.

Hailstorms begin to develop in the southern part of this region in March, April, and May. Farther north they begin in June and July, and in the extreme northern part in July and August. Thus, hailstorms are most prevalent during the growing season in each area.

Tobacco is particularly susceptible to hail damage. Its broad leaves, extending almost horizontally, break sharply at the stalk when pounded by hail. The leaf itself is delicate and its value is drastically reduced by even a small amount of puncturing and tearing. Hailstorms, occurring throughout most of the growing season, are a constant menace. Because of tobacco's high value per acre, if only a few acres are hailed out, the result is a heavy loss to the grower. The production per acre averages about a thousand pounds and sells from forty to forty-five cents per pound. North Carolina, the greatest tobacco-producing state, has annual hail losses exceeding $3,000,000. This is greater than the losses for any other state east of the Mississippi River (Figure 1).

Fruit, especially apples, peaches, apricots, grapes, and plums, is easily damaged even by comparatively small hailstones, which can pit and bruise it enough to make it unfit for market.

Fruit is the main item of loss from hail damage in California, Washington, Michigan, New York, Pennsylvania, and West Virginia (Table VI in Chapter V).

FIG. 1.—*Average Annual Hail Damage from 1944 to 1953.* (*From Official records of the U. S. Weather Bureau.*)

Perhaps the most violently destructive of all hailstorms in point of crop damage occurred in southeastern Iowa on August 18, 1925, from Poweshiek County to the southeastern part of the state. Fields of corn, as much as seventy-five acres in extent, were left without a stalk standing. Destruction was so complete that many tenant farmers abandoned their leases and sought other employment. Losses over the area of destruction were estimated at $5,000,000.

The most extensive hail damage to property other than crops took place in Kansas over a path two hundred miles long, from Kingman and Sumner counties through Cowley, Sedgwick, and Butler counties into Missouri. The heaviest damage was at Wichita, in Sedgwick County, and at El Dorado, Butler County. The losses to property other than crops in these two counties, including the Wichita losses, was estimated at $12,750,000. Damage in other areas was not estimated. As so often occurs, it was impossible to ascertain what percentage of the total damage was due to wind and what percentage to hail, but it is known that hail caused the major loss. Wind, adding force to the impact of the hailstones, increased their destructiveness.

In the Mediterranean region of Europe hailstorms have wrought havoc with vineyards, orchards, cereal crops, and livestock since pre-Biblical days. Aristotle (384-322 B.C.), in his *Meteorologic*, discusses hail and the causes of its formation. The artist, Benvenuto Cellini, tells of a terrific fall of hail which he encountered while traveling with some companions “about a day’s journey from Lyons.”

Coronado describes a severe hailstorm which struck his expedition in 1541, apparently in an area of what is now Texas. The hail caused his horses to stampede and resulted in much damage to his equipment. His description of the storm sounds very much like accounts of recent storms, except that there were no crops or buildings to be damaged and, of course, no insurance to cover losses.

In recent years there has been a tendency in some quarters to think that excessively damaging hailstorms might be caused by atomic explosions. This theory was examined and evaluated by the United States Weather Bureau. The conclusions drawn by the scientists who undertook this evaluation are stated as follows in a report by the Chief of the Weather Bureau:

> We have tested the effectiveness of the type of material believed to be present in atomic clouds and found them to be sufficient as freezing nuclei. We do not know any theory of hail formation which would indicate any effect from the debris of atomic explosions, nor are there any data which tend to imply there is any relation between atomic explosions and the occurrence of hail. When hailstones form in air which contains debris from an atomic explosion some of this debris will be caught in the hailstones, which will then be radioactive. This is believed to be due to the tendency of hailstones, particularly when wet, to collect dust particles they may encounter as they fall through the air.

For centuries men have tried to find a way to suppress hailstorms. In Europe the ringing of church bells to prevent hail was a practice for ages. This was finally forbidden by papal decree. Later, a form of hail cannon was widely used, on the theory that shooting vortex rings into the upper atmosphere would break up the ascending and gyrating currents supposed to cause hail. None of these methods, of course, was successful, but they persisted for a long time because the human tendency is to try anything to avert disaster.

In the past few years there has been much experimentation with dry ice and silver iodide in seeding clouds that might result in hailstorms. Some extravagant claims for this method have been made, but careful investigations do not bear them out. After an analytical evaluation of such claims, the United States Weather Bureau issued the following statement: "On the possibility of influencing hailstorms artificially we have attempted to assess the results of several hail-suppression projects. These evaluations have been inconclusive. This does not imply that artificial effects are impossible, but the evidence is not convincing."

One of the best authorities on the possibility of hail suppression is Mr. H. T. Harrison, superintendent of Weather Service for United Airlines, at Denver. He is located in a region where hail is severe and where there has probably been more experimentation in seeding clouds to prevent hail than in any other part of the country. As an official of United Air Lines, he is vitally interested in the subject because planes often encounter hail, sometimes with damaging results. When asked if well-developed hailstorms could actually be dispersed by spraying, his answer was: "My guess would be, no. Once the cumulo-nimbus clouds, the clouds from which hail falls, have reached the active stage, it is too late to accomplish anything by seeding. I had quite a number of discussions with Brandau and Kooser several years ago when they were working on fog-dispersal tests and they were frank to admit that they never made any claims of controlling thunderstorms that break out simultaneously over large areas. Their sole claim with their clients was that they could seed isolated, building-up cumulo-nimbus clouds at their formative stage and cause the clouds to pass quickly through the hail stage before stones of any considerable size could form."

Even granting that isolated clouds which threaten to develop into hail clouds could be broken up in their formative stages, the cost would be prohibitive to attempt the dispersal of all such clouds over a large area, such as western Kansas, and to continue the effort throughout the growing season, when hail is a constant menace.

An impartial investigation of the matter would require years of intensive study and would be complicated by the claims of the so-called "rain makers," some of whom now announce that they can suppress hailstorms—for a consideration. As long as people are willing to pay for cloud spraying in the vain hope that it will be effective in preventing hail, there will be men who will claim that it can be done and that they have been able to do it. Such claims are not confirmed by adequate data.

Science has made such rapid strides in recent years that no intelligent person is likely to say that it will never be possible to suppress hailstorms, even though it is not possible with present facilities and techniques. The impossible of today often becomes the commonplace of tomorrow.

III. When and Why Hailstorms Occur

There are three general classifications of hail: graupel or soft hail, small hail, and true hail.

Graupel, or soft hail, is white, opaque, usually round but occasionally conical, and of a snowlike structure. It is not often more than a quarter of an inch in diameter, with a crisp texture easily crushed and with a tendency to rebound when it strikes hard ground. This rebound causes it to fall apart. Soft hail occurs mainly at temperatures above the ground freezing point, and it falls mostly inland, before or together with snow.

Small hail is about the size of soft hail but is semitransparent. Like soft hail it is round, sometimes conical, and consists in general of a grain of soft hail as a nucleus with a very thin layer of ice around it. This layer of ice gives it a glazed appearance. It is not easily compressed nor is it crisp in texture. The pellets remain intact even when they strike hard ground. They are wet because they fall usually at temperatures above freezing and often fall with rain.

Both soft and small hail may occur without accompanying thunderstorms and occur frequently in the winter season along the central and north Pacific Coast in this country and in adjacent sections of British Columbia. Neither soft nor small hail is large enough to be very destructive. They are not to be confused with sleet. Sleet is frozen raindrops, almost clear particles of ice, which freeze before reaching the ground. Nor is sleet the same thing as freezing rain, which freezes on contact with objects such as branches, wires, the ground itself, coating everything smoothly with ice.

True hail falls almost exclusively during violent thunderstorms and never with surface temperatures below freezing. This type of hail varies in size, up to five inches in diameter, and can be very destructive.

A hailstorm has about the same duration as a "heat shower," lasting sometimes as long as half an hour, but fifteen minutes is the average. In long-path hailstorms, which often occur in Kansas, Nebraska, Montana, and other states, the fall of hail may continue for an hour or more as the storm spreads or progresses along its path, but at any given point the duration is much shorter. Occasionally one storm may follow another in quick succession.

For the United States as a whole, 73 per cent of all hailstorms develop between 2:00 P.M. and 9:00 P.M. The hours of greatest frequency are from 4:00 P.M. to 7:00 P.M. Forty per cent of all hailstorms on record have occurred during this period (Table III). Only 10 per cent occur between midnight and noon. Kansas, the state which ranks first in hail damage, has 15 per cent of its hailstorms in this midnight to noon period. The hours of least frequency over the nation are from 6:00 A.M. to noon, when, as official records indicate, less than 4 per cent of all hailstorms occur.

The month of greatest frequency is June. Almost 25 per cent of the total number of hailstorms are recorded for this month (Table IV). They begin in January and February in the more southern states, Alabama, Arkansas, Louisiana, Mississippi, Oklahoma, Tennessee, and Texas, and reach their greatest frequency in June over practically all the remainder of the country except some of the more northern states. In Iowa, Minnesota, and Nebraska, all heavy corn-producing states, hail is most prevalent in July, when corn is especially susceptible to damage. In Montana, where the wheat crop matures in the late summer and early fall, hail is more frequent in August than in any other month. A large number of damaging hailstorms have occurred in that state as late as September.

TABLE III

Hours of Occurrence of Hailstorms, 1944-53

(Data compiled by the United States Weather Bureau.)

This tabulation is based on the reported time of each hailstorm in each state for which such information is available, over the period 1944-53. Hours used are in local standard time of the place where the hailstorm occurred.

Figures opposite names of states give number of hailstorms beginning at each hour, local standard time, during the 10-year period ending with 1953.

A. M.

	12-1	**1-2**	**2-3**	**3-4**	**4-5**	**5-6**	**6-7**	**7-8**	**8-9**	**9-10**	**10-11**	**11-12**
Alabama	1											
Arizona		1				1						
Arkansas	1	3	3	3	2	4	2	1	2	1		1
Cal.	1										1	1
Colorado					1	1					2	3
Delaware										1		
D. C.												

Florida				1			1			1		1
Georgia					1				1			2
Idaho											1	
Illinois	1											
Indiana	2	1	3	1					1			
Iowa	1	1	5		3	2	1		1			
Kansas	10	11	6	10	5	5	6	4	3	4	3	1
Kentucky								1		1		
Louisiana	1	1		1		2						
Maine												
Maryland												
Mass.	1											
Michigan				1							1	
Minnesota	2	2	2	1	1	1	2		1		1	1
Miss.												
Missouri			2	1	3	2			1	2	1	1
Montana	11	3	4	3		2	2	1	1	2	2	
Nebraska	2	4	4	4	2	2	2	2	1	2		3
N. H.	1											
N. J.												
N. M.	1			1			1		2			1
N. Y.	1	1	1									
N. C.		1	1		3	1	2	1		1	1	
N. D.		1		1		1		1			2	
Ohio								1	1			
Oklahoma	5	6	1	4	2	1			1		4	3
Oregon												

Penn.	1									1		
R. I.												
S. C.			1		1							1
S. D.		1		1	1							1
Tennessee							1				1	
Texas	6	7	5	1		1		2	1	2		1
Utah										1		
Vermont						1						
Virginia	1								1			2
Wash.												
W. V.												
Wisconsin	1	1				1						
Wyoming	1											
Total	52	45	38	34	25	28	20	14	18	19	19	23
Per cent	1.6	1.4	1.2	1.1	.8	.9	.6	.4	.6	.6	.6	.7

P. M.

	12-1	**1-2**	**2-3**	**3-4**	**4-5**	**5-6**	**6-7**	**7-8**	**8-9**	**9-10**	**10-11**	**11-12**
Alabama		1	1	2	6	1	1	2		1		
Arizona	2	2	4	1	7	5	1	2	1		1	1
Arkansas	4	1	5	4	10	2	3	2	4	1	2	2
Cal.			1	1		1						
Colorado	4	12	18	25	31	21	16	5	7	4	1	2
Delaware												
D. C.							1					1
Florida	1	2	4	4	9	7	2	1	2	1		

Georgia			7	6	4	11	1	2	1		2	1
Idaho		2	4		3	6	4	2	1			
Illinois	1	7	4	5	5	6	7	2	2	3		2
Indiana	3	1	5	6	11	7	6	7	4		2	3
Iowa	4	2	4	3	6	9	9	6	2	2	1	3
Kansas	10	5	15	20	58	37	68	56	39	23	22	19
Kentucky	1	2	6	4	3	3	3	1	1			
Louisiana	1	1	1	1	3	2		1	2			1
Maine	1		1		1							
Maryland			1	3	3	3	2	3	2			
Mass.	1	1		2	1					3		
Michigan	1	1		1	1	2	2	2	1	1		1
Minnesota	6	1	7	10	10	20	12	11	8	3		2
Miss.		2	2	1	3	2	2		1	1	1	
Missouri	1	4	5	6	11	9	9	1	7	2	3	3
Montana	12	24	38	77	99	78	73	53	33	25	9	7
Nebraska	8	4	8	30	30	35	28	28	31	17	12	8
N. H.				1								
N. J.				1								
N. M.	3	10	9	8	13	10	7	2	5	4	1	1
N. Y.		2	7	1	1	1		2	1		1	
N. C.	2	7	19	38	39	30	21	8	7	3		2
N. D.						2	1	1	1	2	1	1
Ohio		1	1	1	2	1	1	2	1	1	1	1
Oklahoma	4	1	7	16	30	26	32	24	21	20	12	10
Oregon				2	2		1					
Penn.	1	4	4	3	4	5	2	1	1	3		

R. I.							1					
S. C.		2	1	4	2		3		2	1		
S. D.	1	1	2	3	2	5	7	3	2	3	1	
Tennessee			1	2	1	2	4	6		2		3
Texas	4	8	8	13	23	28	31	27	24	17	11	7
Utah	1		1	1								
Vermont			1									
Virginia	1	3	19	10	18	16	13	5	6	5		1
Wash.						1	1	1				
W. V.	1	1	5	5	6	3	3	1	3			
Wisconsin	4	3	3	5	4	6	7	3	2		1	1
Wyoming		5	8	4	5	6	3	7	2	3		1
Total	83	123	237	330	467	409	388	280	227	151	85	83
Per cent	2.6	3.8	7.4	10.3	14.6	12.8	12.1	8.8	7.1	4.7	2.7	2.6

TABLE IV

Months of Occurrence of Hailstorms, 1944-53

(Data compiled by the United States Weather Burea

This tabulation is based on reported hailstorms in each state for as such information is available. It covers the period 1944-53.

Data are for the 10-year period ending with 1953.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov
Alabama		4	3	4	4			1			
Arizona				2		3	11	7	6		
Arkansas	2	2	19	8	18	5	2	3	1		1
Cal.				4				2		6	4
Colorado				1	20	48	48	28	7	1	

Delaware								1			
D. C.						1					
Florida	2		6	10	12	3	3		1		
Georgia				7	21	6	2	2		1	
Idaho					2	6	6	9			
Illinois			4	3	6	4	6	17	2		1
Indiana			4	7	8	17	14	8	4		
Iowa			3	4	4	17	21	15	1		
Kansas			8	25	131	149	61	42	18	5	1
Kentucky		1		5	8	1	1	4	2	1	1
Louisiana		2	5	1	6	1	1			1	
Maine	1						1		1		
Maryland				1	5	5	3	3			
Mass.					1	3	3	2			
Michigan						4	2	9			
Minnesota			2	1	6	29	33	25	8		
Miss.		3		4		2	2	2	1		
Missouri	1	1	8	4	17	24	4	8	2	1	2
Montana					14	126	201	204	14		
Nebraska		1			41	74	88	58	4	1	
N. H.									1	1	
N. J.					1						
N. M.				2	21	23	16	12	4	1	
N. Y.					2	6	8	2	1		
N. C.				11	37	39	68	30	2		
N. D.						6	5	3	1		
Ohio				1	5	3	1	2	3		

Oklahoma		3	9	36	82	61	12	12	8	4	2
Oregon							2	2			
Penn.				1	12	6	5	1	4	1	
R. I.				1							
S. C.			1	5	6	3	3				
S. D.					2	15	9	8			
Tennessee		3	9		4	3	1	1			
Texas		9	13	45	78	45	9	14	2	6	2
Utah						1	2	1			
Vermont						2					
Virginia				1	42	23	17	17	1		
Wash.						3					
W. V.				1	20	1	5		1		
Wisconsin					1	10	10	19	2		
Wyoming					5	18	15	4	3		
Total	6	29	94	195	642	796	701	576	105	24	12
Per cent	.2	.9	2.9	6.1	20.0	24.9	21.9	18.0	3.3	.8	.4

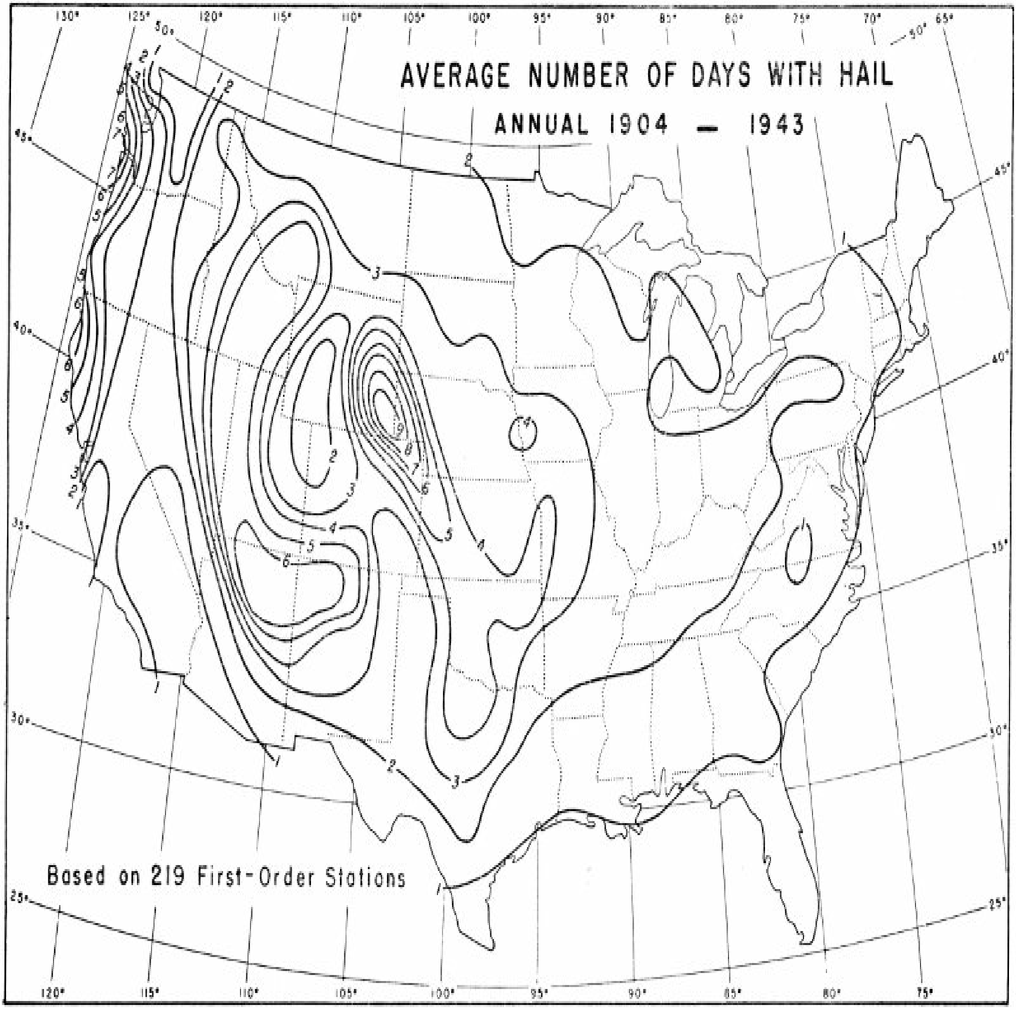


FIG. 2.—*Average Annual Number of Days with Hail. Values include all occurrences of hail, whether small hail or hail large enough to cause damage.*
(*U. S. Weather Bureau, Hydrometeorological Report No. 5.*)

After August, hailstorms are infrequent in most parts of the country. There are marked exceptions, however. In 1950, St. Louis suffered one of its most destructive hailstorms on December 2. Oklahoma has had at least two severely damaging storms rather late in the year. One was at Altus on October 22, 1943, for which the loss was estimated at $250,000; another one struck Garvin, Stephens, and Comanche counties on October 14, 1925, resulting in losses that amounted to $750,000.

Records kept at First-Order stations of the Weather Bureau indicate that hail falls more frequently in southeastern Wyoming than in any other area of comparable size. Hail occurs here on an average of slightly more than nine times annually (Figure 2). The nearest approach to this record is that of the north Pacific Coast, where the average is seven times annually. In Florida and Maine the frequency of hail is less than once a year. These figures are somewhat misleading in that they include all types of hail, ranging from the most destructive kind to the soft hail and the small hail, which do little or no damage.

During the growing season the greatest frequency of damaging hail is over Kansas, eastern Nebraska, and Iowa. These three areas together have a total average fall of twenty times annually (Figure 3). In northern Texas, Oklahoma, Kansas, and eastern Colorado, hailstorms become frequent between April 15 and May 15. Farther north and west they reach their peak from May 15 to June 15 (Figure 4).

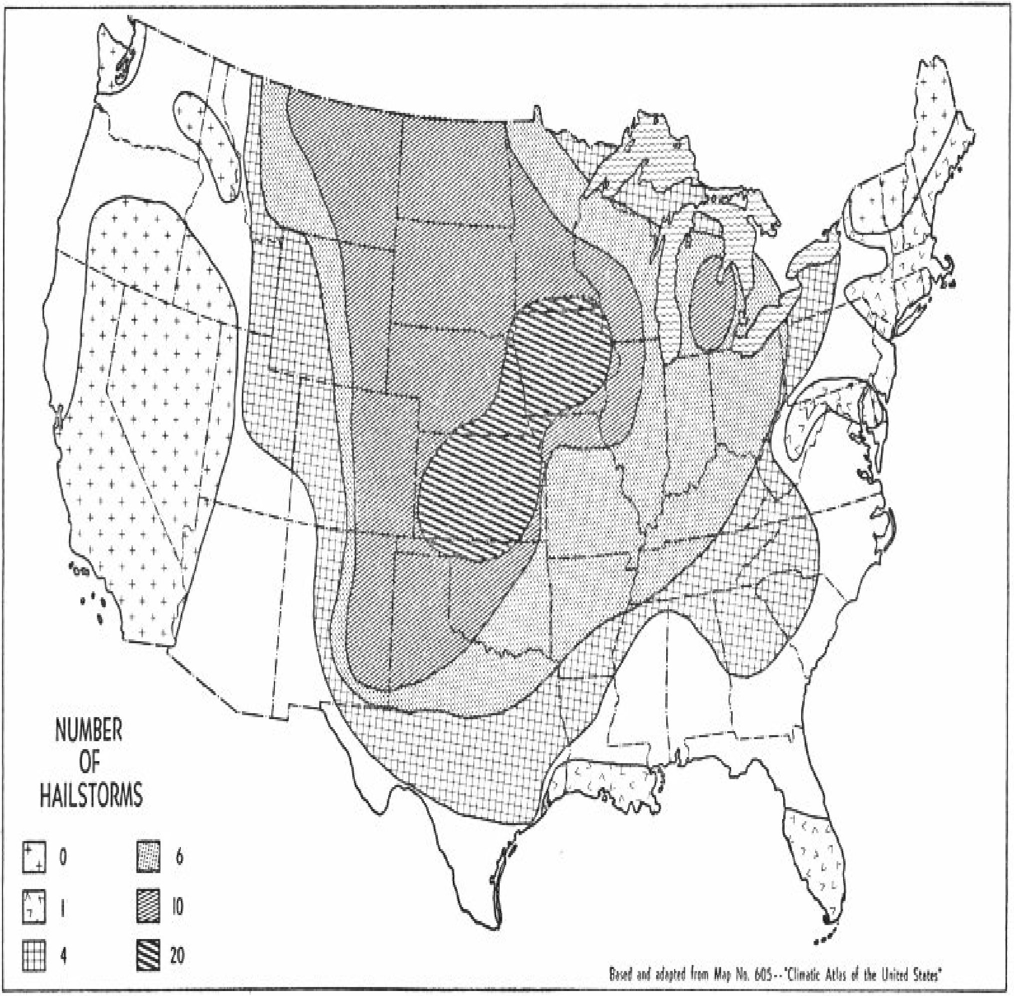


FIG. 3.—*Normal Number of Hailstorms Per Growing Season.*

(*From* Climatic Atlas of the United States, *by S. S. Visher. Adapted with permission of the Harvard University Press.*)

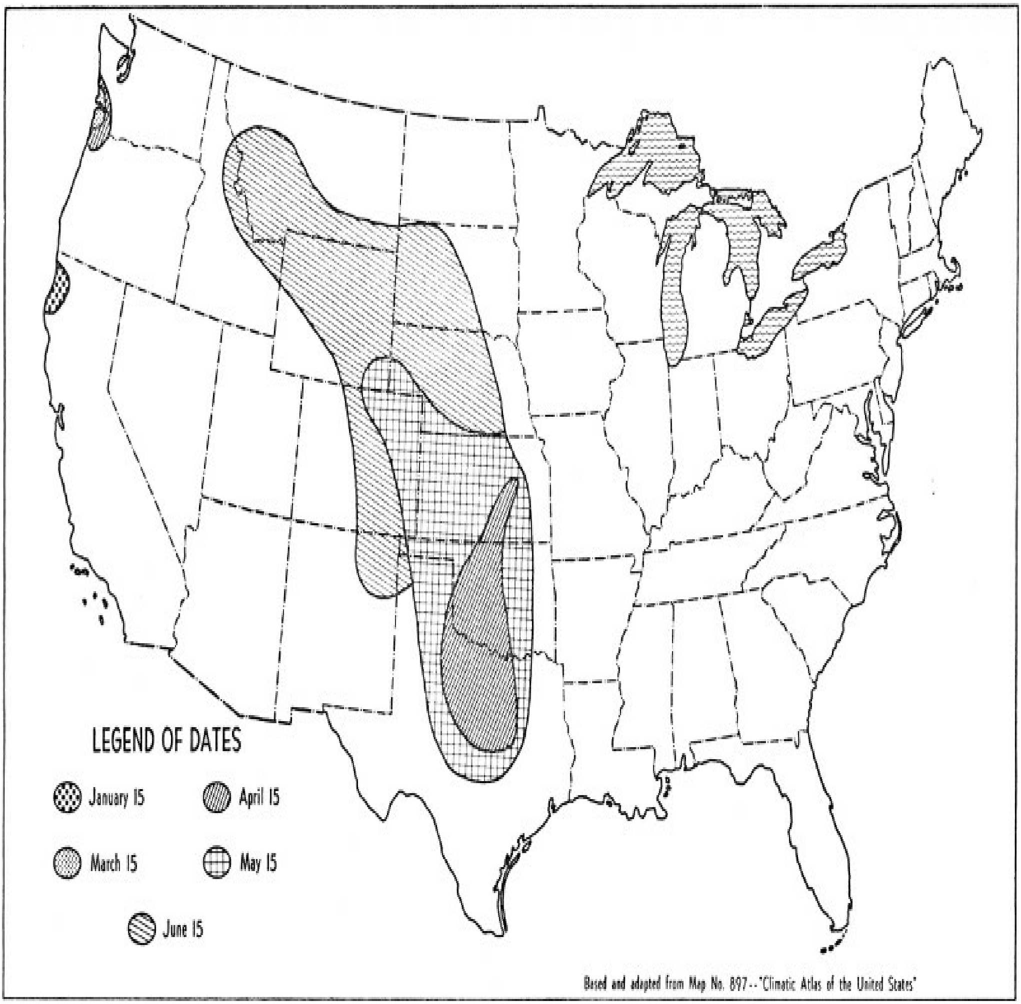


FIG. 4.—*Average Dates When Hailstorms Become Frequent.*
(*From* Climatic Atlas of the United States, *by S. S. Visher. Reproduced by permission of the Harvard University Press.*)

Although damaging hailstorms occur in conjunction with thunderstorms, in the High Plains east of the Rockies, Where hail is more destructive than elsewhere, only about 10 per cent of the thunderstorms result in hail that reaches the ground (Figure 5). In Florida, thunderstorms are more frequent than in any other state but the occurrence of hail is rare. Along the West Coast, hail is actually more frequent than thunderstorms but this is soft or small hail, not true hail.

Heavy hail has been known to fall from a blue sky, close in advance of or just behind a thunderstorm. Apparently the hail forms in a chimney of ascending air currents in the storm and is thrown from the top of the air chimney and at some distance from the storm cloud itself.[3]

There is a more or less general belief, especially in Iowa, where hail damage is frequent, that hail goes in streaks and that some localities are immune to hail. Meteorologists are very doubtful of this. They point out that a similar supposition might apply to rainfall. Records for a period of five to ten years or longer may point up certain areas as consistently deficient in rainfall as compared with adjacent areas, but as the record is continued over a longer and longer period, this seeming deficiency will not be in evidence.

It is a well-known fact that records of hail and hail damage over the country are far from complete. The Weather Bureau is the only government agency authorized to compile reports on hailstorms. Until the last few years shortage of funds has compelled the Bureau to depend on its substations, on co-operative observers, and on such newspaper accounts as are available for any and all data on hail, except that which fell at its First-Order stations. Many hailstorms simply were not reported, and in a great many instances estimates of damage from reported storms were not available. Actual and complete damage estimate, such as that obtained by a survey at the location of the storm, have never been possible except in rare cases (Table V).

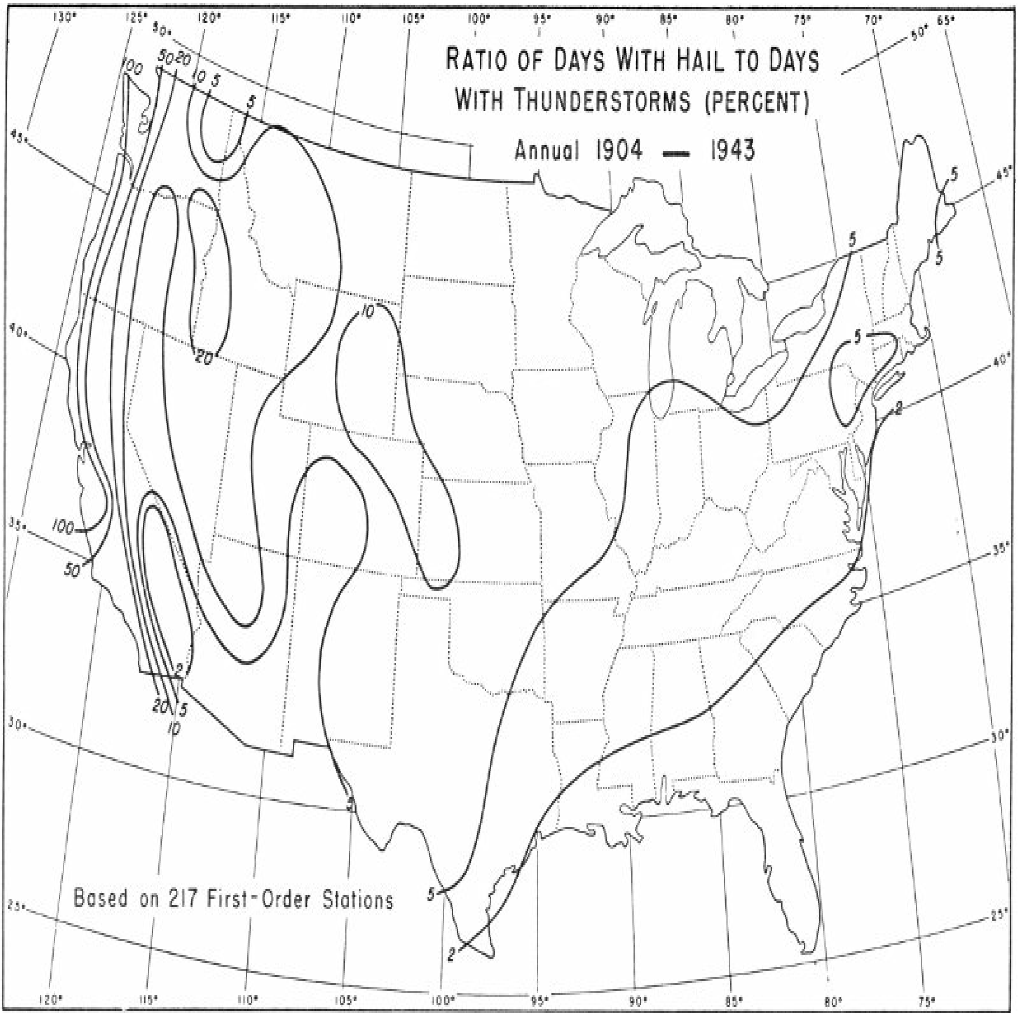


FIG. 5.—*Ratio of Days with Hail to Days with Thunderstorms. Values and isolines indicate percentage of thunderstorms that result in hail which reaches the ground.*
(*U. S. Weather Bureau, Hydrometeorological Report No. 5.*)

TABLE V

Cities and Counties With Records of Three or More Severe Hailstorms

Location	*Date*	*Estimated Damage*
Colorado		
Denver	July 27, 1954	$1,000,000 [a]
	May 27, 1953	120,000 [a]
	June 16, 1950	750,000
	May 30, 1948	3,800,000 [a]
	Aug. 26, 1944	1,000,000
	Aug. 16, 1933	150,500 [a]
	June 2, 1927	500,000
Pueblo	July 25, 1950	651,000
	July 22, 1948	130,000
	July 2, 1941	155,000
	Aug. 18, 1941	50,000
	Aug. 21, 1941	51,000
	June 17, 1938	[b]
Weld County	June 18, 1950	200,000 [a]
	July 23, 1950	300,000
	Aug. 16, 1933	150,500 [a]
	July 13, 1927	1,000,000
	Aug. 7-8, 1922	2,000,000 [a]

Phillips County	July 29, 1947	2,000,000 [a]
	July 14, 1947	120,000 [a]
	June 25, 1945	100,000 [a]
Connecticut		
Hartford	July 17, 1951	200,000 [a]
	June 8, 1946	600,000
	Aug. 1, 1929	1,000,000
Florida		
Gadsden County	May 17, 1950	100,000
	May 6, 1949	150,000
Iowa		
Plymouth County	July 6, 1952	1,000,000 [a]
	Aug. 15, 1952	500,000
	July 24, 1937	200,000
	July 7, 1924	[b]
Kansas		
Cheyenne County	May 7-8, 1952	1,066,000 [a]
	May 18, 1949	2,375,000 [a]
	June 27, 1949	1,000,000 [a]
	June 13, 1948	[c]
	June 14, 1948	[c]
	June 13 & 16, 1948	4,450,000

		June 5, 1947	1,000,000
		July 2, 1946	1,250,000
		May 30, 1945	200,000
		May 20-21, 1938	500,000 [a]
		June 25, 1935	108,000
	Thomas County	June 7, 1953	2,500,000 [a]
		May 7-8, 1952	1,066,000 [a]
		June 27, 1949	1,000,000 [a]
		June 13-16, 1948	4,450,000 [a]
		May 30, 1945	1,000,000 [a]
	Sherman County	May 21, 1952	1,444,000 [a]
		June 21-22, 1951	5,716,000 [a]
		May 18, 1949	2,375,000 [a]
		May 30, 1945	1,000,000
	Wichita	June 21, 1953	9,180,000 [d]
		June 23, 1951	14,340,000 [a][d]
		May 21, 1937	600,000 [a]
Louisiana			
	New Orleans and vicinity	Feb. 26, 1939	200,000
	New Orleans	April 17, 1924	100,000
		March 17, 1904	[b]
		April 16, 1879	

			[b]
Minnesota			
Rock County	July 5, 1953	350,000	[a]
	July 3, 1937	180,000	[a]
	Aug. 27, 1936	100,000	[a]
Missouri			
St. Louis	Aug. 7, 1953	100,000	
	March 31, 1952	100,000	
	Dec. 2, 1950	4,000,000	[a]
	May 14, 1945	610,000	
	May 28, 1927	1,000,000	
	April 14, 1922	200,000	
Montana			
Chouteau County	Aug. 11, 1945	6,000,000	
	Aug. 11, 1944	400,000	
	Oct. 8, 1944	600,000	
	June 25, 1942	250,000	[a]
	July 30, 1942	1,500,000	
Nebraska			
Cheyenne County	July 2, 1953	6,100,000	[a]
	May 26, 1952	600,000	
	June 23-24, 1952	1,300,000	
	July 13, 1952	150,000	
	June 5 & 25, 1951	3,000,000	

	Aug. 16, 1927	200,000 [a]
North Platte	Aug. 29, 1952	800,000
	Aug. 29, 1950	300,000
	Aug. 5, 1932	500,000
Scotts Bluff County	June 25, 1951	3,000,000 [a]
	Sept. 22, 1948	520,000
	June 28-29, 1947	1,500,000
	July 17, 1944	3,000,000 [a]
New Mexico		
Roswell	May 20, 1951	500,000 [a]
	May 12, 1950	240,000 [a]
	May 16, 1947	300,000 [a]
	June 2, 1946	200,000 [a]
North Carolina		
Beaufort County	May 19, 1953	165,000 [a]
	July 30, 1952	1,732,000 [a]
	June 27, 1951	1,150,000 [a]
Oklahoma		
Oklahoma City	Sept. 12, 1950	987,000
	May 16, 1943	750,000
	Feb. 23, 1936	[b]
	Sept. 18, 1923	1,000,000
	March 22, 1917	9,500

	May 22, 1915		[b]
	April 12, 1911		[b]
	April 25, 1909		[b]
Kay County	April 17, 1953	1,050,000	[a]
	Aug. 5, 1952	1,600,000	[a]
	May 19, 1951	200,000	
Tillman County	May 8, 1949	500,000	
	May 12, 1948	300,000	
	Sept. 13, 1925	500,000	
Washita County	June 5, 1953	105,000	
	May 22-23, 1952	1,313,000	[a]
	May 23, 1952	100,000	[a]
	May 12, 1930	450,000	[a]
South Carolina			
Spartanburg County	April 24, 1952	1,000,000	
	May 9, 1932	101,000	[a]
	Aug. 29, 1929	200,000	
South Dakota			
Beadle County	June 24, 1952	3,500,000	[a]
	Aug. 12, 1952	105,000	[a]
	Aug. 7, 1951	64,000	[a]
Texas			
Dallas County	April 8, 1938	1,000,000	

	April 25, 1933	478,000 [a]
	May 8, 1926	875,000 [a]
San Antonio	April 23, 1953	200,000
	May 16, 1946	2,000,000
	April 2, 1944	1,005,000
	April 6, 1938	120,000
	March 5, 1935	1,005,000
Virginia		
Frederick County	May 11, 1951	101,000
	May 18, 1950	100,000
	Aug. 30, 1945	110,000 [a]
Washington		
Yakima County	June 21, 1938	25,000
	June 12, 1935	65,000 [a]
	June 14, 1928	300,000
Wyoming		
Laramie County	June 21, 1951	105,500
	Sept. 6, 1951	175,000
	July 14, 1948	100,000
Cheyenne	June 11, 1944	500,000
	June 14, 1944	140,000
	June 14, 1926	140,000

[a] Part of this damage occurred in other areas of the storm path.

[b] Damage severe but not estimated.

[c] Damage included in total for June 13-16, 1948.

[d] Damage increased by strong winds accompanying the hail.

During recent years the Bureau has placed more emphasis on obtaining hail reports. In the midwestern heavy-damage area it subscribes to clipping bureaus which forward accounts of all severe storms to the Weather Bureau office. As a result there has been a material increase in the number and details of storm reports published during recent years. Even so, many comparatively small losses escape the network of reporting facilities and there are still many instances in which no estimate of damage can be obtained.

Hail insurance companies, of course, maintain detailed records of all crops insured and losses paid. These are sent in to a central organization, the Crop-Hail Insurance Actuarial Association, in Chicago, which compiles and analyzes them and publishes the figures for each state. These figures reveal some very important facts about hail risks over the country, but they give an incomplete picture of total hail losses, since only a small percentage of crops is insured. The compiled figures on hail losses to property other than crops are also deficient in that in most instances no attempt is made to ascertain how much of the total loss is due to hail and how much to wind.

Table V lists practically all localities in the country that have reported three or more severe hailstorms in the past twenty-five to thirty years. But the only cities in the list are those where full-time employees were on duty at First-Order stations of the Weather Bureau. There are many other towns and cities that kept no records of storms.

Denver, Colorado, has a record of seven hailstorms in twenty-seven years. Pueblo has had six in fifteen years. No other places in the state have reported any number comparable to these. In Louisiana, where few hailstorms have been recorded, New Orleans has reported a total of four. Oklahoma City has records of eight hailstorms in its history, while few other towns in the state have reported even as many as two. St. Louis, Missouri, has had six of these storms in thirty-one years, but rarely have two or more been reported from any other locality in that state. Cheyenne County, Kansas, has had eleven; Cheyenne County, Nebraska, about one hundred miles northwest, has reported six; Weld County, Colorado, five; and Scotts Bluff County, Nebraska, four. It is quite likely that adjacent counties where records show so few storms in comparison have not reported all that occurred.

Small hailstones are believed to exist in all severe thunderstorms but they may often melt before they reach the ground and fall as large raindrops instead. Byers states that there is increasing evidence that in certain instances large hailstones frequently fall from instability showers, often with little thunder and lightning and sometimes none at all.[4]

The approach of a well-developed thunderstorm is a terrifying sight to many people, portending as it so often does an onslaught of damaging winds as well as hail. The cloud may rise over the horizon when most of the sky is nearly clear. As it nears the zenith, there is frequently a greenish tinge to it, which some persons attribute to the presence of hailstones in formation. Actually this greenish cast is merely a reflection of the earth's vegetation, usually grass. The color disappears when the sky becomes entirely overcast.

People who have experienced severe hailstorms are often curious about what the atmospheric conditions are that result in this phenomenon. They may have a vague conception of freezing temperatures at certain distances above the earth and of uprushing air currents that have something to do with the situation. But this is only part of the picture.

A hailstone starts from a small rounded nucleus of either compacted, partially melted snow or from a large raindrop in which freezing has already begun a mile or two above the ground. This freezing formation can increase to a quarter of an inch in diameter as super-cooled droplets of water continue to freeze upon it, but several things must happen to it before it falls to the ground without melting. From this point there are two commonly held theories concerning the further growth of the nucleus. The first and older theory, advanced by Humphreys, Brunt, and Grimminger, is that great uprushes of air cause the hailstone to make alternate trips up and down through the atmosphere.[5] The second theory, favored by Byers, Schumann, and Bilham, is that the hailstone makes a long fall through the air and is at times almost stationary in its downward path.[6]

Humphreys maintains that the nucleus meets a strong updraft within the cloud and is blown into the area of freezing temperatures, where it quickly gathers a coating of snow and frost. Then the incipient hailstone gets into a weaker updraft or tumbles into the edge of an ascending current. In either case it falls back into the region of liquid drops, where it gathers a layer of water, part of which is frozen by the low temperature of the nucleus. Again it meets an upward gust and again moves from the area of rain to the area of snow. Each time an upward journey is completed, a new layer of ice and a fresh layer of snow have been added. There may be several of these upward journeys made. The size of the hailstone will be roughly proportional to the strength of the upward currents that lift it into the freezing area.

Since its weight increases approximately as the cube of its diameter, and the supporting force of the air varies as the square of its speed, the ultimate size the hailstone can reach is soon attained. An exceedingly strong updraft, and one high enough for the air to be very cold, is essential to the formation of a sizable hailstone. Consequently, the largest hail falls from the front portion of a thunderstorm, where the strongest updrafts exist.

The long-fall theory assumes that the growth of the hailstone takes place in one continuous drop, during which it captures super-cooled droplets that lie in its path through subfreezing layers of air. This fall is slowed materially by updrafts of air which need not be as forceful as those assumed in the multiple-incursion theory. The vertical speed is one of the main suppositions, however. The stone always continues downward, though its fall may be slowed to a standstill at times. The most important factor seems to be the concentration of the super-cooled droplets between the initial point and the location of the freezing level in the air. One meteorologist explains that the layers of the hailstones are determined by their surface conditions as they come into contact with the super-cooled droplets.

Either theory assumes the existence of uprushing currents of air at tremendous speeds. It is known from the lifting effects of tornadoes that such updrafts exist. Pilots tell of being unable to lose altitude even by attempting power dives against the upward currents. However, such stories are usually lacking in complete particulars.

Humphreys conducted test experiments on the uprush of air necessary to support and lift large hailstones. He used actual wind-tunnel measurements made at the Bureau of Standards and elsewhere. He took into consideration the fact that hailstones vary in density but he did not make allowance for turbulence. The results of his computations are given in the following table:

Updrafts of Air at Three-fifths Its Sea Level Density Necessary to Support Hailstones of Varying Size and Density [a]

	Density of Hailstones				
	0.9	**0.8**	**0.7**	**0.6**	**0.5**
Diameter of Stone in Inches	***Miles per Hour***	***Miles per Hour***	***Miles per Hour***	***Miles per Hour***	***Miles per Hour***
1	62	59	55	51	47
2	89	84	78	73	66

2.5	103	98	91	84	77
3	123	116	109	101	92
3.5	154	145	136	126	115
4	210	198	185	172	157
5	248	234	219	203	185

[a] By W. J. Humphreys in U. S. W. B. *Monthly Weather Review* (August, 1928), 314.

Since turbulence of the air is believed to be a factor in the ability of updrafts to support hailstones, Grimminger recomputed Humphreys' figures for a hailstone of 0.8 specific gravity. His results, according to the experience of some meteorologists, come nearer to actual conditions than do those of Humphreys.

Upward Speed of Air Necessary to Support Hailstones of 0.8 Specific Gravity[a]

	A	***B***	***C***
	Much Turbulence	***Little Turbulence***	***Least Turbulence***
Diameter of Stone in Inches	***Miles per Hour***	***Miles per Hour***	***Miles per Hour***
1	63	65	54[b]
2	206	91	78[b]
3	244	112	

			101[b]
4	258	264	123[b]
5	278	—	157[b]

[a] From G. Grimminger, “Upward Speed of Air Necessary to Support Hailstones,” U.S.W.B. *Monthly Weather Review* (July, 1933), 199.

[b] Resistance curve interpolated.

The shapes of hailstones are often puzzling. One of the most unusual, and the most destructive for its size, is a hailstone with spikes or brush-shaped protuberances. Lloyd states that such a stone forms on a nucleus shaped like a top.[7] Consequently, it rotates in one plane as it falls, somewhat as the earth does, with a bulge at the equatorial zone. Centrifugal force, due to rotation, causes any water on the outside to move away from the hailstone, much as water and mud tend to fly off the wheel of a moving automobile. If the rate of rotation is not sufficiently rapid to cause this water to fly off the hailstone, its tendency is to press outward and protrude from the stone as it freezes. Other water freezes to it and finally a spike is formed, just as an icicle is formed in cold but not too cold weather. Centrifugal force moves the water along the surface of the hailstone spike, but in the case of the icicle, it is gravity that moves the water downward. Examination shows that the structure of the spike is similar to that of an icicle, cone built upon cone.

Sometimes a change in direction of air currents may reverse the rotation of a hailstone. When that happens an additional set of spikes may develop. Water tends to collect also on the underside of the hailstone and freeze into small bumps that resemble drops of water hanging from the underside of a sheet of glass.

Another curious hailstone formation is that of a comparatively small and many-sided pyramid with a spherical base. Schumann explains this as the result of explosion.[8] The hailstone starts from a nucleus that is only beginning to freeze, and after it has grown in size and has passed into very cold air, the outer part freezes completely. There can be little or no transfer of low temperatures from the surface to the more or less liquid center. Because of increasing pressure of the outer layers the freezing point of the center would be slightly lower than that of the outer surface. Should the hail be carried to such a great height that all external liquid would be frozen, a temperature below freezing would finally penetrate the nucleus. (This is quite possible, as evidenced by temperatures of five to twenty-three degrees Fahrenheit in hailstones that were examined immediately after they reached the ground.) When the nucleus freezes, it expands with great force, shattering into pyramids with spherical bases. In instances when the liquid content of the hailstone is small, the parts may not be completely severed from each other and may refreeze into odd shapes upon release from pressure. Sometimes the expansion will merely produce small fractures radiating from the center, as has often been observed.

When it is possible for the nucleus to remain liquid or semi-liquid at the center while a frozen layer forms over the surface of the stone, or if the crystal-like liquid mixture is not firmly frozen to the shell, the resulting fracture may produce the lens- or saucer-shaped hail which occasionally falls.

IV. Forecasting Hail

The forecasting of hail is a comparatively recent innovation in Weather Bureau service. As commercial aviation developed, the hazard of hailstorms became more and more apparent. The National Advisory Committee for Aeronautics made an exhaustive study of this danger faced by pilots in flight and published its findings and conclusions for the benefit of aviation.[9] The following statements are from its report:

“Since more and better instruments have been installed in aircraft, pilots are more inclined to fly through clouds and to land with weather conditions below contact minimum. As a result, aircraft are more frequently flying through thunderstorms which contain hail. These hail contacts can cause severe damage to aircraft, although no fatal accident is known to have been caused solely by it. Nearly all the nose section and the leading edges of the wing and tail are subject to damage. Windshields have been broken or cracked to such an extent pilots feared broken pieces of glass would be blown into their eyes.

Instances of Plane Damage by Hail
Tabulated by The National Advisory Committee for Aeronautics

Type of	*Location*	*Altitude ft.*	*Diameter*

Airplane	*Date*	*of Storm*	*M.S.L.*	*of Stones*	*Damage*
Douglas DC-6	April 27, 1948	Ohio	18,000	[a]	Leading edge of wing, tail, and cowlings, and nose section.
Douglas DC-6	May 25, 1948	Texas	16,000	[a]	Windshield, nose cap battered. Cowlings and leading edges dented. Repair cost, $18,146.
Douglas DC-6	May 25, 1949	Texas	14,000	1.5 in.	Nose, windshield, cowlings and all leading edges. Repair cost $25,165.
Douglas DC-3	May 12, 1947	Arkansas	2,500	[a]	Elevator ripped, windshield cracked, landing lights broken, and nose dented.
Beech D18S	June 19, 1948	West Va.	7,000	1.3 in.	Horizontal and both vertical stabilizers, nose glass, and landing lights damaged.
Boeing B-29	Oct. 31, 1947	Texas	14,000	1.8 in.	All leading edges of wings, horizontal and

					vertical stabilizers, all engine cowling, propellor cuffs, cooling fins, cylinders, nose glass cracked.
Douglas DC-3	Aug. 19, 1945	Wyoming	14,000 to 22,000	[a]	Elevators stripped, holes in both ailerons, cabin windows cracked on right side. Dents in fuselage.

[a] Not estimated.

“Hailstones less than three quarters of an inch in diameter do not cause serious damage to aircraft at speeds between two hundred and three hundred miles per hour. Calculations from photographs of hail damage to planes indicate the largest hailstones to be encountered in flight are about two inches in diameter. Pilot reports indicate the horizontal distance flown in hail averages about five miles but ranges from one to thirty miles.”

The first forecasts of hail, with the probable size of hailstones, were issued in February, 1950, for the benefit of military aviation. These forecasts were prepared by Colonel E. J. Fawbush and Major R. C. Miller of the Severe Weather

Warning Center, Tinker Air Force Base, Oklahoma City. Shortly afterwards the United States Weather Bureau began the forecast of hail as a service to civilian fliers and to the general public.

This new service proved so valuable that the Severe Local Storm Warning Center (usually referred to as SELS) was established at Washington, D. C., manned by highly trained specialists who work in close co-operation with the district forecast centers of the Bureau. Late in 1954, the SELS center was moved to Kansas City, Missouri, not only because of better communication facilities, but also because Kansas City is closer to regions of greatest frequency and severity for both hailstorms and tornadoes.

The Severe Weather Warning Center, headed by Colonel Fawbush and Major Miller, was maintained at Tinker Field for approximately six years. It used the same general and special weather reports as SELS of the Weather Bureau, but there was little or no consultation between the two services.

Early in 1956 the warning center at Tinker Field was moved to Kansas City, Missouri, and located in a room adjacent to that occupied by SELS. Under this more efficient arrangement there is frequent and at times almost continual consultation between the personnel of the two units. The Severe Weather Warning Center, headed by Major Miller, issues routine forecasts of hail, probable size of hailstones expected, severe thunderstorms, and tornadoes. These forecasts are for the benefit of military establishments, including in particular the aircraft stations. The Weather Bureau unit, SELS, issues warnings of severe thunderstorms, hail, and tornadoes for the benefit of civilian aviation and the general public. It does not attempt to forecast probable size of hailstones but quite frequently specifies, in connection with warnings of severe thunderstorms, that large or heavy hail is indicated.

An increased knowledge of conditions in the upper air is a basic necessity for accurate forecasting of weather in general and especially for hail and tornado forecasts. A new instrument called the radiosonde, developed in the middle 1930's, has greatly increased such knowledge, thereby enabling forecasters to make more accurate and more informative predictions. Carried aloft by a balloon, the radiosonde not only registers the pressure, temperature, and humidity of the air, but also transmits this information by radio signal to the ground station from which it was released.

The helium-filled balloon rises slowly enough to permit the instrument to register its measurements accurately but with enough speed to prevent winds from blowing it too far away from the ground station before it collects and transmits its data. A brightly colored parachute is attached so that when the balloon finally bursts from reduced air pressure, the radiosonde will fall gradually to the ground without damage to anything beneath it. The ground operator already has a record of its readings before it starts to descend.

As a rule, radiosondes rise no higher than ten to fifteen miles, but in some instances they have reached altitudes close to twenty miles. Some are equipped with a device that makes it possible by radio direction finding to obtain their speed and direction of movement. The instrument itself is about the size and shape of an old-fashioned dinner pail and packaged in a strong cardboard container. Directions printed on the outside instruct that it be mailed, without payment of postage, to the reconditioning center at Joliet, Illinois. Usually no reward is offered for this service. It is considered purely a matter of public duty.

The spot where a radiosonde finally falls to the ground may be as far as two hundred miles from the point where it was launched. Many persons are mystified by the device if they have never seen nor heard of one before. During World War II, some radiosondes were sent to Military Intelligence, who took the matter up with the nearest Weather Bureau officials to make sure the package did not contain explosives originating with the enemy. There is a story of an old "sourdough" in Alaska who found one and, believing it to be a radio receiver, spent the winter trying to get reception from a broadcasting station.

At the present time radiosonde observations are made every twelve hours at some ninety points throughout the country. These observations are made by the Weather Bureau, the Air Force, and the Navy. A few of these stations take observations every six hours and during periods when severe storms are anticipated, even more frequent observations are made. Data transmitted by the radiosonde are coded and placed on teletype circuits for transmission to all weather offices, both domestic and international, that might have use for the information. From this data the forecaster is able to determine conditions of the atmosphere from ground level to and beyond the height where hail and other storms originate. Knowing the vertical distribution of temperature and humidity aloft, the forecaster can compute the stability or instability of the atmosphere and determine the areas where updrafts are likely to develop enough to culminate in hailstorms.

An atmospheric condition likely to become unstable is that of a layer of warm, moist air overrun by drier, cooler air. In such a situation, the warmer the air is near the ground, the more likelihood there is for turbulence. This often occurs over the Great Plains and the Mississippi Valley when warm, moist air—Tropical Maritime air—moves northward from the Gulf of Mexico and is overrun by the drier, cooler air from the Pacific Ocean—Pacific Maritime air—flowing eastward or northeastward across the western plateau and the Rocky Mountains. This Pacific Air is dry because it lost most of its moisture in crossing the mountains. Anything that will disturb the equilibrium of the two layers of air, such as the turbulence frequently existing east of the Rockies, will result in a sudden uprush of air currents. From such conditions formations develop conducive to severe thunderstorms and hail.

Figure 6 is a section of a weather map depicting just such conditions at 6:30 P.M. on June 8, 1954. The area of low pressure over eastern Colorado was attended by a flow of warm, moist air from the Gulf of Mexico to the warm front extending from north-central Kansas into Iowa. The area of high pressure over the Texas Panhandle brought dry and cooler air to overrun the warm air of the low pressure area. The surface temperature was very high—104 degrees at Salina, Kansas, at 3:00 P.M. A radiosonde launched at that time from the Smoky Hill Air Force Base near Salina recorded temperatures and humidity aloft that favored the great updraft of air currents necessary to produce thunderstorms and hail.

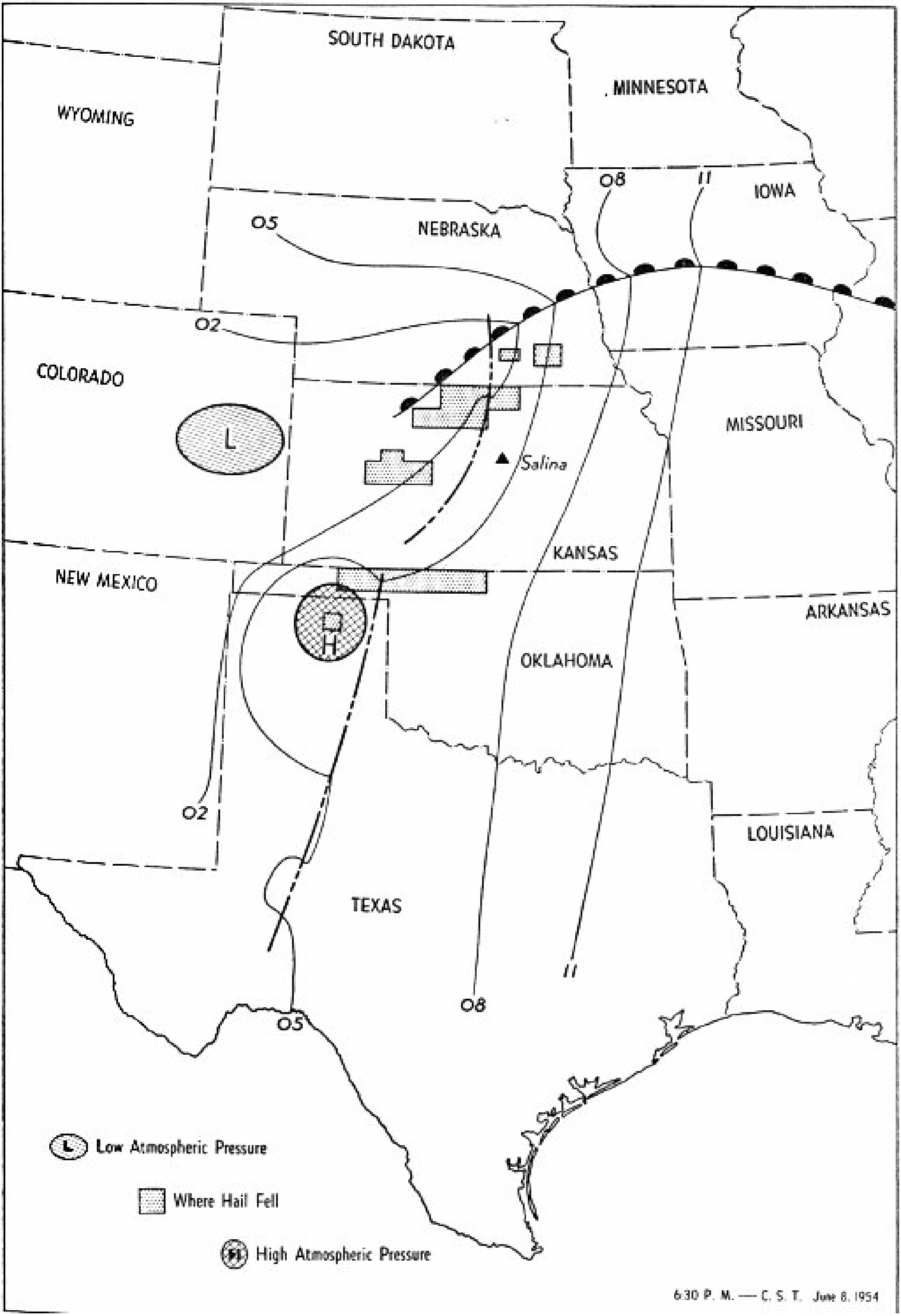

SOUTH DAKOTA
MINNESOTA
WYOMING
08
11
IOWA
05
NEBRASKA
02
COLORADO
L
MISSOURI
Salina
KANSAS
NEW MEXICO
ARKANSAS
H
OKLAHOMA
02
LOUISIANA
TEXAS
11
08
05
Low Atmospheric Pressure
Where Hail Fell
High Atmospheric Pressure
6:30 P. M. — C. S. T. June 8, 1954

FIG. 6.—*Typical Distribution of Atmospheric Pressure Likely to Result in Hailstorms.*
(*Courtesy Severe Local Storm Warning Center, U. S. Weather Bureau, Kansas City, Missouri.*)

Between 4:00 P.M. and 7:00 P.M. hail in the north-central counties of Kansas resulted in a crop loss of $225,000, mostly in Osborne County, where the hail was extremely heavy. Between 5:30 P.M. and 6:00 P.M. the west-central counties of the state suffered hail damage estimated at $10,000. Thirty minutes later, in Gage County, Nebraska, hail caused a loss of $10,000. Between 6:30 P.M. of that day and 2:00 A.M. of the following day, hail in extreme northern Oklahoma, from Beaver County to Alfalfa County, resulted in damage amounting to $40,000. At Alva, Oklahoma, a tornado was sighted high in the air but it did not reach the ground.

This particular atmospheric condition over the High Plains east of the Rockies during the spring and summer months accounts for the fact that hail is more frequent and damaging there than anywhere else in the world. Also, the northward-moving warm, moist air must flow upslope as the elevation of the ground gradually increases. This upflow adds to the development of turbulency which sets off hailstorms.

As yet, the forecaster has no method of measuring updrafts by instruments. He has the benefit of his experience, however, in relating many previous records of radiosonde readings to frequency and size of hailstones. The tabulations of Humphreys and Grimminger in Chapter III show approximately the upward speed of air currents necessary to support hailstones of varying sizes. These speeds range from near 65 miles per hour for hailstones an inch in diameter to great uprushes of 123 to 264 miles per hour for hailstones as large as four inches in diameter.

Fawbush and Miller studied 274 air soundings of conditions that produced hail which reached the ground.[10] From these soundings they were able to determine the size of hailstones likely to result from conditions shown by the radiosonde. More recently, Bates and Foster have been able to confirm to a great extent the findings of Fawbush and Miller by relating the maximum vertical velocities, as computed from readings of the radiosonde, to the actual size of hailstones that reach the ground.[11] Fawbush and Miller, in their extensive investigations of conditions in the upper atmosphere, found that there was a close relationship between the elevation of the wet-bulb freezing level and the size of hailstones.

Many persons are familiar with the fact that in order to measure the humidity of the air just above ground level, the Weather Bureau uses two thermometers—one with the bulb unwrapped, called the “dry thermometer,” and the other with the bulb wrapped in thin moistened cloth, called the “wet thermometer.” These thermometers are whirled to increase evaporation. The reading of the dry thermometer changes little, but evaporation cools the wet-bulb thermometer. The drier the air, the faster it cools, until it reaches a point where it will cool no further. This is called the wet-bulb reading. By means of the dry- and wet-bulb readings, together with specially prepared tables, the observer can compute the humidity of the air.

If the air is sufficiently cold and dry, the wet-bulb reading will finally reach 32 degrees Fahrenheit. This is called the wet-bulb freezing point. Of course it is impossible to obtain the wet-bulb freezing point in the upper air by this method, but use of the radiosonde makes it possible to compute just how high above ground this reading was at the time the ascent of the radiosonde was made.

Fawbush and Miller were able to reach some important conclusions:

1. Hailstones maintain their size for at least 9,000 feet of free fall, after which rapid melting and disintegration take place.

2. The most favorable height of the wet-bulb freezing level for production of large hailstones is near 8,000 feet.

3. The fall of hail larger than ⅛ inch in diameter is most probable when the wet-bulb freezing level lies between 5,000 and 11,000 feet above ground.

4. The fall of large hailstones to the earth's surface will be less probable when the wet-bulb freezing level lies above 11,000 feet or below 5,000 feet.

5. Hailstones will generally be about the same size at the ground as aloft when the wet-bulb freezing level is not more than 11,000 feet above ground.

Fawbush and Miller found also that practically all large hail, from 2 to 4 inches in diameter, fell when the wet-bulb freezing level was between 7,000 and 9,000 feet above ground; that 69 per cent of hail of all sizes fell when the wet-bulb freezing level was from 7,000 to 11,000 feet; and that no hail larger than ¼ inch fell when the freezing level was lower than 5,000 feet or higher than 12,000 feet.

These findings are tabulated on page 53.

*   *   *   *   *   *   *   *

The wet-bulb freezing level is of great assistance to the forecaster in making two general predictions, (1) that thunderstorms will or will not occur, and (2) that thunderstorms will contain updrafts of sufficient or insufficient speed to cause the formation of hailstones that will reach the earth. If the freezing level is below 5,000 feet or above 12,000 feet, thunderstorms are not likely to occur.

The forecaster also has the problem of determining to what extent conditions in the upper atmosphere, as shown by radiosonde data, will change within the next few hours; how fast and in what direction the changes are likely to be; and whether there will be an increase or decrease in intensity.

Frequency of Hailstone Size in Relation to the Wet-Bulb Freezing Level
Computed by Fawbush and Miller, Tinker Air Force Base, Oklahoma City (from investigation of 274 cases).

Height of Wet Bulb Freezing Levels (feet)	***Total Cases***	***Reported Diameter of Hailstones, in Inches % of***										
		⅛	**¼**	**½**	**¾**	**1.0**	**1.5**	**2.0**	**2.5**	**3.0**	**3.5**	**4.0**
0000-1,000	1.5	4	0	0	0	0	0	0	0	0	0	0

1,001-2,000	0.7	2	0	0	0	0	0	0	0	0	0	0
2,001-3,000	0.7	2	0	0	0	0	0	0	0	0	0	0
3,001-4,000	2.6	5	2	0	0	0	0	0	0	0	0	0
4,001-5,000	1.1	3	0	0	0	0	0	0	0	0	0	0
5,001-6,000	3.6	0	1	4	2	2	1	0	0	0	0	0
6,001-7,000	10.9	7	3	7	4	1	2	4	1	1	0	0
7,001-8,000	15.7	2	5	10	6	2	6	3	4	3	1	1
8,001-9,000	22.6	2	8	20	10	10	5	1	2	2	1	1
9,001-10,000	20.1	0	16	17	9	7	4	1	1	0	0	0
10,001-11,000	10.9	1	14	6	4	2	2	1	0	0	0	0
11,001-12,000	7.7	4	12	4	0	1	0	0	0	0	0	0
12,001-13,000	1.5	0	4	0	0	0	0	0	0	0	0	0
13,001-14,000	0.4	0	1	0	0	0	0	0	0	0	0	0

Radar is considered as a possible means of detecting hailstorms at a distance, but this is still a controversial subject. As a general rule, Weather Bureau offices over the country are equipped with 10 cm. radar which displays too coarse a signal to be very effective in the detection of hail, and little or no use seems to have been made of it in this connection.

United Air Lines began equipping its DC-3 planes out of Denver with the C-Band 5.5 cm. radar on June 1, 1953, and demonstrated an apparent capability of detecting prominent hail shafts in four out of five instances within a radius of twenty miles. The identifying forms (pointing fingers, hooked fingers, and scallops) showed up best at ranges of two to twenty nautical miles. It was found that this radar would penetrate two to twenty miles or more of heavy rain equal to or greater than 2.4 inches per hour and that it provided pilots with satisfactory warnings of hail shafts.

Mr. H. T. Harrison, superintendent of Weather Service for United Air Lines, at Denver, reports that radar is just about as effective when used as a fixed instrument on the ground as when it is used in a DC-3 airplane in flight, but that when it is used on the ground, an upward tilt of the antenna of 4° or more is generally necessary in order to segregate nearby ground clutter.

At best, it seems that ground radar can be counted on to give warning of approaching hail only up to an hour or two in advance. The hail might end within an hour, and the only thing that can be expected of radar is to tell what is happening at the time of the reading. It would, however, enable stations to report hail at some distance and give forecasters a more complete picture over a larger area. This should be of value in issuing warnings and in determining verifications of warnings.

V. Insurance Against Hail Damage

The following press dispatch appeared in Kansas newspapers a few years ago:

> A young man, the son of an extensive wheat grower in the western part of the state, called up his father, who was in Kansas City on business, and the conversation went as follows: "Dad, do you have hail insurance on your wheat?" "No, son, I haven't," replied the father. "You haven't any wheat, either," said the son. "We had a bad hailstorm last night and all your wheat was hailed out."

The only protection against heavy losses from hail damage is adequate insurance. Some growers still prefer to carry their own risks, but crops are now insured annually to the extent of $700,000,000.

The purpose of all insurance is to distribute risks over a large territory and over long periods of time, so that individuals will not be affected disastrously when losses occur. Some growers delay taking out hail insurance on their crops because of the cost, which, in high-risk regions, may be $15 to $20 per $100 for full coverage. Some wait until a neighbor's crop has been hailed out or until a bad hailstorm has occurred in an adjoining county, but a grower does not save anything by waiting.
The rate is the same, whether the insurance is written at the beginning of the season or just before the harvest. Most policies have a clause that protects a grower who takes out hail insurance early and then loses his crop from other causes. A

farmer cannot rush to an insurance agent when a thunderstorm is imminent and obtain a policy that takes effect immediately. There is always an interim of twenty-four hours from the time crop-hail insurance is applied for until it becomes effective.

Until comparatively recent years, rates charged were largely a matter of guesswork, sometimes unreasonably high, sometimes too low for insurance companies to stay in business. Often in widely level areas, where we now know that the hail risk varies but little over a distance of a hundred miles or more, one county might have several damaging hailstorms while adjacent counties might escape entirely. In such instances, the county which had suffered severe damage would be given a much higher insurance rate than the others. There was little knowledge then of the fact that ground elevation has a great deal to do with hail risk and that different crops vary greatly in liability to hail damage.

Hail losses are always high in a year of heavy rainfall during the growing season, since most rains at that time are from thunderstorms which may also produce hail. In 1915, the wettest year on record up to that time in Kansas, hail losses over the state exceeded all previous records. The result was that many insurance companies became bankrupt, and others, whose policies permitted, pro-rated their losses. In 1951, the year of heaviest rainfall on record and the year of most damaging hail in several midwestern states, hail insurance companies paid out 95 per cent of all premiums collected for that year. In Oklahoma the losses paid exceeded premiums by 56 per cent. In 1945, another year of excessive hail, insurance companies paid in Kansas 6 per cent more in losses than they had received in premiums. In Oklahoma insured losses for that year amounted to more than twice as much as the premiums paid. Hail losses on insured crops in Iowa in 1943 exceeded premiums by 23 per cent. In Nebraska in 1947 the excess was 42 per cent.

During the past twenty to thirty years, companies insuring crops against hail risk have pooled their experience and insurance data with the Crop-Hail Insurance Actuarial Association, of Chicago. This agency analyzes the figures for each state by counties and in some states by congressional townships. Reports of these analyses are published for each state separately and are available to any person requiring information. A summary of these reports is given in Table VI.

The basic problem of crop-hail insurance is, of course, the rates charged. These must of necessity be higher than corresponding rates on other property, such as buildings or automobiles. In every state these rates are subject to review and justification by a state agency, such as a state insurance commission, before they can be put into effect. The most important factor in determining the rates for crop-hail insurance is the “loss ratio.” This is the expression in dollars and cents of an insurance company’s loss per one hundred dollars of insurance written in a particular region. This is sometimes called the “loss cost.” It is computed from the experience of insurance companies for each county or township that has sufficient data for the purpose. The loss ratio may vary greatly, depending upon the kind of crop insured, the average frequency and severity of hailstorms, and ground elevation.

TABLE VI

Crop-Hail Insurance Statistics

From reports of Crop-Hail Insurance Actuarial Association, Chicago, Illinois (All insurance values apply to non-deductible Policies. Values covered by policies with deductible Clauses have been recomputed by accepted formula to indicate full coverage.)

(*a*)	***Length of record, years***
(*b*)	***Loss ratio***[a]
(*c*)	***Average rate in latest year of record***[b]
(*d*)	***Average annual liability insured***
(*e*)	***Average annual losses of insured crops***
(*f*)	***Crops most heavily insured, in order of amount of insurance***

States	**(*a*)**	**(*b*)**	**(*c*)**	**(*d*)**	**(*e*)**	**(*f*)**
Alabama	29	$0.97	$2.59	$151,964	$1,467	Cotton and tobacco.
Arizona	26	1.24	2.96	1,458,586	17,994	Cotton and barley.
Arkansas	10	1.77	3.73	466,324	8,194	Tree fruits and wheat
California	27	6.08	2.91	558,520	33,949	Fruit and wheat.
Colorado	22	9.61	15.14	2,154,127	165,741	Wheat and barley.
Connecticut	17	4.80	12.94	1,325,614	63,681	Tobacco and apples
Delaware	17	1.30	3.16	72,471	939	Peaches and apples
Florida	30	2.26	4.65	924,971	20,916	Tobacco

						and vine crops.
Georgia	29	2.42	4.21	8,083,770	200,358	Tobacco and cotton
Idaho	26	1.96	3.81	3,263,249	76,007	Wheat and truck crops.
Illinois	29	0.72	1.72	19,477,103	141,020	Corn and soybeans.
Indiana	21	0.75	2.32	3,465,937	25,898	Corn and vegetables
Iowa	24	1.74	2.99	25,951,796	442,755	Corn and oats.
Kansas	30	4.39	7.13	32,086,525	1,417,195	Wheat and oats.
Kentucky	21	2.11	3.12	7,646,468	161,624	Tobacco and tree fruits.
Louisiana	29	[c]	3.00	[c]	[c]	Cotton and vegetables
Maine	16	0.83	2.56	2,607,841	21,624	Potatoes and apples
Maryland	17	1.57	3.24	523,648	8,233	Wheat and apples.
Massachusetts	18	3.61	10.70	692,788	25,036	Tobacco and apples
Michigan	28	1.30	4.01	406,522	4,884	Tree fruits and grapes.

Minnesota	27	2.23	5.10	17,808,737	396,852	Corn and oats.
Mississippi	29	1.45	2.54	406,415	5,892	Cotton and vegetables
Missouri	21	1.60	2.75	3,281,304	52,666	Cotton and wheat.
Montana	27	5.09	9.63	11,072,868	525,152	Wheat and barley.
Nebraska	27	3.52	6.39	16,708,170	596,600	Corn and wheat.
Nevada	5	[c]	2.52	[c]	[c]	Wheat and barley.
New Hampshire	18	1.63	5.20	74,450	1,561	Apples and tobacco.
New Jersey	18	1.70	3.81	481,117	8,182	Tomatoes and peaches.
New Mexico	19	7.70	13.31	458,992	19,517	Wheat and cotton.
New York	17	2.15	3.73	2,556,828	55,061	Apples and beans.
North Carolina	30	2.60	4.76	40,012,438	1,064,957	Tobacco and cotton
North Dakota	27	2.96	6.27	17,853,135	531,856	Wheat and barley.
Ohio	20	0.92	2.67	1,805,085	16,588	Corn and vegetables
Oklahoma	30	3.89	5.86	9,932,555	346,422	Wheat and oats.

Oregon	28	0.74	2.05	4,215,753	30,651	Wheat anc barley.
Pennsylvania	17	2.44	4.42	1,596,390	38,930	Apples and peaches.
Rhode Island	18	5.68	5.66	20,376	1,156	Apples and tomatoes.
South Carolina	29	2.46	4.28	7,507,149	183,119	Tobacco and cottor
South Dakota	27	3.80	6.99	18,320,247	606,116	Wheat anc corn.
Tennessee	21	1.50	3.14	3,230,847	48,582	Tobacco and cottor
Texas	38	5.67	6.89	16,463,578	844,257	Wheat anc cotton.
Utah	28	1.44	3.23	328,396	4,442	Wheat anc barley.
Vermont	18	2.18	4.80	140,737	3,070	Apples and tobacco.
Virginia	30	3.34	6.13	5,589,883	186,727	Tobacco and wheat
Washington	28	0.44	1.81	7,766,578	34,044	Wheat anc apples.
West Virginia	18	4.97	8.13	316,342	15,707	Apples and peaches.
Wisconsin	19	2.69	4.71	1,318,540	37,496	Tobacco

						and corn.
Wyoming	20	8.27	12.56	104,550	6,918	Wheat and barley.

[a] Loss ratio is the average loss per $100 of insurance written. The value given is the average for the period of record.

[b] Rate per $100 of risk involved.

[c] Not sufficient insurance written to make representative values possible.

When computed from adequate data the loss ratio is one of the best indications of hail risk. It may range from less than $1.00 per $100 in areas of states along the Gulf Coast and in parts of Iowa, Illinois, Indiana, and Ohio to $9.00 or $12.00 per $100 in western Kansas, the Texas and Oklahoma panhandles, northeastern Colorado, the western areas of Nebraska, South Dakota, and North Dakota, and also parts of Wyoming and Montana (Figure 7). Even in some of the high elevations of California, east and northeast of Sacramento, where fruit is raised extensively and where most of the state’s crop-hail insurance is written, loss ratios exceed $12 per $100.

One of the important factors of hail risk is the increase of risk in proportion to the increase of ground elevation. In the southeastern and some extreme eastern counties of Kansas, where elevations are below one thousand feet, the loss ratio is as little or even less than $1.00. In the central counties where elevations rise to fifteen hundred or two thousand feet the loss ratio ranges from $3.00 to $6.00, and in the extreme counties with elevations well above three thousand feet it may be $12.00 or even more (Figure 9 in Chapter VI). This means that, on the average, from 10 to 12 per cent of all wheat, insured or uninsured, is destroyed annually by hail. Similar conditions prevail in Oklahoma (Figure 10 in Chapter VI).

In Kansas, hail insurance rates are determined by allowing a weight of 25 per cent to township experience, 25 per cent to county experience, and 50 per cent to elevation. In particular townships where comparatively little insurance has been written, it is necessary to determine a rate based on judgment alone. The approximate increase in the loss ratio in proportion to elevation in Kansas is as follows:

***From*:**	***To*:**	***Increase in Loss Ratio***
1,000 feet	1,500 feet	$1.50
1,500 feet	2,000 feet	1.50
2,000 feet	2,500 feet	1.75
2,500 feet	3,000 feet	2.00

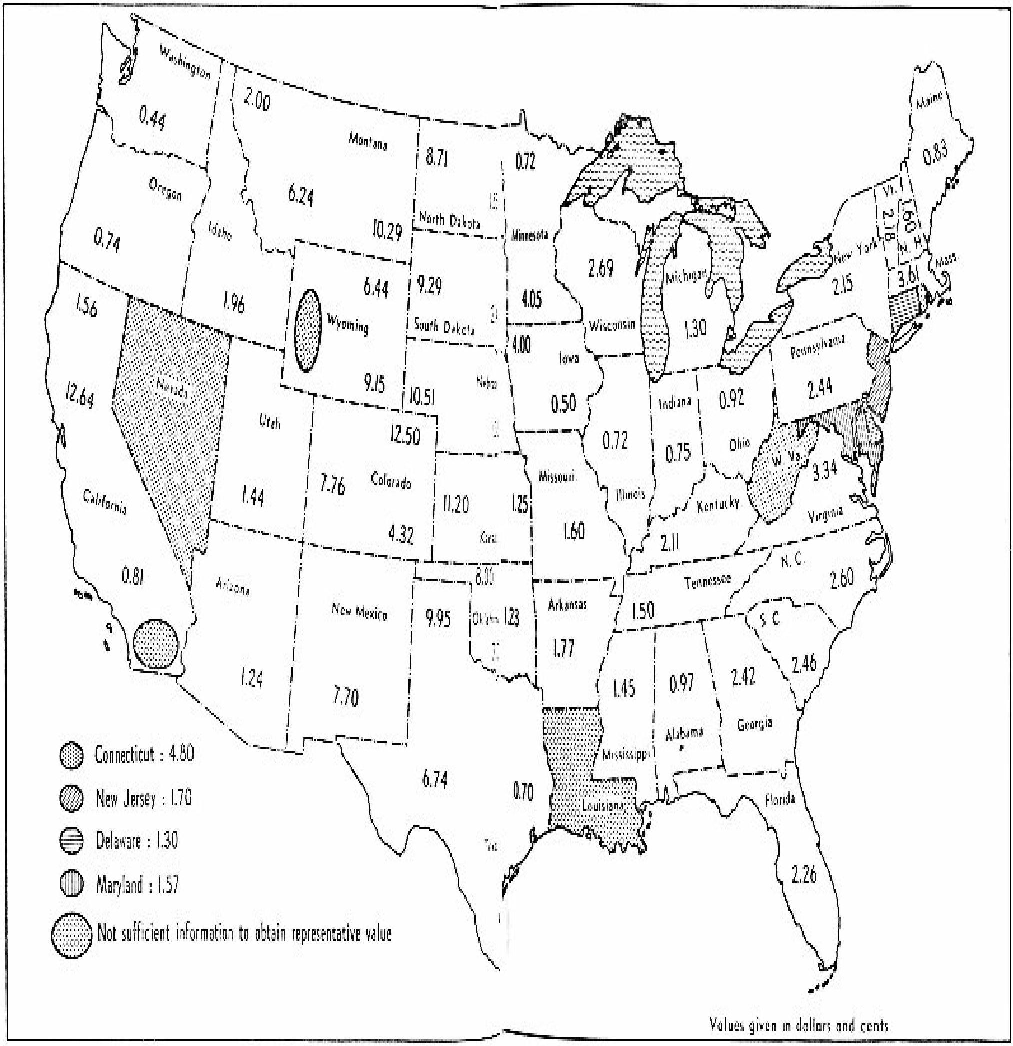


FIG. 7.—*The Risk of Hail Damage Over the United States. Values show the average loss ratio on each $100 of crop insurance written. In a state where hail risk varies greatly, two or more entries indicate this variation.* (*From data compiled by the Crop-Hail Insurance Actuarial Association, Chicago, Illinois.*)

A similar system of approximating the loss ratio with elevation is used in Oklahoma, Nebraska, South Dakota, North Dakota, Minnesota, and Iowa, as shown by the following tabulation:

Increase in Loss Ratio with Elevation

Elevation in feet	***Minn.***	***Iowa***	***North Dakota***	***South Dakota***	***Okla.***	***Nebr.***
1,000-1,500	$1.85	$1.15	$1.40	$1.30	$1.45	$1.45
1,500-2,000	——	——	1.05	1.10	1.70	1.15
2,000-2,500	——	——	1.95	1.20	1.30	0.90
2,500-3,000	——	——	2.00	1.40	1.80	1.40

According to Richard J. Roth, secretary of the Crop-Hail Insurance Actuarial Association, under whose supervision these rates were prepared, Texas also shows a similar increase of hail risk with elevation, but computations have not yet been made for that state because statistics for divisions smaller than counties were not begun until 1946. But it is expected that the accumulation of statistics will soon be sufficient to adapt the elevation rating for Texas also.

It is highly probable that hail risk shows a like increase with elevation in Eastern states having mountainous areas, but the amount of experience with insurance in those regions is not yet sufficient to prepare reliable tabulations.

The fact that a state has a high average loss ratio does not necessarily mean that its total hail losses are particularly high. Much depends on the amount and kind of crops produced and their value per acre. The tabulation below compares the five states bearing the highest average loss ratio (Figure 7) with the five states in which hail damage is greatest (Table II in Chapter

II).

Highest Average Loss Ratio	
Colorado	$9.61
Wyoming	8.27
New Mexico	7.70
California	6.08
Rhode Island	5.68
Greatest Average Hail Damage	
Montana	$5.09
Kansas	4.39
Nebraska	3.52
North Dakota	2.96
Iowa	1.74

Insurance rates on crops (except crops that are especially liable to hail damage) vary but little east of the High Plains, usually ranging from $1.50 to $4.00 per $100 of risk. West of a north-south line through the eastern area of North Dakota and extending into middle Texas, insurance rates increase rather rapidly toward the mountains. West of the Continental Divide, rates show a sharp decrease except in northwestern New Mexico and northern Arizona, where they remain comparatively high (Figure 7).

Certain other crops take a much higher insurance rate than cereals. In North Carolina, for instance, the cereal rate is not much above $3.00 but rates on tobacco range as high as $9.00.

Also in Massachusetts and Connecticut, cereal rates are about $2.50 but tobacco runs as high as $14.00 to $17.00, depending on the variety. Over most of California, rates on cereals are usually $1.50 to $2.00, but in Placer County, where fruit is grown extensively at high elevations, rates on such crops range as high as $5.00.

In regions of high risk, crop insurance is often written with a 10 per cent or a 20 per cent deductible clause which gives growers appreciably lower rates but does not give complete protection. A policy with a 10 per cent deductible clause carries a rate 25 per cent lower than one with full coverage. A policy with a 20 per cent deductible clause decreases the rate by 33⅓ per cent. In case of hail damage, such policies pay nothing for the first 10 per cent or the first 20 per cent of loss.

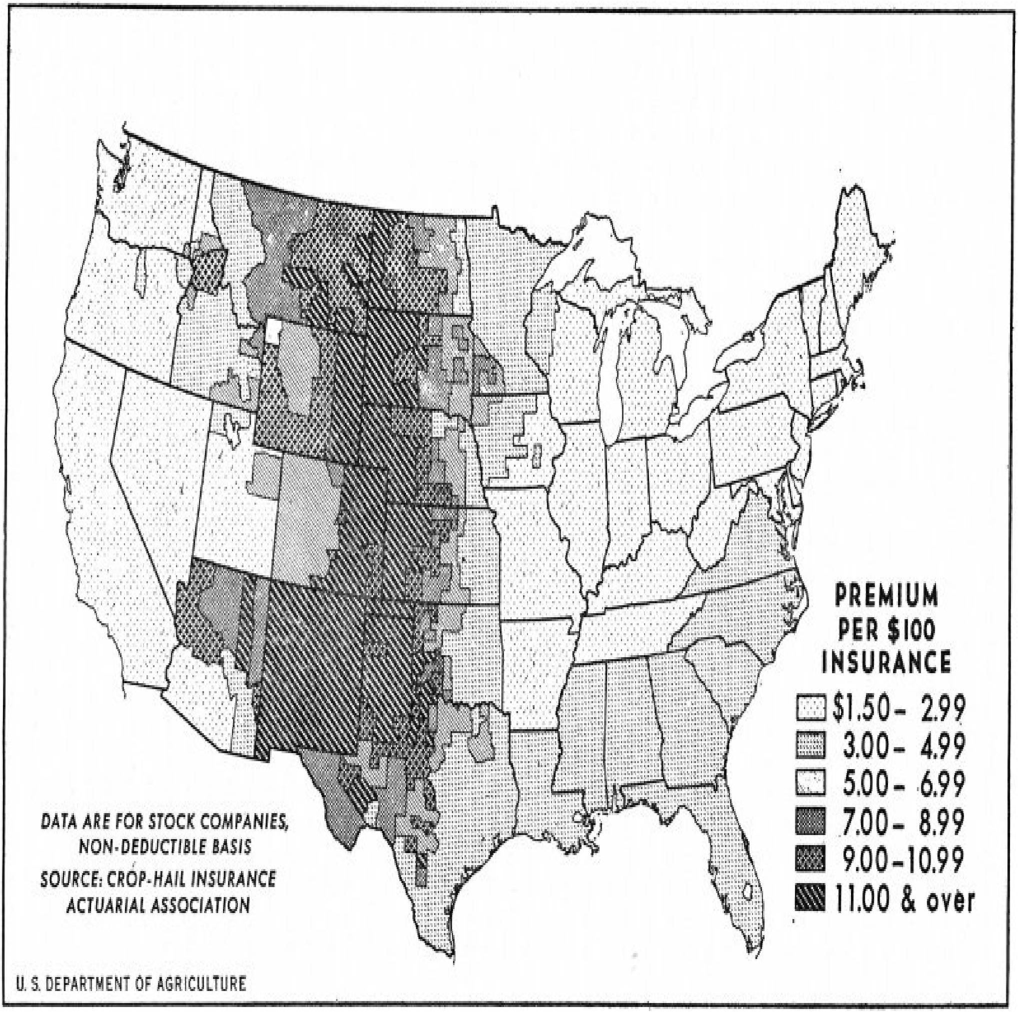


FIG. 8.—*Hail Insurance Rates for Small Grains in 1950.*

Recently, a new method of policy payment called Excess Over Loss Endorsement has been introduced. Instead of a deduction of 10 per cent or 20 per cent of the loss the farmer is allowed everything in excess of 10 per cent or 20 per cent. Decrease in the full coverage rate amounts to 33⅓ per cent for a 10 per cent deduction in risk and 50 per cent for a 20 per cent deduction. This is not the practice in most states, however. In some states the decreases are 20 per cent and 33⅓ per cent, respectively, from the full coverage rate. Policies with deductible clauses are common in areas of extreme hail risk. They are used almost exclusively in Colorado, New Mexico, and Wyoming, where rates are higher than in other sections of the country.

Rates for insurance on automobiles and buildings are much lower than for crop insurance. Buildings and automobiles are seldom, if ever, destroyed by hail, while crops may be a total loss over wide areas. Since hail damage to property other than crops is usually accompanied by wind damage and since it is almost impossible to ascertain just how much of the damage is from hail and how much from wind, no specific rate is fixed for hail risk, as in crop insurance. The insurance company pays the loss without consideration to wind or hail damage separately or to any other sources of damage that might be specified in the policy.

Insurance against hail damage to automobiles may be obtained under either of two coverages. One is the Comprehensive Coverage, which insures for any direct or accidental loss or damage from practically any source, with the exception of collision damage, which must be purchased separately. The other is the Extended Coverage, which insures against fire, theft, and other perils, including direct and accidental loss or damage from windstorms, hail, earthquakes, explosions, and external discharge of leakage or water. The rates for the second coverage vary according to states and regions.
This variation gives some index of the hail risk, since wind and hail are the chief perils named. The rates, as tabulated below, were furnished by the National Automobile Underwriters

Association, New York City:

States and Areas	*Rate of $100 of Insurance (in cents)*
Eastern states	5
Southern states (except Florida and Texas)	10
Florida	30
Texas	15
Midwest and mountain states	10
(except the following):	
Kansas	25
Oklahoma	25
Colorado	25
New Mexico	25
Wyoming	25
Far West and Pacific Coast states	10
(except the following):	
Arizona	20
Nevada	20
Utah	20

Rates for Extended Coverage on residences are about the same for any city or state, except where hurricane peril increases rates materially. There is a variation in rates for business buildings even in the same city, depending on the kind of building and to what use it is put. Modern fireproof structures carry the lowest rates because they are more or less immune to wind or hail damage. In a number of states where comparatively high rates for Extended Coverage prevail, insurance companies offer owners of residences the option of a $50 deductible clause, which permits a lower rate. Under this policy the owner is not paid for any loss of $50 or less. If the loss is more than $50 he is paid only the amount in excess. In some Eastern states subject to hurricane damage, a $50 or $100 deductible clause is mandatory.

In the tabulation below, Extended Coverage rates are those in effect April 1, 1956, and apply to residences only. They were obtained through the courtesy of the Western Actuarial Bureau, in Chicago, and the Inter-Regional Insurance Conference, New York City. These rates apply to coverage for one year only. To obtain the rate for a two-year coverage, multiply the rate given by 1¾; for a three-year coverage, multiply by 2½; for a five year coverage, multiply by 4.

State		***Extended Coverage Rates per $100 of Risk***	
California	$0.04		
Colorado			
Western slope	.12		
Eastern slope	.26		
Connecticut	.18	($50 deductible)	
Florida	(All Florida rates quoted provide for $100 deductible)		
		At 50 per cent of risk	80 per cent of risk

zone 1	Seacoast,		$0.70	$0.504
zone 2	Seacoast,		.47	.338
zone 3	Seacoast,		.31	.223
	Inland	.19	.137	
Georgia				
	Beach	.30	($50 deductible)	
	Seacoast	.20	($50 deductible)	
	Inland	.10	($50 deductible)	
Illinois		.14		
Indiana		.16		
Iowa		.18		
Kansas		.48		
		.34	($50 deductible)	
Kentucky		.13		
Louisiana				
	Seacoast	.23	($50 deductible)	
	Inland	.13	($50 deductible)	
Maine		.17		
Massachusetts		.30	($50 deductible)	
Michigan		.10		
Minnesota		.24		
		.16	($50 deductible)	
Missouri		.22		
		.16	($50 deductible)	

Nebraska	.32	
	.20	($50 deductible)
New Mexico	.18	
New York	.20	
	.08	($50 deductible)
North Dakota	.22	
	.16	($50 deductible)
Ohio	.10	
Oklahoma	.46	
	.34	($50 deductible)
Rhode Island	.30	
South Dakota	.32	
	.22	($50 deductible)
Tennessee	.14	
Wisconsin	.10	
Wyoming	.14	

VI. The Hail Hazard by States

Since 1944 the United States Weather Bureau has been able to obtain fairly comprehensive data on the occurrence of hail and hail damage as reported from each state. The averages used in this book are for the ten-year period ending in 1953. Records prior to that period are not sufficient to give an accurate representation of the hail hazard. Particular details of the more damaging storms in each state are given, together with a tabulation of the most severe hailstorms in its record.

The hail risk in each state, according to the average loss ratio and the average insurance rate for crops, is computed from the experience of insurance companies over periods of twenty to thirty years. This information comes from compilations of the Crop-Hail Insurance Actuarial Association, of Chicago, which acts as a clearing house for data from insurance companies over the nation. Damage figures for individual storms were estimated by Weather Bureau officials in practically every instance, and the information used was from the most authentic sources available at the time. It has never been possible for the Bureau to make ground surveys of actual hail damage.

ALABAMA

Hail risk in Alabama is one of the lowest prevailing anywhere in the country, but there have been a few heavy losses from individual storms. In the 1944-53 period sixteen hailstorms of varying intensity were reported, and four of them were severe (Table IV in Chapter III). Hail damage during that period amounted to $2,881,250. This is greater than the losses in either of the adjoining states, Georgia or Mississippi.

The experience of hail insurance companies over a twenty-nine-year period in Alabama indicates a loss ratio of $0.97. This is the insurance company's loss on each one hundred dollars of insurance written. The ratio is much lower than that of most states. The average rate for crop insurance is $2.29 per hundred dollars (Table VI in Chapter V). Seventy per cent of losses to insured crops has been to cotton and 24 per cent to tobacco.

Most of Alabama's severe hail losses have been in the northern counties. The greatest loss from a single storm was $1,500,000 on April 16, 1946. Nearly all of this damage, extending from Madison County to Calhoun County, was to property other than crops. The next greatest hail loss was $550,000 on May 14, 1950, between Ethelsville and Peterson. Of this amount $500,000 involved damage to crops. Hailstones were the size of ice cubes in the vicinity of Reform, where the heaviest damage occurred.

Three hailstorms struck within an hour of each other on the afternoon of February 25, 1950, with losses totalling $43,000. The first one occurred at 4:00 P.M. in the southeastern part of Tuscaloosa County and covered an area of three hundred square miles. The damage, mostly to fruit trees, shrubbery, and roofs, amounted to $10,000. The second storm was at Talladega Springs, Talladega County. Hailstones as large as marbles drifted several inches deep in low places. Damage was estimated at $3,000. The final storm of the day extended from Clanton, Chilton County, to the vicinity of Montgomery. Hail was heavy at Marbury and Verbena, with stones as large as an inch in diameter. Losses, amounting to $30,000, was mainly from damage to roofs, gardens, and windows. Ice on the pavement slowed highway traffic between Montgomery and Birmingham for an hour.

Some Especially Damaging Alabama Hailstorms

Location	***Date***	***Estimated Damage***
Clanton, Chilton County, to Montgomery	Feb. 25, 1950	$ 30,000
Pickens and Tuscaloosa counties	May 14, 1950	550,000
Huntsville to Plevna, Madison County	Aug. 6, 1947	100,000
Madison County to Calhoun County	April 7, 1946	1,500,000
Birmingham (near)	April 25, 1932	[a]
Pickens and adjacent counties	May 22, 1928	300,000
Birmingham (near)	May 11, 1921	[a]
Washington County	April 8, 1920	[a]

[a] Severe but damage not estimated.

ARIZONA

Although the risk of hail over Arizona is fairly high, aggregate losses from hail damage have been comparatively small because the state is sparsely settled and because so much of the land is unproductive. Out of twenty-nine hailstorms reported in the state, five were severe (Table IV in Chapter III). Losses over the reported ten-year period amounted to $1,787,350. Many heavy hailstorms probably strike in thinly settled areas but are not reported because there are so few crops or buildings to suffer damage. Most of Arizona's hail falls in July, August, and September.

Insurance experience over a twenty-six-year period gives Arizona an average loss ratio of $1.24 and an average insurance rate of $2.96, both of which are higher than the corresponding values for such states as Indiana, Ohio, and Alabama, and not much below those of Iowa (Table VI in Chapter V). Damage to cotton constitutes more than 90 per cent of losses to insured crops.

As might be expected, most of the reported severe hailstorms have been in Maricopa County, where Phoenix is located. Here the population is dense, and irrigation produces valuable crops on small acreages. On September 18, 1950, shortly after noon a violent thunderstorm with high winds struck the Phoenix area. Hail damage amounted to $680,000. The path of heavy hail extended from Eleventh Street and Buchanan Road to Forty-eighth Street and Indian School Road. The ground was covered to a depth of two inches with hailstones as large as three inches in diameter. There was extensive damage to aircraft at Sky Harbor Airport, where twenty-two planes were demolished and as many more damaged by the hail and wind. Thirteen people were hospitalized.

On April 11, 1952, hail losses near Litchfield Park in Maricopa County totaled $400,000. The storm path began four miles north of Luke Air Force Base and extended northward. Hailstones averaging one-half inch in diameter destroyed 560 acres of lettuce ready for harvest and 1,550 acres of cotton. Chandler, also in Maricopa County, suffered hail damage amounting to $157,000 on September 21, 1952. In this storm some of the hailstones were as large as golf balls. Many composition roofs were heavily damaged.

In the Path of Destruction

Thirty seconds of flight through a hailstorm did this to a

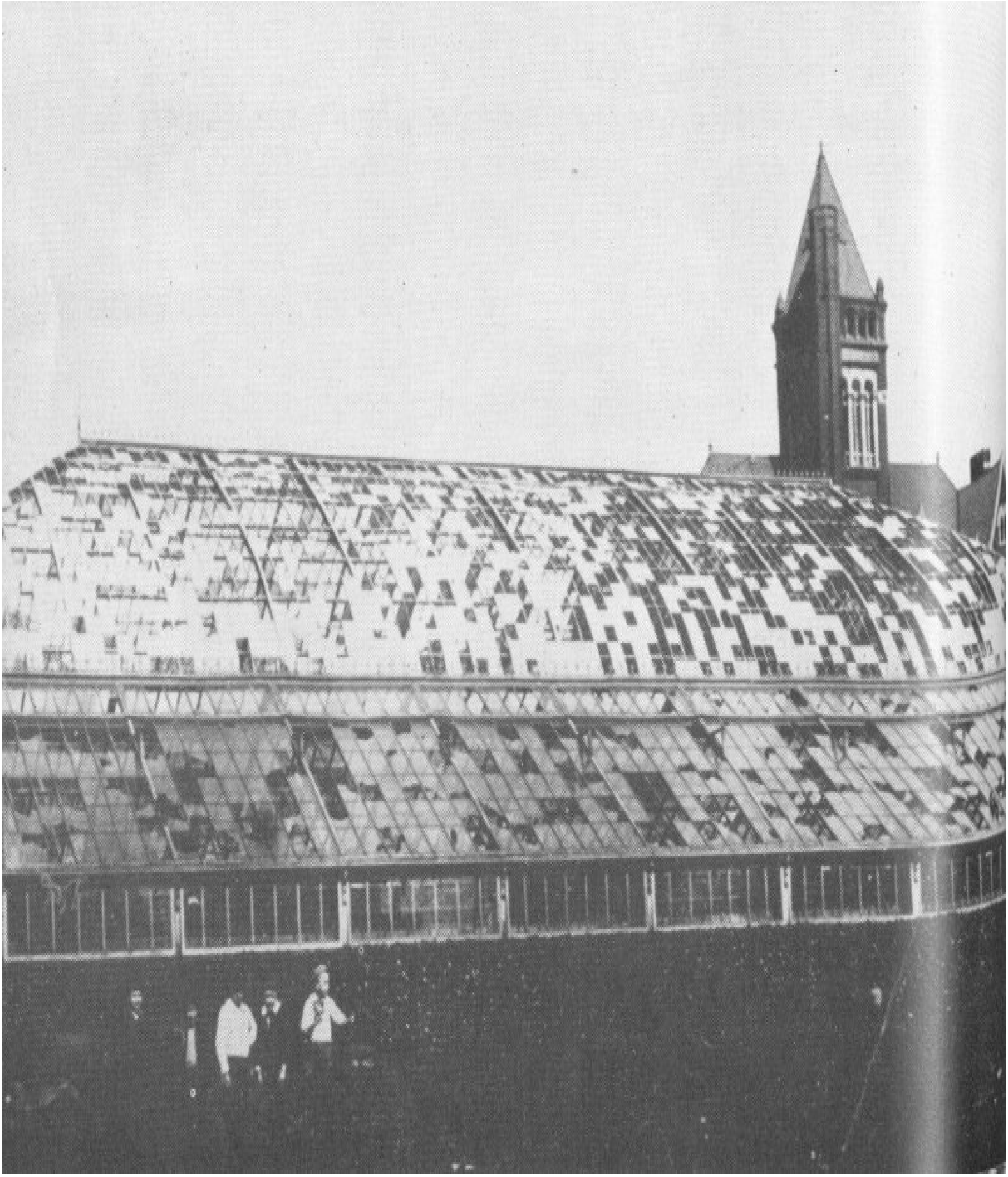
DC-6. The shattered windshield was replaced before this picture was taken. From *Technical Note 2734,* National Advisory Committee for Aeronautics.

What hail can do to an automobile. This storm at Weatherford, Oklahoma, July 1, 1940, caused damage amounting to $300,000. Courtesy U. S. Weather Bureau and the Oklahoma Publishing Company.

Windows after an Oklahoma hailstorm. This storm

occurred near Moore, Oklahoma, April 28, 1956.
Courtesy Bea Bragg, Norman Transcript.

What hail can do to a shingle roof. Near Weatherford, *Oklahoma, July 1, 1940.* Courtesy U. S. Weather Bureau and the Oklahoma Publishing Company.



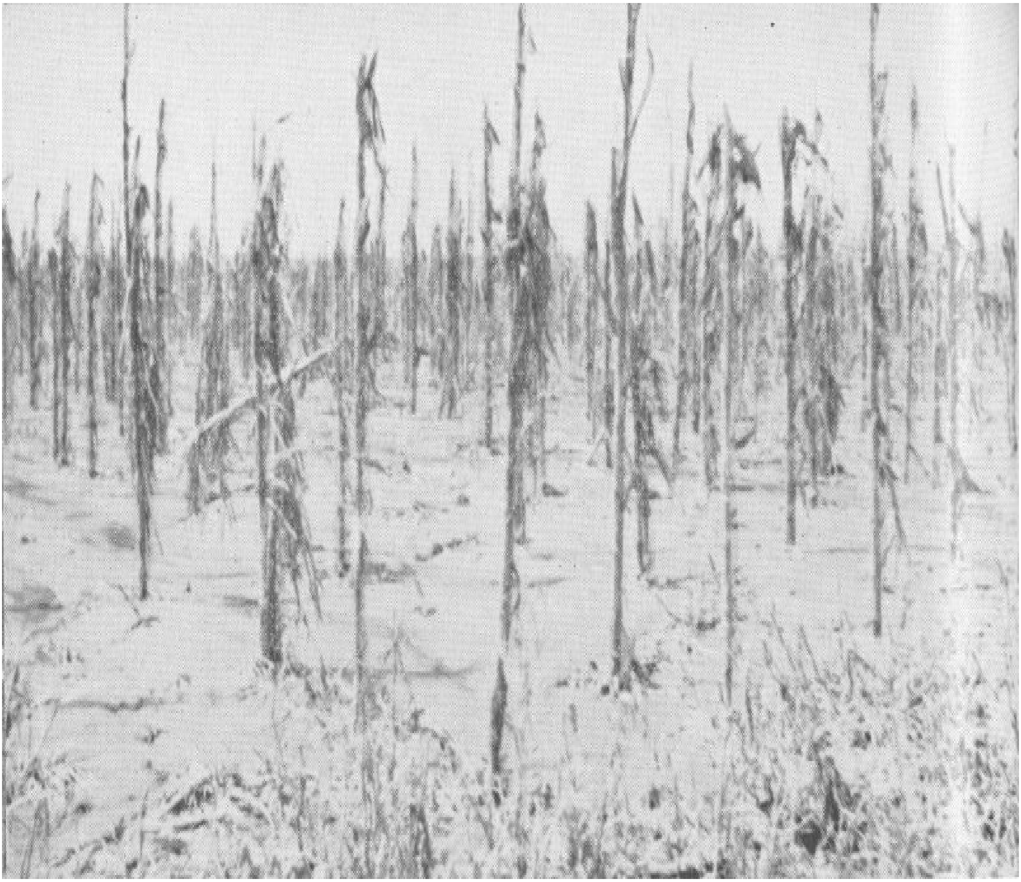
What hail does to a greenhouse. Allegheny Conservatory, Pittsburgh, Pennsylvania, May 20, 1893. Courtesy U. S.

Weather Bureau.

Hail ruined this fine field of cantaloupes near Lecompton, Kansas, July 23, 1937. With vines and leaves completely destroyed, the melons could not mature. Courtesy U. S. Weather Bureau.

Hail damage to an irrigated farm near Pueblo, Colorado, *August 21, 1941*. Courtesy U. S. Weather Bureau.

Total loss of a promising potato crop, from a hailstorm northeast of Greeley, Colorado, July 13, 1927. A yield of *three hundred bushels to the acre was expected from this irrigation project.* Courtesy J. L. Williams.



Remains of a promising corn crop in Marshall County, Kansas, after a hailstorm on July 23, 1944. The storm swept three paths of destruction through one of the important corn-producing areas of Kansas. Courtesy Byron E. Guise.

What hail did to a luxuriant pine forest in Pickens County, Alabama, May 22, 1928. These trees were ruined because it was too late in the season for new leaves to form.

Some Especially Damaging Arizona Hailstorms

Location	***Date***	***Estimated Damage***
Litchfield Park (near), Maricopa County	April 11, 1952	$400,000
Chandler, Maricopa County	Sept. 21, 1952	157,000
Elfrida, Cochise County	July 27, 1951	25,000
Eloy, Pinal County	Aug. 11, 1950	60,000
Phoenix, Maricopa County	Sept. 18, 1950	680,000
Buckeye, Maricopa County	Aug. 13, 1939	85,000
Ganado to Fort Defiance, Apache County	July 28, 1931	275,000

ARKANSAS

Hail losses in Arkansas have been much higher than in states immediately to the east but much less than in Oklahoma, to the west. Sixty-three hailstorms were reported in Arkansas during the 1944-53 period, thirteen of which were classed as severe (Table IV in Chapter III). Damages totaled $3,811,700 (Table II in Chapter II). More than half of the hailstorms in Arkansas occur in March, April, and May, and the greatest frequency is from 1:00 P.M. to 8:00 P.M. (Tables III and IV in Chapter III).

Hail risk over the state is not particularly high. The loss ratio has averaged $1.77, which is only about half the risk in Oklahoma. The average rate for crop insurance for the state as a whole is $3.73. Hempstead, Howard, and Sevier counties, in the southeastern part of the state, are the areas of greatest risk, while the least risk apparent is in Clay and Mississippi counties, in the extreme northeastern part. Sixty-five per cent of losses to insured crops involves tree fruits and 13 per cent, cotton.

The most damaging hailstorm in the state's record was on April 8, 1948, with a loss of $1,100,000 in Union, Ouachita, Calhoun, and Bradley counties. At El Dorado, four thousand homes and one thousand automobiles were damaged. Hail losses amounting to $100,000 were reported at Johnsville, Smackover, and Stephens. Large numbers of chickens and other poultry were killed, but crop damage was negligible. The next most damaging hailstorm occurred at Eureka Springs, shortly after midnight on May 20, 1938, when buildings, automobiles, crops and other property were damaged to the extent of $600,000. The crop loss amounted to $100,000.

In Mississippi County on March 3, 1952, another hailstorm involved a loss of $300,000. It damaged roofs and windows at Manila and destroyed nearly a thousand tons of fertilizer at Blytheville Airport, where a warehouse roof was so battered that rain flooded the contents of the building. On May 9, 1952, a hailstorm at De Queen, Sevier County, in the southwest part of the state, caused a loss of $307,500 in damage to buildings, automobiles, field crops, gardens, and berries. Six months later to a day, on December 9, 1952, a storm moving in from the southwest struck Lepanto, Poinsett County. Hailstones weighing five and one-half ounces were reported. The most severe damage was to school buildings, where a total of 226 window panes was broken. Crops, of course, had already been harvested. Damage was estimated at $100,000.

Some Especially Damaging Arkansas Hailstorms

Location	***Date***	***Estimated Damage***
Pope County	March 3, 1952	$ 100,000
Mississippi County	March 3, 1952	300,000
De Queen, Sevier County	May 9, 1952	307,500
Lepanto, Poinsett County	Dec. 9, 1952	100,000
Pope County to White County	April 6, 1951	350,000
Union County to Bradley County	April 8, 1948	1,100,000
Eureka Springs	May 29, 1938	600,000
Scott County to Jefferson County	April 26, 1933	100,000
Miller County	June 24, 1926	100,000
Washington County	May 28, 1924	100,000

CALIFORNIA

Along the coast, approximately 85 per cent of the hail occurs during the rainy season, November to March. Mostly soft hail or graupel, it causes little damage. The area of damaging hail is in the fruit growing districts east and north of Sacramento, where ground elevation is between one thousand and three thousand feet. In this area 70 to 77 per cent of the hail falls between February and May. This is true also at Fresno, in the San Joaquin Valley. Fresno has reported four severe hailstorms in the twenty-nine years ending in 1953, but damage was estimated for only one of them. Ninety-seven per cent of all hail losses in the state involves tree fruits, which are highly susceptible to hail damage, even from hailstones of comparatively small size.

In the 1944-53 period, California reported six hailstorms, four of which were severe. Hail damage for the ten-year period totaled $3,918,600. Most of this occurred in El Dorado, Placer, and Sutter counties. In this area the loss ratio ranges from $8.17 to $12.64, which almost equals the hail risk in the High Plains east of the Rockies.

The greatest hail loss ever reported in California occurred in 1944, when two storms struck so close together, one on April 8, the other on April 19, that only their combined damage was ascertained. This amounted to $2,000,000. The two storms occurred in the Sacramento Valley and in the foothill district of the Sierra Nevada Mountains. Practically all the damage was to the fruit crop. The next greatest loss was $1,000,000 on April 28, 1951, from Placer County to Amador County and along the San Joaquin Valley. Again in Placer County, on April 29, 1953, in the Auburn, Bowman, Newcastle, Ophir, and Mt. Vernon districts, losses from hail totaled $750,000.

The hail marked pears, plums, cherries, and peaches to the extent that growers were required to thin fruit again, and special care had to be taken in sorting the fruit at the packing houses. The heaviest damage was over an area of five square miles but comparatively light over another area of equal size.

On September 21, 1916, in the district around Monterey Bay, a freak hail and thunderstorm occurred in which hailstones two and one-half inches in diameter were reported. Hailstones of this size are very rare in California.

Some Especially Damaging California Hailstorms

Location	***Date***	***Estimated Damage***
Placer County	April 29, 1953	$ 750,000
Placer County to Amador County	April 28-29, 1951	1,000,000
Fresno	April 8, 1950	[a]
Sacramento Valley	April 8,19, 1944	2,000,000
Fresno	June 14, 1937	32,000
Red Bluff	May 31, 1927	100,000
Fresno	April 8, 1926	[a]
Sutter County	May 7, 1926	300,000
Fresno	May 19, 1925	[a]

[a] Severe but damage not estimated.

COLORADO

Colorado has the highest hail risk in the country. Over a period of twenty-two years, the loss ratio has averaged $9.61 and the average insurance rate is $15.14, both computed for full coverage. These are higher than the corresponding values for any other state (Table VI in Chapter V). Consequently, practically all crop insurance in Colorado is written with a 10 or 20 per cent deductible clause, which gives a lower rate but not complete protection, since the grower must bear a portion of the loss.

In the ten years ending with 1953, Colorado reported 153 hailstorms, of which 32 were severe (Table IV in Chapter III). Most of them occurred between 1:00 P.M. and 7:00 P.M. Total damage over that period amounted to $31,152,976, the eighth largest hail loss in the nation (Table II in Chapter II).

Damage to wheat makes up 95 per cent of losses to insured crops in Colorado. Fewer losses occur in the northwestern counties, largely because crop acreage is scattered in that section. Severe hail falls in the mountains of Colorado but there is little or nothing to damage. Heavy losses have been reported in the irrigated sections west of the Rockies but most of the state’s hail damage occurs east of the Continental Divide. The tabulation below indicates the extreme hail risk in the northeastern counties of Colorado:

County	*Loss Ratio*	*Average Insurance Rate* [a]
Logan	$16.22	$20.05
Phillips	16.44	20.09

Sedgwick	10.76	18.77
Weld	13.26	17.50

[a] In determining rates, insurance companies consider the loss ratio over a long period of years with special weight to recent experience. If losses have been especially heavy in recent years, rates are raised but not to exceed 25 per cent in any one year. This accounts for apparent discrepancies between loss ratio and rates as shown above.

Nine Colorado hailstorms in thirty-nine years have caused losses of a million dollars or more each. Many others have resulted in losses well over a hundred thousand dollars each. Several of these storms struck large cities and irrigated sections, where crop value per acre runs high. Denver has reported seven severe hailstorms in a twenty-one-year period and Pueblo four in sixteen years. If records had been kept as carefully in other places as in these two cities, where Weather Bureau officials are on duty full time, many more storms in Colorado would probably have been added to the record—and to the state's already heavy losses.

One of the most destructive hailstorms in the state devastated a rich agricultural section from the eastern part of Morgan County to Washington County on August 7, 1922. On the following day, hail reached southwestern Weld County and northwestern Adams County, covering an area of approximately 680 square miles. Crop losses totaled $2,000,000. Chief crops affected were wheat and truck crops such as beans, corn, and sugar beets. In Washington County, near the hamlet of Pinneo, this storm struck a passenger train.

Large jagged pieces of ice, blown by a sixty-mile an hour wind, broke all windows on the exposed side of the train. Several passengers were injured by flying glass and bruised by the hailstones. The coaches were so severely damaged that it was necessary to furnish another train to take the passengers to their destinations.

On the late afternoon of May 30, 1948, a hailstorm hit Denver and the surrounding area, resulting in a loss of $3,800,000. There was heavy damage to automobiles and buildings in and near Aurora and Adams City. In the Welby district, crops were almost completely destroyed. Another Denver hailstorm on August 26, 1944, caused damage amounting to $1,000,000. Trees and vegetable crops were shredded. Heavy damage was sustained in the city. In greenhouses the glass broken amounted to twenty carloads.

On September 4, 1951, a hailstorm just north of the famed summer resort of Colorado Springs caused a loss of $1,150,000 over an area ten by twenty miles. Some of the hailstones were from one and one-half inches to almost three inches in diameter. Major damage was to roofs, windows, greenhouses, and automobiles. The storm, extending as far as Peterson Field, was highly destructive to such crops as beans, sorghums, and winter wheat.

Some Especially Damaging Colorado Hailstorms

Location	***Date***	***Estimated Damage***
Denver and vicinity	July 27, 1954	$1,000,000
Denver and vicinity	May 27,	120,000

	1953	
Sedgwick (near), Sedgwick County	June 30, 1953	101,000
Washington County to Yuma County	May 31, 1952	100,000
Northeast part of Colorado	June 26, 1952	2,060,000
Colorado Springs	Sept. 4, 1951	1,150,000
Denver	June 16, 1950	750,000
Greeley and vicinity, Weld County	June 18, 1950	200,000
Weld County	July 23, 1950	300,000
Pueblo	July 25, 1950	651,000
Colorado Springs to Fowler area	Sept. 15, 1950	350,000
Denver and vicinity	May 30, 1948	3,800,000
Portland and vicinity, Fremont County	May 30, 1948	490,000
Logan County	June 15, 1948	1,100,000
Strasburg, Arapahoe County	June 18, 1948	100,000
Holyoke, Phillips County	June 25, 1948	100,000

Canon City	July 14, 1948	100,000
Trinidad	July 14, 1948	250,000
Watkins, Adams County	July 15, 1948	400,000
Pueblo	July 22, 1948	130,000
Florence and Penrose, Fremont County	Aug. 13, 1948	450,000
Bent County	Sept. 6, 1948	750,000
Fleming and Holyoke, Phillips County	June 29, 1947	2,000,000
Holyoke and vicinity, Phillips County	July 14, 1947	120,000
Mesa County	May 10, 1946	1,000,000
Las Animas County	June 30, 1946	100,000
Avondale and vicinity, Pueblo County	June 30, 1946	100,000
Vineland, Pueblo County	June 30, 1946	600,000
La Junta and vicinity	June 30, 1946	100,000
Rocky Ford	June 30, 1946	100,000
Del Norte, Rio Grande County	July 8,	500,000

	1946	
Lamar and vicinity	June 24, 1945	100,000
Denver and vicinity	Aug. 26, 1944	1,000,000
Sterling, Logan County	May 13, 1942	600,000
Pueblo and vicinity	July 2, 1941	155,000
Ft. Collins and vicinity	July 10, 1941	102,500
Alamosa, Alamosa County	Aug. 11, 1941	500,000
Pueblo	Aug. 18, 1941	50,000
Sugar City, Crowley County	Aug. 20, 1941	50,000
Pueblo	Aug. 21, 1941	51,000
Pueblo and vicinity	June 17, 1938	[a]
Trinidad	June 14, 1937	[a]
Rocky Ford and vicinity	Aug. 22, 1933	275,000
Denver and Weld County	Aug. 16, 1933	150,000
Florence, Fremont County	Sept. 6, 1930	250,000

Fountain, El Paso County	June 5, 1929	250,000
Fleming, Logan County	June 23, 1929	300,000
Limon and vicinity	June 1, 1927	350,000
Denver	June 2, 1927	500,000
Weld County	July 13, 1927	1,000,000
Fowler and vicinity, Otero County	June 17, 1926	200,000
Weld, Adams, Morgan, and Washington counties	Aug. 7-8, 1922	2,000,000
Pueblo	June 24, 1897	[a]

[a] Severe but damage not estimated.

CONNECTICUT

Since Connecticut is one of the leading states in the production of tobacco, which is especially susceptible to hail damage, the hail risk is higher here than in almost any other state east of the Mississippi River. Damage to tobacco comprises 98 per cent of all hail losses on insured crops in the state. The loss ratio for hail insurance averaged $4.80 over the seventeen years ending with 1953. This is higher than that of any other

Eastern state except Rhode Island and West Virginia. Rates on crops other than tobacco are much lower. The average rate for full coverage of crops is $12.94, which exceeds that of any other state except Colorado (Table VI in Chapter V). Consequently, most crop insurance in Connecticut is written with a 10 or 20 per cent deductible clause.

Because most hailstorms extend from the small area of Connecticut into other New England states, the Weather Bureau has included Connecticut in the losses for all of New England, with no computation for the state alone. New England's losses on insured crops for the seventeen-year period have amounted to $1,082,577. This is only a fraction of the total losses.

Some Especially Damaging Connecticut Hailstorms

Location	***Date***	***Estimated Damage***
Hartford and parts of Rhode Island	July 17, 1951	$ 200,000
Connecticut Valley	July 20, 1949	[a]
Hartford and vicinity	June 8, 1946	600,000
Scattered areas	Aug. 16, 1930	1,500,000
Hartford and vicinity	Aug. 1, 1929	1,000,000
North-central area	Aug. 5, 1927	365,000
Hartford County	Aug. 31, 1920	2,000,000

[a] Severe but damage not estimated.

DELAWARE

No heavily damaging hailstorms have been reported from Delaware. The experience of insurance companies over a seventeen-year period indicates a very low hail risk for the state. The average loss ratio is $1.30, well below the average for the country. Hail losses to insured crops in seventeen years have totaled only $15,972, ninety-five per cent of which involved damage to apples and peaches.

DISTRICT OF COLUMBIA

Two severe hailstorms have been reported in the District of Columbia, an area less than ten miles square. The first one occurred in the District and adjacent parts of Maryland on April 29, 1938. Some hailstones were reported to be three inches in diameter. Damage was principally to greenhouses, skylights, and automobiles. In Seaford and Bridgeville, in the Georgetown area, there was heavy loss to trees, strawberries, and asparagus. Total loss was set at $100,000.

The second storm, on May 26, 1953, was more severe. It moved at a speed of forty miles an hour from the northwest across the District and back into Maryland in the vicinity of Suitland. Its path was three miles wide and fifteen miles long.

It struck the southeastern part of Washington, D. C. The hailstones ranged in size from that of golf balls to baseballs. One of the larger stones, which undoubtedly had melted somewhat, was found by the Weather Bureau to have a maximum diameter of four and one-eighth inches and weighed approximately seven ounces. Many of the hailstones measured as much as three inches in diameter. Official records listed four people injured. Undoubtedly, other accidents occurred but were not reported. Hundreds of windows were broken and many roofs badly damaged. Automobiles had their bodies dented and windshields shattered. The damage loss was estimated at $200,000.

Some Especially Damaging Hailstorms in the District of Columbia

Location	***Date***	***Estimated Damage***
Washington, D. C. and vicinity	May 26, 1953	$208,500
Washington, D. C. and vicinity	April 29, 1938	100,000

FLORIDA

From 1944 to 1953, Florida reported thirty-seven hailstorms, of which four were severe. More than half of them occurred in May and June, and the hours of greatest frequency were from 2:00 P.M. to 6:00 P.M. (Tables III and IV in Chapter III). The hail damage for that period totaled $2,521,150, according to reports collected by the Weather Bureau. This is almost a third greater than the hail damage in Georgia over the same period.

Experience of insurance companies over a thirty-year period gives Florida an average loss ratio of $2.26. The hail risk seems to be fairly uniform over the state except in Monroe County, in the southern tip, where the loss ratio average is $6.96. Tobacco incurs 90 per cent of all losses to insured crops, and damage to vineyards comprises 8 per cent.

In the twenty-nine years ending with 1953, Florida has had two hailstorms, each of which resulted in losses of $1,000,000 or more. Seven other storms have caused damages amounting to $100,000 or more each. Hailstorms have occurred all the way from Miami, near the southern tip of the state, to Panama City, near the northwestern edge.

The most destructive Florida storm on record struck in and near Panama City on March 21, 1950, with a loss of $2,000,000. At the Tyndall Air Force Base, hailstones up to two and a half inches in diameter ripped through airplane wings, smashed glass, and damaged automobiles. Several people suffered slight injuries. A million-dollar hail loss occurred in Polk County, near the central part of the state, on April 3, 1941. The chief damage was to citrus crops near Waverly, Lake Wales, Lake Alfred, and Winter Haven. On April 5, 1925, the Miami area was damaged by hail to the extent of $300,000, over a storm path twelve miles long. Thirty-five people were injured.

Some Especially Damaging Florida Hailstorms

Location	Date	Estimated Damage
Panama City	Mar. 21, 1950	$2,000,000
Gadsden County	May 17, 1950	100,000
Gadsden County	May 6, 1949	150,000
Volusia County	May 22, 1944	125,000
Polk County	April 3, 1941	1,000,000
Volusia County and Flagler County	May 15, 1939	100,000
Goulds and Perrine and vicinities	April 15, 1931	100,000
Miami (near)	April 5, 1925	300,000
Leon and Gadsden counties	June 18, 1913	250,000

GEORGIA

During the 1944-53 decade Georgia reported thirty-nine hailstorms, eight of which were severe. Almost all of them occurred in April, May, or June and between the hours of 2:00 P.M. and 6:00 P.M. (Tables III and IV in Chapter III). Hail damage for the ten years totaled $1,894,656, which is less than that of adjacent states. No Georgia hailstorm on record has resulted in damage amounting to more than a quarter of a million dollars. The average loss ratio for the state is only $2.42 and the crop-hail insurance rate is $4.21. Hail risk seems to be somewhat higher in the southern part of the state than it is in the northern areas. Eighty per cent of losses to insured crops has been to tobacco and 17 per cent to cotton.

The greatest hail loss ever reported in any one day in the state was from two storms on May 17, 1950, one in Thomas County and the other in Ware County, both in the southern part of the state. In Thomas County, scattered hail covered an area of two hundred square miles, with heaviest damage between Boston and Coolidge. Fields of cotton, corn, tobacco, watermelons, and other crops were destroyed, with losses totaling $200,000. In Ware County, crops sustained heavy damage. Tobacco, standing waist high in the fields, was stripped and slashed to the ground. Losses from this storm amounted to $150,000.

One of the heaviest urban losses reported in Georgia was at Athens, in Clarke County, on April 18, 1948. Hailstones two inches in diameter fell over an area of about twenty square miles. Window panes and plate glass were shattered, roofs and automobiles damaged. Loss for the peach crop alone was estimated at $50,000, with total losses amounting to $250,000.

Another double onslaught of hailstorms struck Elbert and Jackson counties on July 8, 1947, causing one of the greatest losses ever known in that vicinity. One storm hit in the eastern part of Elbert County about 3:00 P.M. and the other in northeastern Jackson County between 8:00 P.M. and 9:00 P.M. Large areas of cotton, corn, vegetables, and fruit were beaten down. Ten children were injured by hailstones up to an inch in diameter. Total damage amounted to $100,000. On May 3, 1952, a storm covering an area of forty square miles swept a path of destruction between Americus and New Era in Sumter County, almost totally destroying crops over an area of thirty-six hundred acres. Damage was estimated at $125,000.

Some Especially Damaging Georgia Hailstorms

Location	***Date***	***Estimated Damage***
Americus (near)	May 3, 1952	$125,000
Cook County	May 4, 1951	100,000
Thomas County	May 17, 1950	200,000
Ware County	May 17, 1950	150,000
Tattnall County	May 20, 1950	250,000
Athens and vicinity	April 18, 1948	250,000
Jackson and Banks counties	May 2, 1948	100,000
Coffee County to Wayne County	May 14, 1939	50,000
Colquitt County	June 21, 1930	250,000
Central area of the state	June 25, 1930	100,000

IDAHO

In the ten-year period ending with 1953, Idaho reported six severe hailstorms out of a total of twenty-three. Losses for the period amounted to $1,073,700. The time of greatest frequency for hailstorms in Idaho is in the late afternoon in the months of June, July, and August (Tables III and IV in Chapter III). The hail risk is not particularly high. Over a period of twenty-six years the loss ratio has averaged only $1.96, much less than that of Wyoming and Montana (Table VI). Seventy per cent of losses to insured crops has been to wheat and 12 per cent to peas and beans. Idaho is famous for its potatoes, but hail damage to that crop has been very small.

One of the state’s most destructive hailstorms involved a loss of only $200,000. It moved up the Payette Valley on June 1, 1947, in a path two miles wide and eight miles long. Hailstones as large as golf balls were reported. Damage was mainly to fruit, alfalfa, and some row crops.

Some Especially Damaging Idaho Hailstorms

Location	***Date***	***Estimated Damage***
Bannock County	July 31, 1952	$140,500
Jefferson County	Aug. 5, 1951	126,200
Fremont County	Aug. 6, 1951	60,000
Nezperce area	June 15, 1950	100,000

Payette County	June 1, 1947	200,000
Power County	July 17, 1945	90,000
Idaho County	Aug. 16, 1941	50,000
Cassia and Twin Falls counties	July 4, 1938	200,000
Grangeville area, Idaho County	July 25, 1937	110,000

ILLINOIS

The actual risk of hail in Illinois is low, but density of population and heavy crop yield, especially corn, make the state particularly vulnerable to almost any hailstorm that strikes.

From 1944 to 1953, Illinois had forty-five hailstorms and fifteen of them caused extensive damage. More than a third of these storms struck in August, when corn is ordinarily approaching maturity (Table IV in Chapter III). Hail losses for the period totaled $10,226,120, placing Illinois tenth in extent of hail damage in the United States (Table II in Chapter II). But for a twenty-nine-year period the average loss ratio is only $0.72, one of the lowest in the country. The rate for crop insurance averages $1.72 (Table VI in Chapter V). Damage to corn comprises 29 per cent of losses to insured crops, and soybean losses make up 13 per cent.

During the twenty-nine years ending with 1953, twenty-four

Illinois hailstorms have resulted in losses of $100,000 or more each. Nine have caused losses ranging between half a million and a million dollars each, and storms on five separate occasions have resulted in damages of a million dollars or more. The day of worst hail damage in the state's record was August 17, 1948, when three hailstorms caused losses totaling $4,000,000 in Whiteside, La Salle, and Lee counties.

The Whiteside storm, with a damage of $2,000,000 was the most destructive in Illinois history. Corn fields were completely devastated and there was heavy damage to buildings, gardens, poultry, etc. It occurred at 4:00 P.M., and two hours later the Lee County hailstorm struck in a five-mile-wide path through the northern and eastern parts of the county. Total losses there amounted to $1,000,000. Damage in the La Salle County area about thirty minutes later resulted in an equally heavy loss.

Probably the most damaging storm in an Illinois city struck Cairo on May 29, 1945. Some forty-five thousand window panes were broken and thousands of roofs heavily damaged. Accompanying winds increased the impact of hailstones, and in places these stones accumulated to a depth of twenty-six inches, some drifts remaining for as long as twelve hours. Losses totaled $1,000,000.

Some Especially Damaging Illinois Hailstorms

Location	***Date***	***Estimated Damage***
Scott County to Sangamon County	Mar. 14, 1953	$ 250,000

La Salle County to Livingston County	Aug. 7, 1953	500,000
Alexander County	Aug. 7, 1953	100,000
Morgan County to Vermilion County	Sept. 18, 1952	500,000
Morgan and Scott counties	June 14, 1948	1,076,500
Whiteside County	Aug. 17, 1948	2,000,000
La Salle County	Aug. 17, 1948	1,000,000
Lee County	Aug. 17, 1948	1,000,000
Carroll County	Aug. 29, 1948	500,000
Whiteside County	Aug. 29, 1948	500,000
Cairo and vicinity	May 29, 1945	1,000,000
Adams County to Madison County	Mar. 30, 1938	60,100
Fairview area, Fulton County	July 10, 1934	150,000
Douglas, Moultrie, and Platt counties	July 13, 1934	300,000
Catlin area, Vermilion County	July 22, 1931	180,000
Calhoun County to Pike County	July 22-23,	331,000

	1931	
Cora to Raleigh, Jackson County	May 1, 1929	720,000
Jackson County to Saline County	May 1, 1928	720,000
Champaign County to Montgomery County	April 4, 1927	165,000
Christian, Sangamon, and Montgomery counties	May 28, 1927	776,000
Warren County	July 21, 1927	165,000
Hancock, Henderson, and McDonough counties	Aug. 18, 1925	510,000
Henry County to Warren County	July 24, 1925	400,000
Henderson County	Aug. 9, 1925	400,000
Hancock, Henderson, and McDonough counties	Aug. 18, 1925	500,000

INDIANA

The hail risk in Indiana is one of the lowest in the country, although several damaging hailstorms have occurred in that state. The loss ratio averages only $0.75 over a twenty-one-year period and the average rate for crop insurance is $2.32. During the 1944-53 decade, sixty-three hailstorms occurred and only six of them were severe. The months of greatest frequency were May, June, and July, usually from 2:00 P.M. to 9:00 P.M. (Tables III and IV in Chapter III). Hail losses for the period totaled $1,671,500. This is almost three times the losses in Ohio, about the same as Michigan's losses, and less than a fifth of those in Illinois. Damage to vegetables amounted to 34 per cent of losses to insured crops, damage to corn, 16 per cent, and damage to tobacco, 1 per cent. The insurance rate for tobacco is more than twice as high as for other crops because of its vulnerability to hail damage.

A unique meteorological event took place in Wabash County, Indiana, July 2, 1924. At Rich Valley, a small town near Wabash, snow was seen to fall from a funnel-shaped cloud at the same time that hail was falling. This snow covered twenty square feet of ground to a depth of eight inches and all around it hail was so deep that it could be shoveled up in places. S. B. Dawes gathered enough snow for a big snowball and rushed to Wabash with it. The story was investigated by the section director of the Weather Bureau at Indianapolis and found to be authentic.[12]

On September 21, 1950, four hailstorms in Cass, Montgomery, and Delaware counties caused losses totaling $1,054,000. The Cass County storm was the most damaging. Accompanied by strong winds, it struck Logansport at 4:00 P.M. and created the worst destruction ever known there. Some hailstones were two inches in diameter. Damage to glass, roofs, automobiles, and other property amounted to $900,000. Losses to crops in the vicinity were estimated at $100.000.

At Evansville, on August 27, 1943, a hailstorm was confined entirely to the city limits. Every building in its path suffered damage to a great extent. The Blackman Floral Company's greenhouse at Weinbach Avenue and Division Street reported 5,000 to 10,000 panes of glass broken or cracked. More than 5,000 panes were shattered at the Ellspermann Floral Company's greenhouse. Churches reported damage to stained glass windows. Roofs, automobiles, and neon signs underwent heavy damage.

Some Especially Damaging Indiana Hailstorms

Location	***Date***	***Estimated Damage***
Benton County to Howard County	May 22, 1953	$ 300,000
Lake Freeman area, Carroll County	Aug. 14, 1951	360,000
Vincennes	May 21, 1950	200,000
Cass County	Sept. 21, 1950	1,000,000
Anderson	June 7, 1948	100,000
Shelby and Decatur counties	July 13, 1947	320,000
Evansville	April 27, 1943	150,000
Allen County	July 21, 1943	1,000,000
Orange County	May 25, 1936	150,000

Hendricks and Morgan counties	June 23, 1936	400,000
Henry County	July 28, 1932	200,000
Jeffersonville and New Albany	April 21, 1929	100,000
Knox and Daviess counties	May 25, 1927	200,000
Indianapolis	April 7, 1922	[a]

[a] Severe but damage not estimated.

IOWA

The number of hailstorms reported over Iowa, as well as the actual hail risk for any particular locality, is comparatively low, but the extensive areas of highly productive land in the state make it almost certain that a fall of heavy hail, covering an area of even moderate size, will result in heavy crop losses. In the ten years between 1944 and 1953, Iowa reported only sixty-five hailstorms but the crop losses for that period totaled $60,171,212. This exceeds the losses of any other states except Kansas, Nebraska, and Montana (Table II in Chapter III). Each of these states has from four to eight times as many hailstorms as Iowa (Table IV in Chapter III). Iowa’s hail damage is more than seven times greater than its damage from tornadoes.

Iowa produces more corn than any other state, and 80 per cent of its hailstorms strike in June, July, and August, when corn is most vulnerable to hail damage. Then it is usually too late in the season to replant. Thirty-nine per cent of losses to insured crops has been to corn and 14 per cent to soybeans. The average loss ratio for Iowa over the twenty-four-year period ending with 1953 is $1.74, and the average rate for crop insurance is $2.99, lower than the rates in many states having much less damage (Table VI in Chapter V). In Colorado, for example, the loss ratio is more than five times greater but actual hail damage to crops is little more than half as much because there are such extensive areas of Colorado land not planted to crops.

The hail hazard in Iowa increases steadily from less than $0.50 per hundred dollars of insurance on crops along the Mississippi River south of Dubuque, where elevations are below a thousand feet, to $4.46 in Osceola County, near the northwest corner of the state, which has an elevation above fifteen hundred feet. Since hail damage depends on the intensity and frequency of storms and on the extent of area where crops are exposed to destruction, the heaviest damage is not necessarily where the loss ratio is highest. The greatest annual hail damage per thousand acres of crop land is in Plymouth County, twenty-five miles to the south and west of Osceola County, but the loss ratio, which is a good index of hail risk, is only 65 per cent of the loss ratio in Osceola County. In many eastern and south-central counties of the state the loss from hail per thousand acres is less than $1.00 annually (Figure 9).

The record of hail damage to crops is more nearly complete in Iowa than in any other state. From 1923 through 1948, township assessors were required to take an annual farm census near the close of each year, in which each of the 200,000 farmers of the state was asked for his estimate of damage caused by hail on his farm during the growing season just passed. While this system had certain weaknesses, as pointed out by Reed[13] and Decker,[14] its value lies in a completeness of coverage that exists nowhere else. A tabulation of these hail losses is given below.

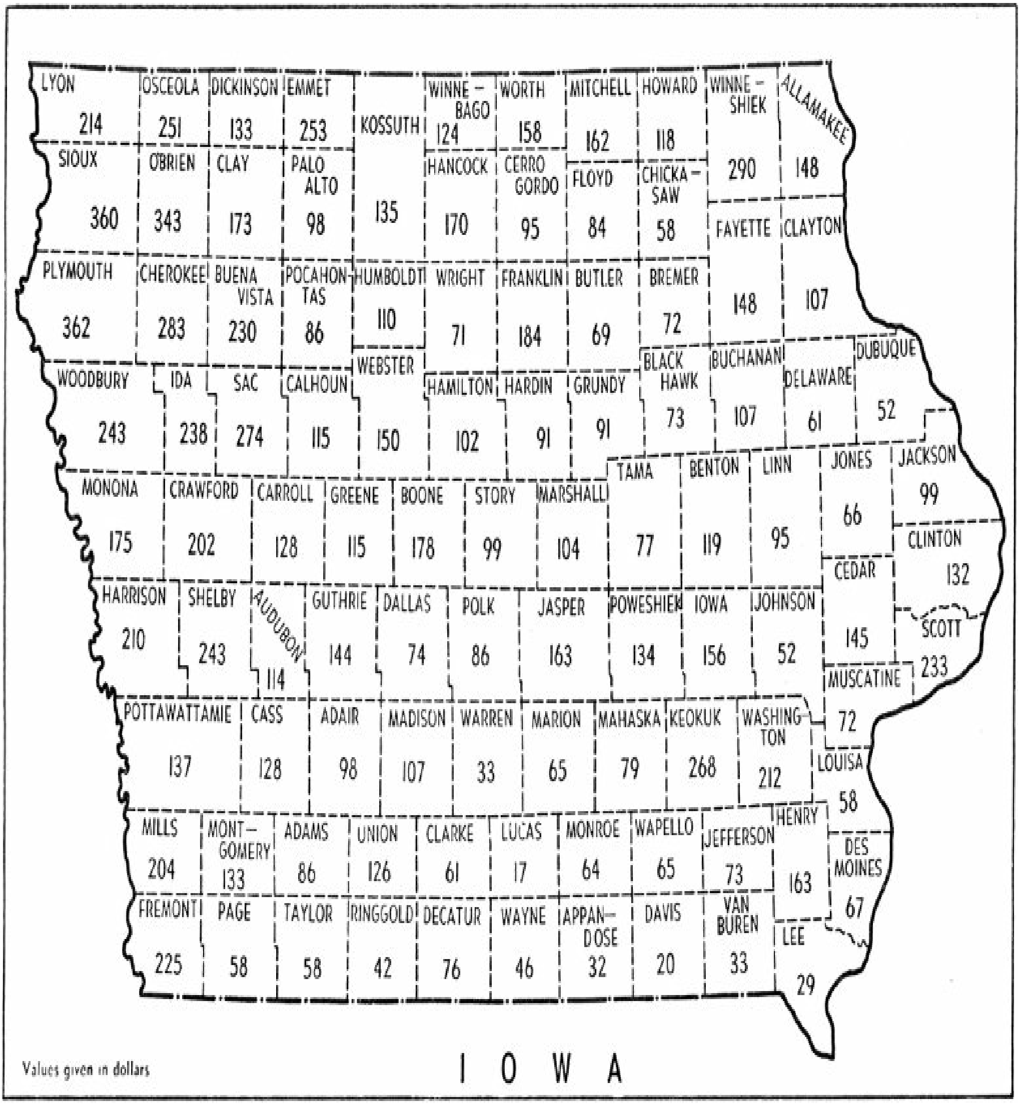


FIG. 9.—*Average Annual Hail Damage per 1,000 Acres in Iowa. By C. E. Lamoureux, section director, U. S. Weather Bureau, Des Moines, Iowa. Values, adjusted to the 1909-14 price index, show the average annual hail losses from 1923 to 1948. Elevations increase from southeast to northwest over Iowa, and hail damage increases correspondingly.*

Annual Hail Losses in Iowa

(Losses for the period 1923-1946, inclusive, were compiled by township assessors from the annual farm census. Losses subsequent to 1946 were compiled by the Weather Bureau in co-operation with the Iowa State Insurance Department.)

Year	***Hail Loss***
1923	$2,319,507
1924	6,903,909
1925	7,975,686
1926	2,342,187
1927	5,064,717
1928	6,363,932
1929	2,541,279
1930	1,598,963
1931	1,378,214
1932	2,077,001
1933	3,188,099
1934	2,165,439
1935	961,147
1936	2,898,790
1937	1,890,235
1938	1,599,187
1939	1,107,816
1940	1,637,645
1941	2,649,434
1942	4,184,133

1943	13,232,824
1944	10,000,175
1945	6,598,883
1946	7,243,263
1947	9,824,523
1948	6,299,869
1949	601,432
1950	2,471,957
1951	5,988,070
1952	3,714,030
1953	7,433,013

The greatest hail loss in the thirty years tabulated above was $13,232,824 in 1943. This is a serious toll on the economy of even a rich state like Iowa.

There is a persistent belief among some people who have made studies of Iowa hailstorms that certain areas exist which are practically free of hail damage, while nearby areas apparently are subject to regular recurrence of hailstorms. Meteorologists who have examined the validity of this theory in regard to any part of the United States are of the opinion that hail, being of a local nature, will inevitably miss some areas and fall heavily on either side, just as local rain showers do, but that over a long period of time hail will occur as frequently in any one place as in adjacent localities, provided, of course, there is no greater variation in topography than exists over short distances in Iowa.

The most damaging hailstorm in the history of Iowa, with probably the most disastrous losses to crops by hail ever experienced anywhere in the United States, occurred on August 18, 1925. Beginning in the southeast corner of Poweshiek County and moving southeastward, it devastated portions of Iowa, Keokuk, Washington, Jefferson, Henry, Des Moines, and Lee counties to the extent of $5,000,000 in damage. The hailstones were of unbelievable size. Some, disk-shaped, were four inches across and two inches thick. Shingle roofs were pierced, livestock killed, and passenger trains caught in the path of the storm had windows shattered. Fields of corn were left with not a single stalk standing. Farms were so completely destroyed that tenants abandoned many of them and sought other employment.

The next most damaging Iowa hailstorm occurred in the northwestern part of the state on July 5, 1953, with a loss of $4,250,000 over an area one hundred miles long and two to seven miles wide through rich corn-growing country. It entered the state along the Minnesota border north of Rock Rapids and moved east-southeast through Osceola County well into Dickinson County, picking up again four miles west of Fostoria, in Clay County, and continuing southeastward through Palo Alto County into Kossuth County. The largest hailstones, some as big as golf balls, accumulated in depths of six to eighteen inches.

A loss of $2,250,000, of which $1,750,000 was to crops, resulted from a hailstorm on June 19, 1951, at McCallsburg and Cedar Rapids and the surrounding areas. The path of the storm was ninety miles long and three to twelve miles wide. Extensive damage was incurred at McCallsburg, Anthony, Clemons, Garwin, Toledo, Tama, Vining, Elberon, and

Keystone.

On August 1, 1922, a hailstorm struck portions of Dubuque, Jackson, Delaware, Linn, and Jones counties, with damage estimated at $500,000. The greatest destruction was to crops in a forty-mile strip from one-half mile to four miles wide, extending from the northwest part of Delaware County southeastward. Dubuque reported one of the worst storms it ever experienced. Eight days later, on August 9, hail damaged a large area in the west-central part of the state, especially in Shelby, Audubon, and Guthrie counties. Losses were well over $500,000, mainly to corn.

A disastrous hailstorm occurred August 6, 1890, extending from Adair County into Union County. It was described as follows by Mr. R. S. Williams in a letter to Henry C. Wallace, of Orient, Iowa: “The hail destroyed all green vegetation and some small animals, such as rabbits, ground squirrels, and all the birds in its path. It fell to a depth of four inches, varying in size from quail eggs to hen eggs, and drifting in many places to a depth of six feet, where it remained, protected by trash, for twenty-six days after the storm.”

Mr. Wallace visited the scene several days after the storm occurred. He reported that the desolation was almost unbelievable. In one cornfield of forty acres there was not a sound ear of corn to be found. The total damage of the storm was not estimated.

A Washington County newspaper gave the following description of a hailstorm that occurred on September 1, 1897: “Imagine, if you can, a tract of country at least sixty miles long and two to three miles wide with 40,000 acres of corn totally destroyed and 70,000 acres more so pounded and wrecked by hail that half of the crop was a loss. At the W. R. Jeffrey farm, in Highland Township, Howard Jeffrey was struck on the forehead by a hailstone and knocked senseless." The loss from this storm exceeded $500,000.

Some Especially Damaging Iowa Hailstorms

Location	***Date***	***Estimated Damage***
Cedar Falls	Mar. 21, 1953	$ 250,000
Northwestern area of the state	July 5, 1953	4,250,000
Sioux and Plymouth counties	July 6, 1952	1,000,000
Plymouth County	Aug. 15, 1952	500,000
Delaware, Fayette, and Chickasaw counties	Aug. 20, 1952	1,000,000
McCallsburg and Cedar Rapids areas	June 19, 1951	2,250,000
Hancock County	Aug. 10, 1950	125,000
Winnebago and Hancock counties	Aug. 14, 1950	250,000
Lyon and Osceola counties	July 19, 1948	140,000
Monona and Harrison counties	July 12, 1947	1,000,000

Palo Alto and Calhoun counties	July 16, 1947	550,000
Kossuth County	June 16, 1946	610,000
Jackson and Clinton counties	Sept. 1, 1945	500,000
Lyon and Osceola counties	July 14, 1944	1,500,000
Boone and Story counties	July 31, 1943	600,000
Dickinson and Palo Alto counties	Aug. 1, 1943	275,000
Monona County to Shelby County	July 8, 1940	985,000
Plymouth County	July 24, 1937	200,000
Calhoun County	July 6, 1932	750,000
Woodbury County	Sept. 30, 1930	1,000,000
Monona County to Sioux County	June 11, 1929	750,000
Boone County to Wright County	July 27, 1926	801,800
Charles City (near)	June 11, 1925	[a]
Poweshiek County to Lee County	Aug. 18, 1925	5,000,000
Scott County	June 13,	500,000

	1924	
Plymouth County to Black Hawk County	July 7, 1924	[a]
Dubuque County to Jones County	Aug. 1, 1922	500,000
Crawford County to Guthrie County	Aug. 9, 1922	500,000
Howard County to Clayton County	June 20, 1908	[a]
Washington County	Sept. 1, 1897	500,000
Adair County to Union County	Aug. 6, 1890	[a]

[a] Severe but damage not estimated.

KANSAS

Kansas grows more wheat than any other state in the union. More than 77 per cent of Kansas hailstorms occur in May, June, and July, just when this wheat crop is approaching maturity or is ready to harvest. The inevitable result is that hail damage in Kansas exceeds that of any other state. Ninety-seven per cent of all losses to insured crops is to wheat. From 1944 to 1953 Kansas reported 440 hailstorms, of which 88 were severe (Table IV in Chapter III). Hail damage over that period totaled $101,877,900 (Table II in Chapter II). This is more than ten times the average damage from tornadoes in

Kansas.

Over half of the hailstorms in the state strike between 6:00 P.M. and 6:00 A.M. (Table III in Chapter III). Many a Kansas wheat grower who neglected to take out insurance on his crop has gone to bed on a summer night confident of a small fortune in wheat practically in his hands and has got up in the morning to find that a hailstorm has wiped out a whole year’s profits.

In 1951, the year of greatest rainfall in the state, hail damage amounted to $31,333,300. Of this total, crop losses comprised $14,975,450, which equaled approximately 6 per cent of the value of the entire wheat crop harvested that year. Damage to property other than wheat was estimated at $16,357,450, greater than any other annual loss ever recorded. It is likely that many small losses which were not reported would add still more to these appalling figures. The year 1915 was second to 1951 in the amount of rainfall, and hail losses for that year exceeded anything on record up to that time. Many insurance companies were forced out of business, and others, whose contracts permitted it, survived by pro-rating losses.

The average loss ratio of crop insurance in Kansas from 1923 to 1953 is $4.39 for the state as a whole, and the average insurance rate is $7.13. Both averages are much higher than for most other states (Table VI in Chapter V). The hail risk, measured by the crop-loss factor, increases steadily from less than $1.00 in some eastern counties where elevations are below one thousand feet to between $8.00 and $12.00 in many western counties where elevations exceed three thousand feet (Figures 10 and 11). Insurance rates for full coverage of wheat range from near $3.00 in the eastern counties to $19.00 or more in some northwestern counties, where the risk is highest. Since such rates are almost prohibitive, much hail insurance in the western half of the state is written with a 10 or 20 per cent deductible clause, affording lower rates but giving only partial protection.

During the thirty-one years ending with 1953, thirty-two Kansas hailstorms caused losses of a million dollars or more each. Five of them damaged property to the extent of $5,000,000 each. Only two out of these thirty-two hailstorms reached the eastern third of the state. More of them occurred in Cheyenne County, in the extreme northwest corner, than anywhere else in the state. Cheyenne County hailstorms for the last twenty years are tabulated below.

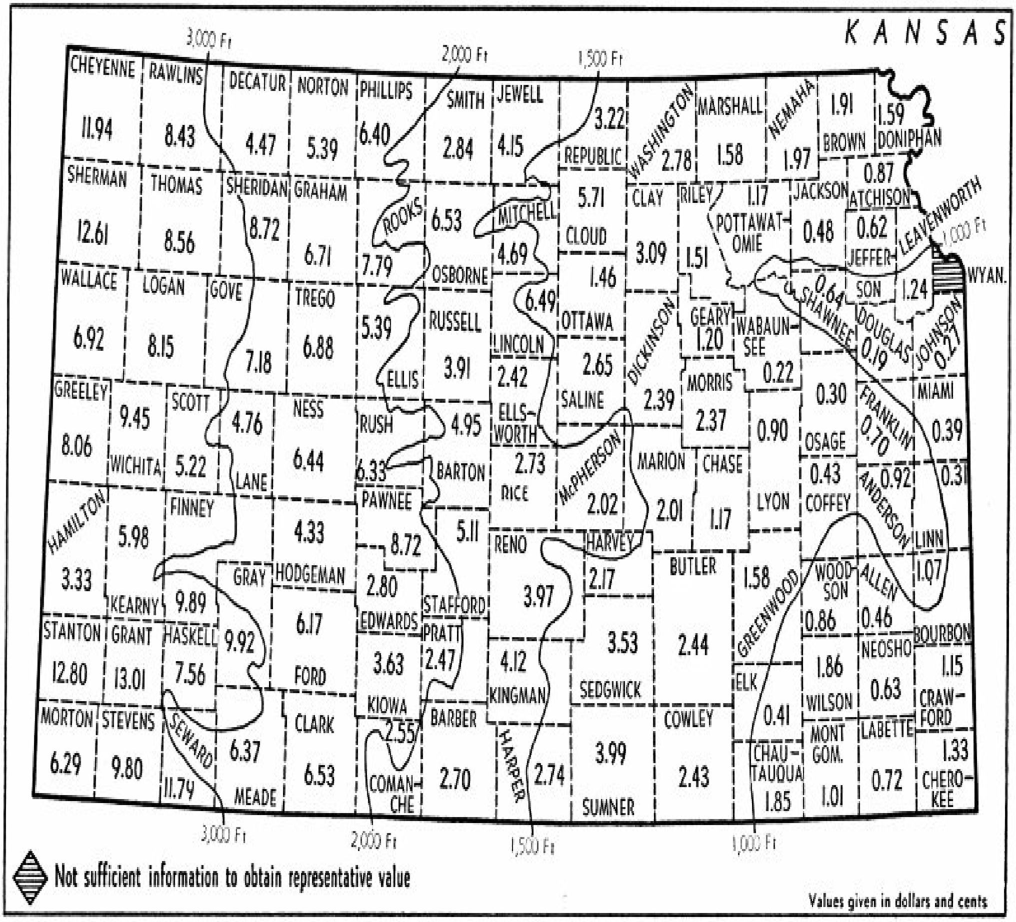


FIG. 10.—*Hail Risk Over Kansas in Relation to Elevation. Values show the average loss ratio as it increases with elevation. For small areas data are not always available.* (*Data compiled by the Crop-Hail Insurance Actuarial Association, Chicago, Illinois.*)

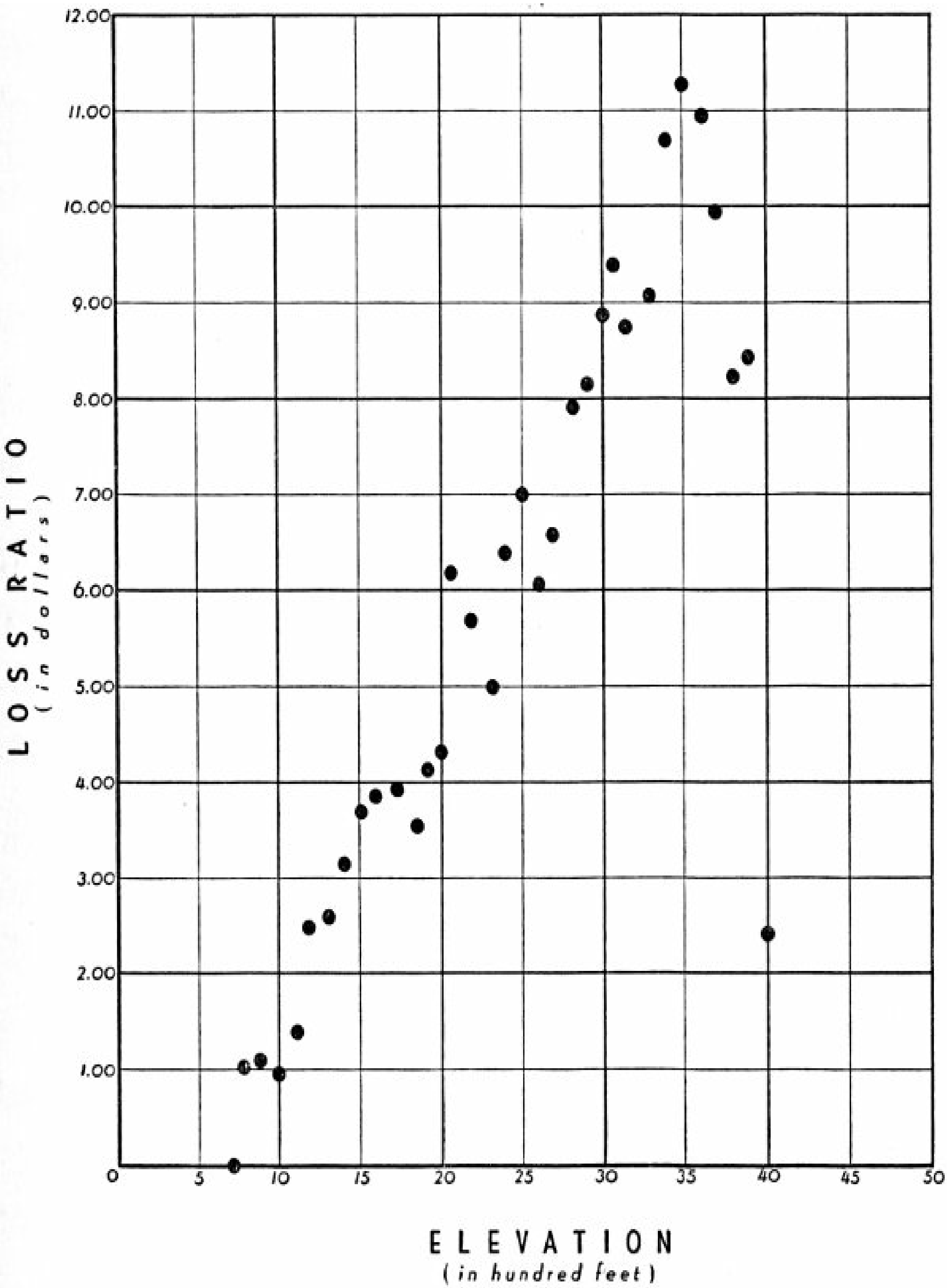


FIG. 11.—*The Increase of Hail Risk with Elevation in Kansas. Dots show proportional increase of loss ratio*

with respect to the rise in elevation from eastern to western Kansas. As the loss ratio increases, rates for hail insurance must of necessity increase accordingly.
(*Diagram by the Crop-Hail Insurance Actuarial Association, Chicago, Illinois.*)

Damaging Hailstorms in Cheyenne County, Kansas

Location (counties)	***Date***	***Estimated Damage***
Cheyenne, Sherman, Thomas, and Sheridan	May 7-8, 1952	$ 1,066,000[a]
Cheyenne, Sherman, and Norton	May 18, 1949	2,375,000[a]
Cheyenne, Thomas	June 27, 1949	1,000,000[a]
Cheyenne	June 13, 1948	[b]
Cheyenne, Rawlins, Sherman, and Thomas	June 14, 1948	[b]
Cheyenne	June 15-16, 1948	4,000,000
Cheyenne	June 5, 1947	1,000,000
Cheyenne	July 2, 1946	1,250,000
Cheyenne	May 30, 1945	200,000
Cheyenne, Sherman, and Decatur	May 20-21, 1938	500,000
Cheyenne	June 25,	108,000

1935

[a] Cheyenne County damage included in this amount.

[b] Cheyenne County damage from the three storms of June 13-16, 1948 totaled $4,000,000.

Losses of this magnitude, mostly to the wheat crop, represent economic disaster to a county with a population of scarcely 6,000, nearly all of whom are dependent on agriculture. The average insurance rate for crops in this county ranges from 18 to 20 per cent for full coverage.

The greatest hail loss in Kansas, estimated at the current value of the dollar, occurred on the late afternoon and early evening of June 23, 1951. Its path extended two hundred miles from Kingman and Sumner counties through Cowley, Sedgwick, and Butler counties into Missouri. Damage in Sedgwick and Butler counties alone amounted to $14,340,000. Of this amount $1,590,000 involved damage to crops. The heaviest loss in any single area which this storm covered was in Wichita and its vicinity, where automobiles, roofs, and windows bore the brunt of the damage. Two years later, almost to a day, on June 21, 1953, another hailstorm, accompanied by excessively high winds, struck Wichita, damaging the town and vicinity to the extent of $9,180,000. Insurance companies reported over 21,000 claims for damage.

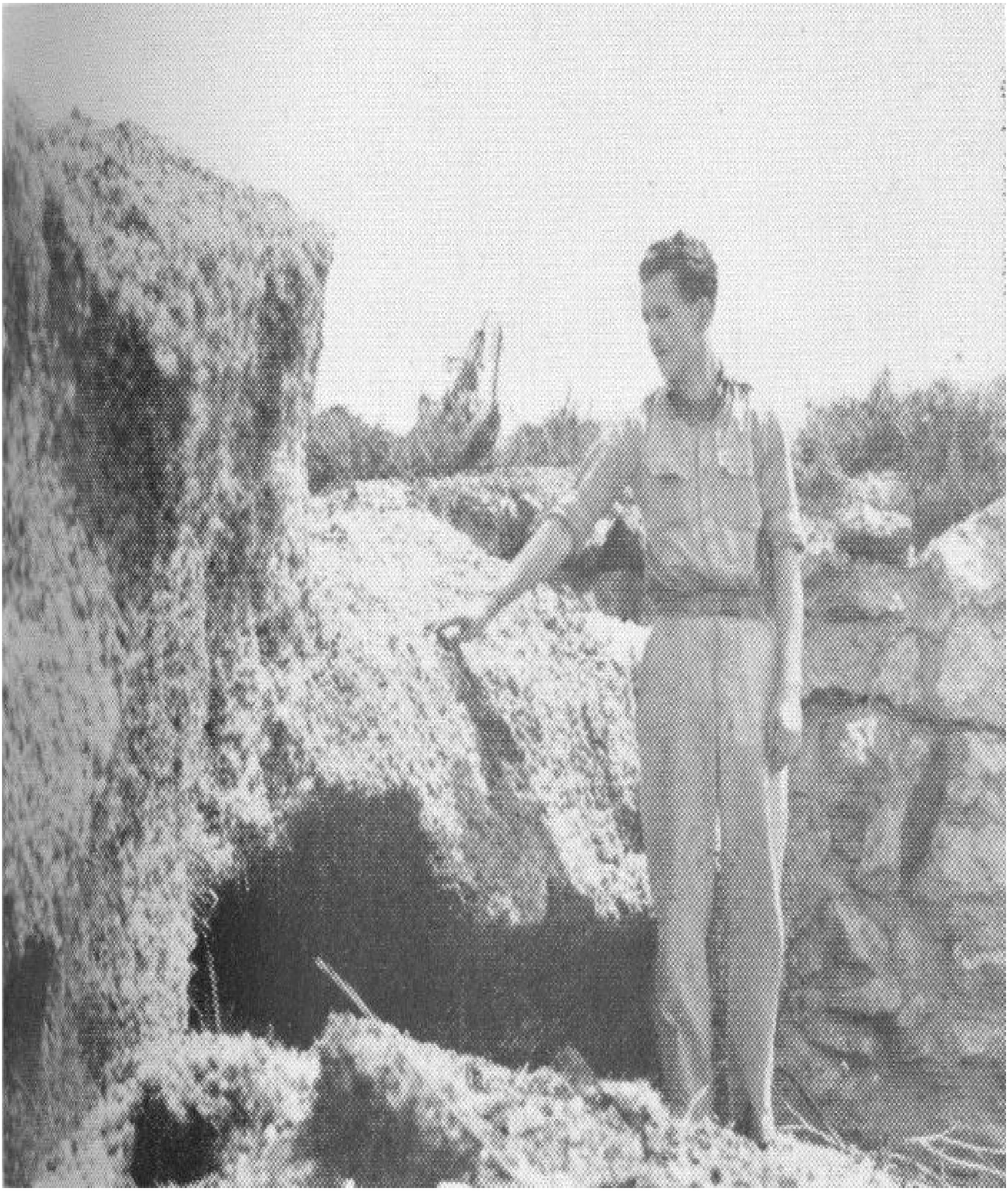
The most violent damage ever recorded in Kansas from a storm outside the large town areas occurred near midnight on May 29-30, 1951, in a path two hundred miles long and in some places fifteen miles wide. Originating near Kit Carson, Colorado, it moved into Kansas through Wallace and Greeley counties, then southeastward through Scott, Kearny, and Finney counties, ending twelve miles southeast of Garden City. Losses totaled $6,215,000, of which $3,590,000 was to crops. Winds of hurricane force from the west and northwest drove hailstones of enormous size with devastating force against all objects in the path. At a farmhouse in northern Kearny County a hailstone came through a north window, rebounded from the floor and struck another window with force enough to break a pane of glass. Damage in general consisted of torn roofs, broken windows, and battered automobiles, farm machinery, and crops. In some instances stucco was actually pounded from the walls of houses and holes beaten into the sides of buildings. West of Garden City there was complete destruction to sixty-thousand acres of irrigated wheat over an area of five hundred square miles.

The most damaging hailstorm ever to occur entirely within the eastern third of Kansas struck Manhattan and vicinity at 4:30 P.M. on July 1, 1950, with damage estimated at $2,512,000. Hailstones two and one-half inches in diameter smashed sixteen thousand windows in eleven greenhouses used for research by the Kansas State College at Manhattan. Damage to buildings at the college was so great that emergency funds had to be requested for immediate repairs in order not to interrupt the full schedule of work at the school. Roofs in Manhattan also were heavily damaged. There was such a demand for immediate delivery of composition shingles after the storm that shipments from factories could not be sent fast enough. Stocks from lumber yards throughout a radius of seventy-five miles were trucked in to supply the demand.

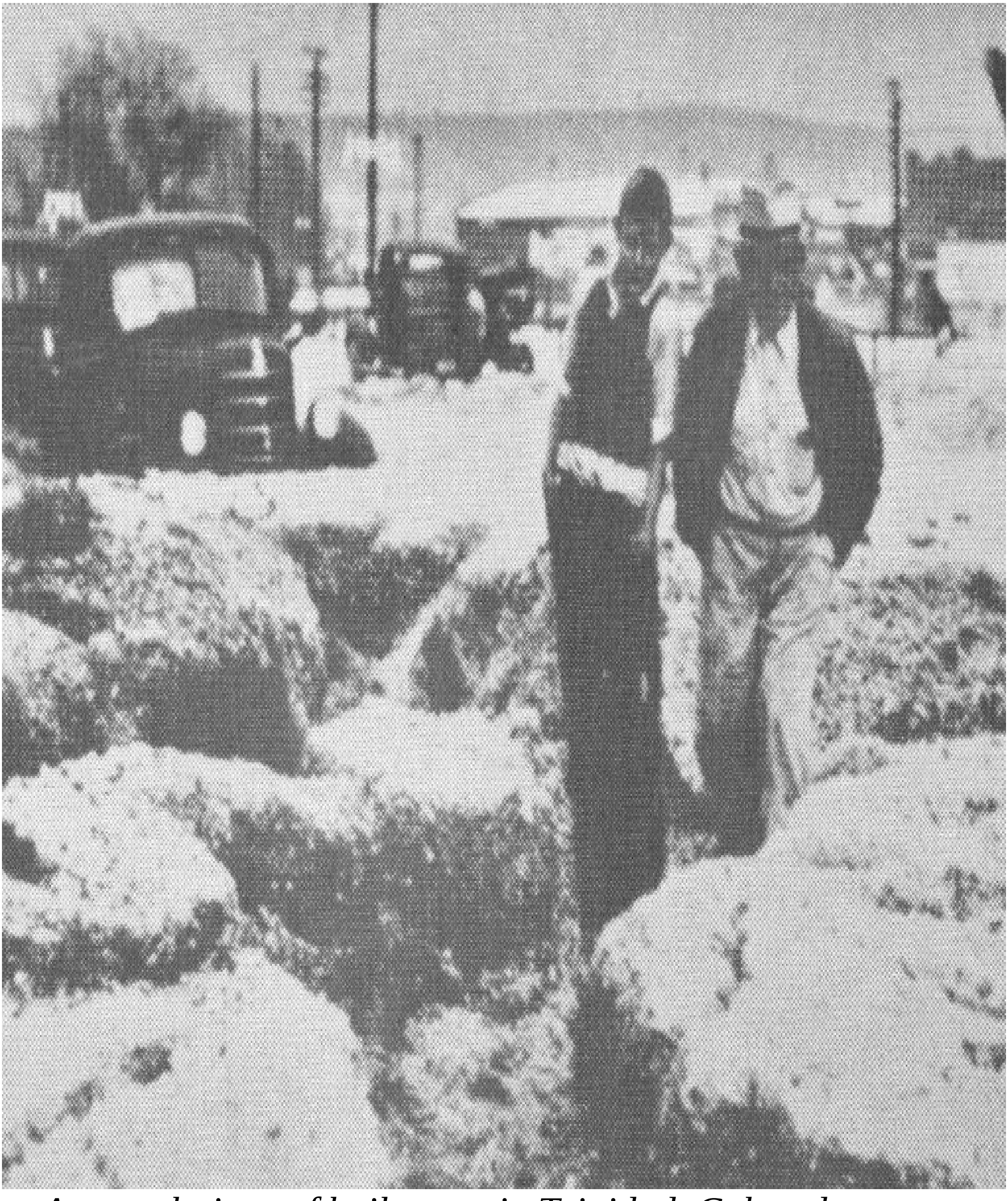
One of the earliest of the violent hailstorms in the state's history struck the capitol city, Topeka, at 7:35 P.M. on June 24, 1897. Hailstones from three to six inches in diameter smashed greenhouses and even heavy glass skylights half an inch thick, and punctured sheet metal and shingle roofs. Twenty-six people were injured by the hailstones, including a boy whose skull was fractured. The glass operating room at the Santa Fe Hospital was demolished and a nurse was injured by the hailstones. The wooden tops of street cars were punctured. Newspapers carried stories of run-away teams, the horses terror-stricken by the deluge of hail. Apparently, the storm did not extend beyond Shawnee County. No estimate of damage was made.

One of the heaviest accumulations of hail ever recorded in Kansas was in a violent storm of hail, wind, and rain in mid-afternoon of August 1, 1954, in Washington, Republic, and Clay counties. Hailstones as big as golf balls fell for thirty minutes and were drifted by torrential rain into enormous heaps. At 9:00 A.M. the following day a drift was measured in a cornfield. It was two hundred feet long, seventy feet wide, and three feet deep. Losses to crops amounted to $1,608,000 from a total loss to all property of $2,140,000.

Hail in Depth and Drift



A nine-inch hail drift at Scott County, Kansas, State Park, *August 26, 1940. Hailstones lay six to seven inches deep on level ground. The drift shown here was carried into a draw by flooding rain that fell with the hail.*

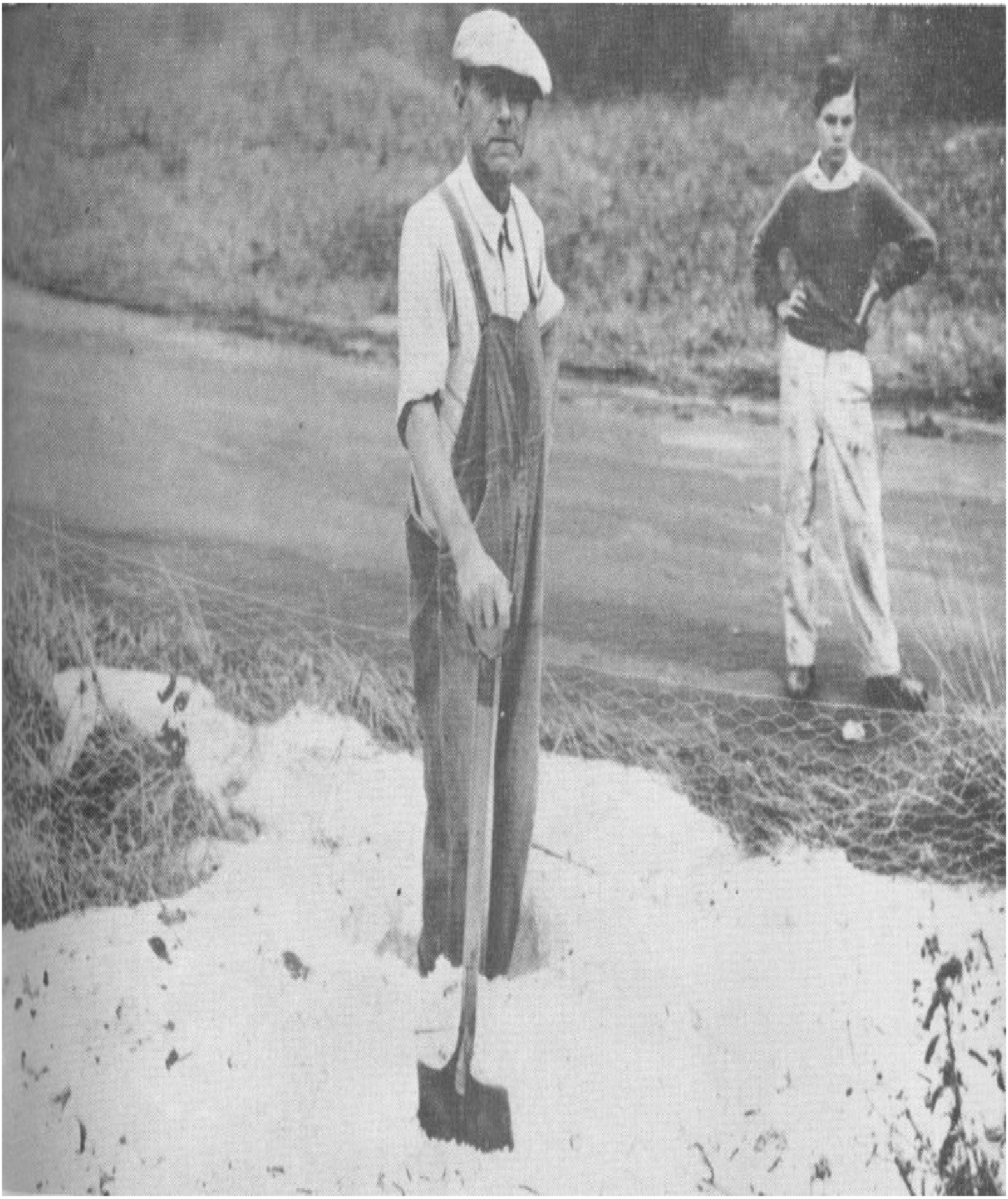


Accumulations of hailstones in Trinidad, Colorado, on

June 14, 1937.

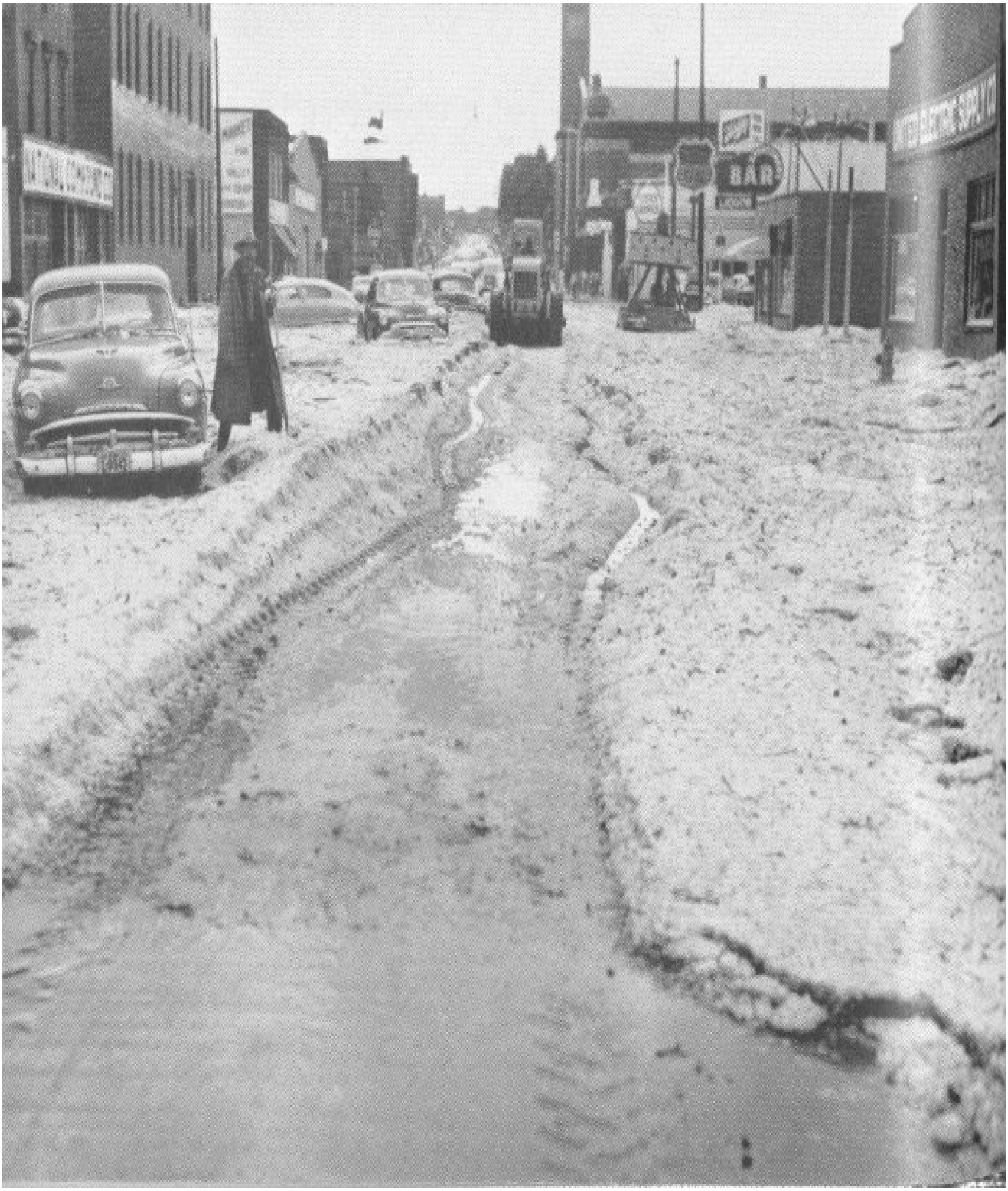
Another view of the Trinidad storm of June 14, 1937. This exemplifies the terrific falls of hail which often occur in eastern Colorado. From *Technical Note 2734,* National Advisory Committee for Aeronautics.

Hailstones two feet deep at Omaha, Nebraska, May 17, 1936. This hail fell on high ground near Fort Omaha and drifted to depths shown here. The automobile was not in the storm but hail piled up around it as the stones washed from higher ground. Courtesy Ed Behuke.



John P. Flibbert (foreground) preparing to dig in to free his poultry yard of tons of hailstones that buried it three feet deep during a storm at Marlboro, Massachusetts, August 31, 1938. Note the height of the hailstone accumulation as compared to the wire fence in the background. Courtesy “United Press Photo.”

Another view of hail drift from the Omaha, Nebraska, storm of May 17, 1936, when heavy rain washed the stones from higher ground.



Hail accumulation at Sioux Falls, South Dakota, June 4, 1956. Traffic was blocked until a snowplow could remove the hail.

Two hours later on the same day another hailstorm struck Ellis, Rush, and Pawnee counties. It left a path of destruction fifty miles long and five to ten miles wide, from Yocemento southward to Larned. Crop damage totaled $930,000 and damage to other property, $820,000.

Some Especially Damaging Kansas Hailstorms

Location	***Date***	***Estimated Damage***
Washington, Republic, and Clay counties	Aug. 1, 1954	$2,140,000
Harper County	May 11, 1953	500,000
Thomas County to Trego County	June 7, 1953	2,500,000
Clay County to Dickinson County	June 21, 1953	776,500
Wichita and vicinity	June 21, 1953	9,180,000[a]
Cowley, Sumner, and Butler counties	June 21, 1953	382,000
Cheyenne, Sherman, Thomas and Sheridan counties	May 7-8, 1952	1,066,000
Sherman County to Washington County	May 21, 1952	1,444,000
Greeley, Wichita, and Scott counties	May 26, 1952	125,000
Meade County to Clark County	May 26, 1952	160,000
Clark County to Stafford County	June 8, 1952	300,000

Lincoln County to Salina County	June 18, 1952	330,000
Haskell County	June 18, 1952	500,000
Harper County	Aug. 5, 1952	430,000
Wallace County to Kearny and Finney counties	May 29-30, 1951	6,215,000
Sherman County to Rice and Reno counties	June 21-22, 1951	5,716,000
Sedgwick County to Allen County	June 23, 1951	14,340,000
Manhattan and vicinity	July 1, 1950	2,512,000
Scott County	July 2, 1950	1,750,000
Sheridan and Gove counties	July 2, 1950	1,000,000
Sherman and Cheyenne counties to Norton County	May 18, 1949	2,375,000
Greeley County to Ford County	May 23, 1949	2,500,000
Cheyenne County to Thomas County	June 27, 1949	1,000,000
Cheyenne, Sherman, Decatur, and Thomas counties	June 13-16, 1948	4,450,000
Ness and Rush counties	June 25, 1948	625,000
Logan County to Scott County	July 16,	1,000,000

	1948	
Reno County	May 27, 1947	1,000,000
Cheyenne County	June 5, 1947	1,000,000
Kingman County	June 25-26, 1947	2,250,000
Sumner County	June 23, 1947	1,500,000
Cheyenne County	July 2, 1946	1,250,000
Cheyenne County	May 30, 1945	200,000
Sherman County	May 30, 1945	1,000,000
Russell County	June 26, 1945	2,000,000
Thomas County	May 30, 1945	1,000,000
Franklin County	June 30, 1945	750,000
Decatur County	June 30, 1945	1,500,000
Rawlins and Thomas counties	June 12, 1944	1,200,000
Barton County	June 22, 1944	1,000,000
Sheridan and Ellis counties	June 15, 1943	1,427,000

Pawnee, Stafford, and Reno counties	June 16, 1943	2,000,000
Republic and Washington counties	June 12, 1942	2,000,000
Cheyenne, Sherman, and Decatur counties	May 20-21, 1938	500,000
Sedgwick, Sumner, and Cowley counties	May 21, 1937	600,000
Cheyenne County	June 25, 1935	108,000
Brown County to Leavenworth County	Aug. 6, 1932	600,000
Kearny County to Haskell and Gray counties	May 4, 1931	1,500,000
Barton, Pawnee, and Stafford counties	June 2, 1927	2,000,000
Dodge City	May 29, 1923	600,000
Topeka	June 24, 1897	[b]

[a] Includes damage from high winds as well as from hail.

[b] Severe but damage not estimated.

KENTUCKY

The hail risk in Kentucky is not particularly high. In the ten years ending with 1953 the state reported only twenty-six hailstorms, seven of which were classed as relatively severe. Only one of these caused losses in excess of half a million dollars. Approximately 80 per cent of them occurred in April, May, and August (Table IV in Chapter III).

The average loss ratio of crop insurance over a period of twenty-one years is $2.11, and the rate of insurance is $3.12 (Table VI in Chapter V). The risk of hail damage seems to be fairly uniform over the state except in Scott County, in the northeastern part, where the loss ratio averages $3.16. Kentucky ranks second in the United States in the production of tobacco, which is highly susceptible to hail damage. Ninety-nine per cent of the state's losses to all insured crops has been from damage to tobacco.

The most damaging hailstorm in the state's history was on August 1, 1952, in Boyle County, near the center of the state. Losses totaled $810,000. Crops, chiefly tobacco, were destroyed or damaged over an area of about eleven square miles. The next greatest loss, amounting to $400,000, was on May 17, 1953, in Henderson County, with heavy damage to crops. In Corydon, Kentucky, practically every building was damaged. Even furniture in the homes and merchandise in stores suffered damage when hailstones crashed through windows, permitting rain to deluge the interiors.

Uniontown, in Union County, had a $200,000 loss on the same day. Almost all residences and nine business buildings were damaged. Hail knocked holes in many roofs, permitting rain to flood the contents. Automobiles after the storm looked as if they “had been beaten by hammers.” A thirty-minute hailstorm on September 13, 1946, over a path five miles wide in Franklin, Owen, and Henry counties, resulted in a loss of $200,000, mostly to the tobacco crop. In some places the ground was covered to a depth of five inches by small hailstones which remained frozen solid for several hours.

Some Especially Damaging Kentucky Hailstorms

Location	***Date***	***Estimated Damage***
Union County	May 17, 1953	$200,000
Henderson County	May 17, 1953	400,000
Boyle County	Aug. 1, 1952	810,000
Fayette and Jessamine counties	Aug. 1, 1952	300,000
Fayette County	Aug. 31, 1949	100,000
Franklin, Owen, and Henry counties	Sept. 13, 1946	200,000
Clark, Fayette, and Bourbon counties	Aug. 3, 1925	125,000

LOUISIANA

Hailstorms are comparatively infrequent in Louisiana but a few of them have caused serious damage. During the 1944-53 period only eighteen storms were reported to the Weather Bureau, four of them classed as severe. More than half occurred in March and May. Damages for the ten-year period amounted to $3,507,900.

Only a very small percentage of crops in Louisiana has been insured. Insurance data, of which little is available, indicate a loss ratio of $0.33, which is probably too low. The rate of insurance for all crops is $3.00. Approximately a third of the losses to insured crops has involved damage to tomatoes.

The two biggest hail losses in the state have been to the strawberry crop in Tangipahoa Parish, east of Baton Rouge. The first of these, on April 28, 1933, occurred in the vicinities of Hammond and Ponchatoula with a loss of $750,000. The second loss, amounting to $1,000,000, and in the same parish, was from a hailstorm centering around Amite and Independence. The strawberry crop was destroyed over an area of two hundred square miles. Hailstones were reported four inches deep in places and “as big as a man’s fist.” Six days later, hail in St. Tammany Parish, in the same section of the state, caused a loss of $305,000. The heaviest damage was to tung groves, where the hail destroyed the blooms, thereby destroying the crop for that year. This storm occurred May 15, 1950.

New Orleans has recorded four severe hailstorms on the following dates: February 26, 1939; April 17, 1924; March 17, 1904; and April 16, 1879. No estimates are available concerning the damage of the storms in 1879 and 1904, but it is known that they were not as damaging as the later ones. The hail of April 17, 1924, covered the entire city except the southern portion. In some places hailstones were four inches deep, impeding the movement of automobiles at North Broad and St. Bernard streets. There was the usual damage to roofs and windows, and paint was knocked off in large patches on the exposed sides of many buildings. Damage to greenhouses amounted to $7,000. The total loss for the city was estimated at $100,000.

Some Especially Damaging Louisiana Hailstorms

Location	***Date***	***Estimated Damage***
Tangipahoa Parish	Mar. 15, 1950	$1,000,000
St. Tammany Parish	Mar. 21, 1950	305,000
Red River Parish	May 15, 1950	50,000
Lafourche Parish to New Orleans	Feb. 26, 1939	200,000
Milton to Youngsville	May 26-27, 1938	[a]
Ascension Parish	April 26, 1933	100,000
Kentwood to Ponchatoula	April 27, 1933	100,000
Hammond and Ponchatoula, Tangipahoa Parish	April 28, 1933	750,000

[a] Severe but damage not estimated.

MAINE

The risk of hail in Maine is slight. From 1944 to 1953 only three hailstorms were reported, and only one of them was severe. For more than twenty years prior to 1943, there is no record of any other severe hailstorm in the state. The loss ratio average on crop insurance in Maine is only $0.83 for an eighteen-year period, and the rate for crop insurance, full coverage, is only $2.56. Losses to insured crops during this period total only $389,242.

The state’s principal crop production is potatoes, and 90 per cent of its insured losses involves damage to that crop, with only 8 per cent in damage to the apple crop. Complete hail damage for Maine has never been computed for the state alone. It has been included in the over-all coverage for the whole New England area.

The one severe hailstorm reported in the state was on July 31, 1947, in Aroostook County, famous for its potato production, and in Penobscot County. Losses, mainly to the potato crop, amounted to $250,000. The maximum damage was unevenly distributed in two narrow strips, one from Eagle Lake to Frenchville, in Aroostook County, and the other from Patten, Penobscot County, to Littleton. An estimated 3,700 acres of potatoes and 300 acres of peas were damaged.

MARYLAND

In the ten years ending with 1953, Maryland reported two severe hailstorms out of a total of seventeen. Nearly all occurred in May, June, July, and August (Table IV in Chapter III). Hail damage in the state during that period totaled $1,160,500. The hail risk to crops is rather small, except in Alleghany County, near the extreme northwestern part of the state, where extensive apple orchards are grown. The loss ratio averages $1.57 for the state as a whole, and the average insurance rate is $3.24 (Table VI in Chapter V). In Alleghany County the loss ratio has averaged $11.01 over a seventeen-year period. Damage to apples comprises 45 per cent of losses to insured crops.

Baltimore has experienced two destructive hailstorms. The first was on May 24, 1925, with a loss of $75,000. It occurred during a period of the hottest weather ever recorded in Baltimore up to that time. The maximum temperature was 98 degrees. The storm struck with little or no wind, and the hail fell straight down, covering the ground rapidly with hailstones the size of hickory nuts. Heavy rain washed the hail into low places. At the intersection of Charles and Lanvale streets the accumulation was six inches deep. It blocked street car traffic until it could be shoveled away. There was enough hail at this one intersection to make three 5-ton truck loads, twenty-two 3-ton loads, and fifteen 1-ton loads. Sewers, blocked with leaves and twigs, flooded hundreds of cellars and basements. Skylights, windows, and greenhouse glass underwent terrific damage. A second Baltimore storm, on May 26, 1937, was equally as destructive.

The most damaging hailstorm reported in the state occurred on June 6, 1917, over the area from Washington County to Anne Arundel County. It destroyed entire fields of wheat and other crops in a path eighty miles long. Damage to roofs, with the consequent flooding of the contents of buildings, was estimated at $500,000. Crop losses in Washington, Frederick, Carroll, Howard, and Anne Arundel counties also totaled $500,000.

In Queen Annes County on June 19, 1948, hailstones as large as goose eggs caused another loss of $500,000. After the storm, grain and hay crops looked “as though they had been mashed by a giant steam roller.” The hailstorm of June 22, 1915, is well remembered in Maryland because it struck the Naval Academy at Annapolis. The storm swept a path five miles wide from Union Bridge through Sykesville, Woodstock, Ellicott City, Annapolis, Claiborne, and Oxford. In the area of the Naval Academy some of the hailstones were four inches in diameter and weighed three to four ounces. This approaches the size of a league baseball, which is nine inches in circumference and weighs about five ounces. At the Academy gymnasium four or five hundred panes of glass were broken. This glass was one-half inch thick. One hailstone crashed through a skylight like a cannon ball and fell to the floor unbroken. Some of the hailstones were covered with knobs, some were pear-shaped, and others were wedge-shaped and rounded on the larger end. It was reported that some of them even contained small pebbles. The storm’s total damage was not estimated.

Some Especially Damaging Maryland Hailstorms

Estimated

Location	*Date*	*Damage*
Kent County	June 19, 1948	$ 100,000
Queen Annes County	June 19, 1948	500,000
Harford County	May 28, 1943	[a]
Salisbury to Cambridge	May 27, 1940	[a]
St. Marys and Calvert counties	Sept. 10, 1939	50,000
Baltimore	May 26, 1937	75,000
Charles County	July 12, 1936	100,000
Garrett County to Anne Arundel County	June 17, 1923	210,000
Garrett County	July 18, 1926	100,000
Baltimore	May 24, 1925	75,000
Talbot County	Aug. 4, 1932	200,000
Washington County to Anne Arundel County	June 6, 1917	1,000,000
Annapolis	June 22, 1915	[a]

[a] Severe but damage not estimated.

MASSACHUSETTS

Although Massachusetts has had several very damaging hailstorms, the Weather Bureau has not published the hail loss for the state separately but has included its losses with the computation for the whole New England area (Figure 1 in Chapter II). Most of the Massachusetts storms extend into adjacent states. In the ten years ending with 1953 there were nine hailstorms in the state and three of them were severely damaging (Tables III and IV in Chapter III). All but one occurred during the summer months, June, July, and August.

The hail risk for crops has a high average, largely because of the preponderance of insurance written on tobacco and apples, both of which are particularly susceptible to hail damage. Fifty-four per cent of losses to insured crops for an eighteen-year period apply to the tobacco crop and 44 per cent to apples. The loss ratio for the state has averaged $3.61, and the rate for full insurance coverage is $10.70. These rates are higher than in most Eastern states. Consequently, many of the crop policies are written with a 10 or 20 per cent deductible clause. Insurance rates on crops other than tobacco or apples are much lower, ranging from $1.40 to $2.50.

One of the most destructive hailstorms to strike the state was on July 20, 1949. Fifteen thousand acres of tobacco were destroyed in Hampshire and Berkshire counties. The storm also devastated much of the Connecticut Valley, extending into

Bennington County, Vermont, and into Merrimack County in New Hampshire. Total losses were not estimated but probably amounted to several million dollars.

On June 10, 1952, there was a hail loss of $500,000 in Middlesex County and the greater Boston area, mostly to market gardens and greenhouses. Lawrence, Massachusetts, underwent a veritable bombardment of excessively large hailstones on July 17, 1924. The damage at Lawrence, Methuen, and Salem was estimated at $75,000, mainly to crops and fruit trees.

Massachusetts hailstorms are listed in this chapter with those of the New England area.

MICHIGAN

Hail losses in Michigan, as in the adjacent states, Wisconsin, Indiana, and Ohio, have been comparatively light. From 1944 to 1953 only fifteen hailstorms were reported in the state and their total damage was only $1,801,120. All of them occurred in June, July, and August, usually in the afternoon (Tables III and IV in Chapter III). The average loss on insured crops is $1.30. Approximately 90 per cent of these losses was in damage to apples and other tree fruits. Grapes, which are especially susceptible to hail damage through the summer months, represent the next highest percentage of loss (Table VI in Chapter V). The hail risk is greatest in Clinton, Newaygo, and Wexford counties. In this area the loss ratio varies from near $7.00 to almost $9.00.

Michigan has had few severely damaging hailstorms. The most destructive was on August 1, 1953, in Gratiot County, in the central area of the state. Accompanied by high winds, this storm resulted in losses totaling $500,000. It completely destroyed whole fields of corn, beans, and other crops from St. Louis to Edgewood.

Some Especially Damaging Michigan Hailstorms

Location	***Date***	***Estimated Damage***
Gratiot County	Aug. 1, 1953	$500,000
Muskegon, Kent, and Ottawa counties	Aug. 29, 1947	108,000
Lenawee County	Aug. 6, 1926	100,000

MINNESOTA

Minnesota ranks eleventh among the states in the amount of hail damage, with losses from 1944 to 1953 totaling $9,807,800 (Table II in Chapter II). During this ten-year period Minnesota had 104 hailstorms, and 17 of these caused losses of $100,000 or more each. Eighty per cent of all the storms occurred in June, July, and August, usually in the late afternoon or early evening (Tables III and IV in Chapter III).

The hail risk in Minnesota is not particularly high, but the extensive areas of valuable crops offer targets that hail can hardly miss when it does occur. Experience of hail insurance companies shows that over a period of twenty-seven years the loss ratio on insured crops for the state as a whole averages $2.23 (Table VI in Chapter V). This ratio is higher in Swift, Rock, Redwood, Lyon, and Lincoln counties, where it averages between $3.72 and $5.84. Losses to the tobacco crop have been somewhat higher than to other crops, averaging $3.07 for each $100 covered by insurance. Corn and oats accounted for over 60 per cent of all losses paid by hail insurance companies over a period of nineteen years.

Twenty-nine hailstorms, each with damages amounting to $100,000 or more, were recorded for the twenty-one years ending with 1953. Five of these caused losses of half a million dollars or more each, and from two storms the losses were a million dollars or more each. Practically all of these hailstorms struck in the southern part of the state.

The most damaging hailstorm in Minnesota occurred shortly after noon on July 18, 1943, in Pipestone, Lyon, Redwood, and Faribault counties with a total loss of $1,615,000, of which $1,325,000 was to crops. High winds that accompanied the hail caused an additional loss of $97,500. The second most violent storm was on May 20, 1945, in the south-central counties, with damage amounting to $1,000,000. Every house in the town of Albert Lea, in Freeborn County, was damaged. In Austin, Mower County, twenty greenhouses were completely destroyed.

Some Especially Damaging Minnesota Hailstorms

Estimated

Location	*Date*	*Damage*
Wabasha County to Winona County	June 13, 1953	$ 200,000
West-central counties	June 24, 1953	225,000
Rock, Nobles, and Jackson counties	July 5, 1953	350,000
Polk County	July 20, 1953	200,000
Martin County	June 24, 1952	120,000
Polk, Norman, and Clay counties	July 9, 1952	250,000
Chippewa County	July 20, 1952	120,000
Willmar and vicinity	Aug. 16, 1952	265,000
Martin County	June 25, 1951	100,000
Jackson and vicinity	June 27, 1951	125,000
Becker County to Wadena County	July 26, 1951	200,000
Extreme southern counties	June 25, 1948	800,000
Southern counties	June 27-28, 1947	125,000
Todd County	July 20, 1946	110,000

South-central area	May 20, 1945	1,000,000
Becker, Hubbard, Otter Tail, and Cass counties	Aug. 3, 1945	125,000
Beardsley, Graceville, and vicinities	June 17, 1944	200,000
Pipestone, Lyon, Redwood, and Faribault counties	July 18, 1943	1,615,000
Pope, Douglas, Kandiyohi, and Redwood counties	July 31, 1943	900,000
Central and extreme southwestern counties	July 17, 1941	767,000
Extreme southeastern counties	July 10, 1940	227,000
Extreme southern counties	July 9, 1938	292,500
Fisher and vicinity	July 21, 1938	100,000
Extreme southern counties	Aug. 6, 1938	532,000
Pipestone, Rock, and Martin counties	July 3, 1937	180,000
Rock County to Brown County	Aug. 27, 1936	100,000
Lincoln County to Cottonwood County	July 5, 1934	200,000
Sibley County to Goodhue County	July 9, 1934	100,000
Central area	Aug. 18,	500,000

Duluth	1934 June 10, 1929	[a]

[a] Severe but damage not estimated.

MISSISSIPPI

Hail losses in Mississippi have been much less than those of other Gulf states or of Tennessee to the north and Arkansas to the west. Comparatively little hail insurance has been written on crops in Mississippi, where hail damage has averaged only $5,892 annually. From 1944 to 1953 only fifteen hailstorms were reported in the state. More of these occurred in February and April than in any other months (Table IV in Chapter III). The loss ratio of crop insurance has averaged only $1.45 (Table VI in Chapter V). Cotton accounts for more than half of the losses to crops, with vegetables next.

The most damaging hailstorm reported in the state was in Copiah County on April 29, 1950. Losses totaled $770,000. The storm swept through important commercial truck garden areas and destroyed or damaged vegetables, mainly cabbage, which were ready for market.

Some Especially Damaging Mississippi Hailstorms

Estimated

Location	Date	Damage
Copiah County	April 29, 1950	$770,000
De Soto, Marshall, Benton, Alcorn, and Tippah counties	April 11, 1943	[a]
Issaquena County	Aug. 30, 1939	60,000
Sunflower County	Aug. 30, 1939	40,000
Washington County	Aug. 30, 1939	10,000

[a] Severe but damage not estimated.

MISSOURI

The reported losses from hail damage in Missouri from 1944 to 1953 totaled $9,377,450. The fact that St. Louis has reported six damaging hailstorms, while nothing approaching that number has been recorded for any other locality in the state, indicates the possibility that many hailstorms in Missouri have not been reported to the Weather Bureau. During the ten-year period seventy-three hailstorms were reported, twelve of which were classed as severe. Most of these occurred in May and June, between 1:00 P.M. and 7:00 P.M. (Tables III and IV in Chapter III). In the thirty-two years ending with 1953 twenty-two hailstorms caused losses of at least $100,000. Three resulted in damage amounting to a million dollars or more each.

The hail risk over the state as a whole is not particularly high. For a twenty-one year period the loss ratio for crop insurance has averaged only $1.60, contrasting strongly to $0.72 in Illinois and $4.39 in Kansas. More insurance is written on cotton and wheat than on any other crops. Only 10 per cent of all crop insurance is on tobacco, although tobacco accounts for 44 per cent of all losses to insured crops. The highest hail risk in the state is in the following counties, as indicated by the loss ratio for each: Buchanan County, $3.01; Cedar County, $8.60; Hickory County, $5.32; and Howard County, $9.68. All of these, except Buchanan County, are in the central or southern areas of the state.

Missouri's most damaging hailstorm was that of December 2, 1950. It left in its wake losses totaling $4,000,000. Hail fell in two major waves over Glendale, Webster Grove, Maplewood, Richmond Heights, and the northern part of St. Louis. Florists and nurserymen suffered losses of $150,000 in glass, and nearly $200,000 in plants which froze from lack of protective covering. The main damage was to roofs, windows, and exposed merchandise.

The second most destructive hailstorm in the state struck Joplin on the afternoon of September 15, 1950, with losses totaling $2,000,000. Hailstones up to three inches in diameter severely damaged an estimated 6,000 to 8,000 roofs, besides the usual destruction to greenhouses, neon signs, automobiles, and windows.

Hailstones almost three inches in diameter fell for twelve minutes in St. Louis on May 28, 1927, resulting in a million-dollar loss. The storm struck the famous Shaw's Botanical Gardens, with its extensive array of greenhouses sheltering almost priceless plants. The loss to the Garden alone amounted to $750,000. Saline County suffered a hail loss of $321,000 on June 14, 1948. Damage was mostly in the rural areas, with losses to crops, livestock and poultry amounting to more than $300,000. One of the most remarkable and destructive hailstorms in the history of the state occurred in the northern part of Nodaway County, September 5, 1898. It moved east across Lincoln and Atchison townships in a path three miles wide. Crops were beaten into the ground and trees and shrubs completely stripped of foliage. The devastated areas had the appearance of midwinter, so complete was the destruction of all growing things. This storm is described in further detail in Chapter II.

St. Louis and vicinity suffered a hail loss of $610,000 on the early evening of May 14, 1945, in which damage to fruit and crops amounted to $200,000, and destruction to greenhouses accounted for another $200,000. On August 7, 1953, Cape Girardeau had a disastrous hailstorm that resulted in a loss of $240,000. Orchards, corn, soybeans, and gardens were severely damaged.

Kansas City had a damaging hailstorm on May 14, 1898. Buggies and carriages afforded no protection from the bombardment. Horses pelted by the hail bolted in every direction, and several persons were injured. Fruit, vegetables, and other crops were crushed to the ground. Some of the larger hailstones were from eight to nine and one-half inches in circumference. When cut open they revealed seven or eight concentric layers outside the core.

Some Especially Damaging Missouri Hailstorms

Location	***Date***	***Estimated Damage***
St. Louis and vicinity	Aug. 7, 1953	$ 100,000
Cape Girardeau	Aug. 7, 1953	240,000
St. Louis and vicinity	Mar. 31, 1952	100,000
Dent County	June 9, 1950	210,000
Joplin and vicinity	Sept. 15, 1950	2,000,000
St. Louis and vicinity	Dec. 2, 1950	4,000,000
Callaway County	Mar. 30, 1949	175,000
Saline County	June 14, 1948	321,000
Cooper County	June 14, 1948	100,000
Sullivan and Linn counties	July 27, 1948	110,000
St. Louis and vicinity	May 14, 1945	610,000
Bates County	May 24-25, 1945	175,000
Carthage, Carterville, Joplin, and vicinities	April 15, 1939	268,000
Ray, Carroll, and Lafayette counties	May 8, 1935	100,000

Platte County	Aug. 6, 1932	150,000
St. Louis and vicinity	May 28, 1927	1,000,000
Scott County	May 30, 1927	470,000
Atchison, Nodaway, and Andrews counties	June 27, 1925	100,000
Barry County	May 12, 1924	500,000
Shelby County to Pike County	June 5, 1924	103,000
Jasper County to Barry County	July 29, 1924	300,000
St. Louis and vicinity	April 14, 1922	200,000
Brunswick	April 16, 1922	[a]
Farmington	April 16, 1922	[a]
Warsaw	April 24, 1922	[a]
Nodaway County	Sept. 5, 1898	[a]
Kansas City	May 14, 1898	[a]

[a] Severe but damage not estimated.

MONTANA

Montana ranks third among the states in hail damage, with losses from 1944 to 1953 totaling $61,225,170 (Table II in Chapter II). In that ten-year period 559 hailstorms were reported, and 41 of them were severe, resulting in losses of $100,000 to $6,000,000 each. Wheat accounts for 90 per cent of all losses to insured crops. Nine-tenths of the hailstorms in Montana have struck in June, July, and August, but many of the more damaging ones have occurred as late as the first ten days of October. The hours of greatest frequency are from 1:00 P.M. to 10:00 P.M. (Table III in Chapter III).

Insurance data show that the average loss ratio for the whole state is $5.09 for full coverage. This is higher than in most other states. The average insurance rate is $9.63 (Table VI in Chapter V). In some counties the rate for full coverage is between $12.00 and $21.00. In this high-risk area much of the insurance carries a 10 or 20 per cent deductible clause to afford a more reasonable rate. Some of the counties having the highest hail risk, as shown by the average loss ratio, are: Big Horn County, $10.59; Dawson County, $9.44; McCone County, $10.68; Richland County, $12.92; Silver Bow County, $12.41; Teton County, $16.99; and Wheatland County, $10.35. Nearly all of these are in the eastern or central parts of the state. The loss ratio in the mountainous region of the western 125-mile border is, in general, lower than in the areas to the east.

The most damaging hailstorm ever to occur in Montana was in Chouteau County on August 11, 1945, when losses amounted to $6,000,000. Few other storms in the United States have equalled its destructiveness. Extending from Carter to the southwestern part of the county, it destroyed all grain crops, damaged houses and farm equipment, and killed poultry and small animals. The second greatest loss in the state resulted from a storm over Richland County, October 9, 1944, which swept a path of destruction twenty miles wide and thirty-five miles long. Damage to wheat, other grains, and wild hay amounted to $2,500,000.

A hailstorm ten miles east of Helena on June 28, 1953, damaged crops to the extent of $420,000, and in Helena itself a hailstorm on July 19, 1948, caused a loss of $300,000, mainly to aircraft, greenhouses, gardens, poultry, roofs, and windows.

Butte was struck by a hailstorm on the afternoon of August 1, 1948, with a loss of $250,000, chiefly to automobiles, buildings and gardens. One of the most destructive hailstorms known in the vicinity struck Kalispell and the surrounding area on June 16, 1931. In the city the greatest losses were to greenhouses. An estimated 175 boxes of glass were required to repair the damage, and plants were cut to ribbons by falling glass and beaten down by the hailstones. From Kalispell, the storm took a course along the river toward Bad Rock Canyon, and all farms in the area were severely damaged. Crops were beaten into the ground, windows smashed, buildings unroofed, and chickens killed by the hundreds. At Lake Ronan there was heavy damage to summer resorts. One man was caught in a boat on the lake and suffered severely from lacerations and bruises from the hailstones. He managed to get ashore but was knocked unconscious before he reached shelter. Three calves were killed and many wild ducks perished. The total loss was not estimated.

Some Especially Damaging Montana Hailstorms

Location	***Date***	***Estimated Damage***
Helena and vicinity	June 28, 1953	$ 420,000
Stanford and vicinity	June 29, 1953	930,000
Fergus County	June 30, 1953	500,000
Stanford (near)	June 30, 1953	300,000
Rock Springs	June 30, 1953	100,000
Miles City	July 23, 1953	300,000
Roosevelt County	July 23, 1953	250,000
Hardin and vicinity	Aug. 9, 1953	200,000
Liberty County	Aug. 21, 1953	600,000
Liberty County	Aug. 24, 1953	400,000
McCone County	July 15, 1952	200,000
Glasgow and vicinity	July 15, 1952	250,000
Valley County	July 15, 1952	500,000

Dutton and vicinity	June 17, 1951	1,000,000
Vida and vicinity	July 16, 1951	1,000,000
Brady and vicinity	July 1, 1950	1,500,000
Helena and vicinity	July 19, 1948	300,000
Butte	Aug. 1, 1948	420,000
Vida and vicinity	Aug. 6, 1948	1,000,000
Glasgow (near)	Aug. 12, 1948	140,000
Glasgow (near)	Aug. 16, 1948	1,000,000
Lewistown and vicinity	July 11, 1947	1,000,000
Cut Bank	July 19, 1947	500,000
Flathead County	Aug. 1, 1947	1,000,000
Lower Milk River Valley	Aug. 12, 1947	1,000,000
Pondera County	Aug. 22, 1947	1,000,000
Toole County	June 22, 1946	1,000,000
Valley County to McCone County	July 16,	1,400,000

	1946	
Chouteau County	Aug. 11, 1945	6,000,000
Stillwater County to Prairie County	June 16, 1944	340,000
Roosevelt and Richland counties	Aug. 1, 1944	500,000
Chouteau County	Aug. 11, 1944	400,000
Golden Valley and Yellowstone counties	Oct. 1, 1944	351,250
Musselshell County	Oct. 1, 1944	410,000
Rosebud and Treasure counties	Oct. 1, 1944	500,000
Fergus County	Oct. 8, 1944	450,000
Cascade County	Oct. 8, 1944	2,000,000
Chouteau county	Oct. 8, 1944	600,000
McCone County	Oct. 9, 1944	1,500,000
Dawson County	Oct. 9, 1944	420,000
Richland County	Oct. 9, 1944	2,530,000
Prairie and Dawson counties	July 8, 1943	200,000

Richland County	July 8, 1943	200,000
Prairie and Dawson counties	July 12, 1943	400,000
Stillwater and Yellowstone counties	Aug. 2, 1943	2,000,000
Daniels County	Aug. 4, 1943	500,000
Chouteau and Teton counties	June 25, 1942	250,000
Sheridan County	July 8, 1942	950,000
Hill County	July 28-30, 1942	400,000
Chouteau County	July 30, 1942	1,500,000
Richland County	June 27, 1941	280,000
Fergus County	July 28, 1941	250,000
Daniels, Sheridan, and Roosevelt counties	July 13, 1940	450,000
North-central counties	Aug. 1, 1940	342,000
Cascade and Teton counties to Sheridan County	June 26, 1934	600,000
Phillips, Sheridan, and Valley counties	July 15-16, 1931	199,300
Kalispell and vicinity	June 16,	

	1931	[a]
Big Horn and Yellowstone counties	Aug. 7, 1931	436,600

[a] Severe but damage not estimated.

NEBRASKA

Nebraska, with its great corn and wheat crops, ranks second among the states in hail damage (Table II in Chapter II). In the ten years ending with 1953 Nebraska had 267 hailstorms, 59 of which were severely damaging. Losses for the ten years totaled $67,643,400, which is an average of $6,764,340 per year. This is more than twice the annual damage by tornadoes. Over a nineteen-year period, approximately two-thirds of the losses to insured crops in the state involved damage to wheat, and about one-fifth was damage to corn.

Insurance companies, for a period of twenty-seven years, show an average loss ratio of $3.52 per $100 of crop insurance. This is for full coverage and for the state as a whole. This ratio is less than that of Kansas or South Dakota but practically double that of Iowa (Table VI in Chapter V).

As in all midwestern states extending into the High Plains, the hail risk increases steadily to the west as elevations increase. In the extreme eastern counties along the Missouri River, where elevations are not much above a thousand feet, the loss ratio of crop insurance ranges from $0.53 to $1.26 per $100 of insurance. Over the western third of the state, where elevations are from three thousand to four thousand feet or more, the loss ratio on full coverage is between $10 and $14. Crop insurance rates for full coverage over much of the high risk areas are as much as $17 to $18 per $100. Consequently, much insurance is written with the usual 10 or 20 per cent deductible clause. Counties having especially high insurance rates are Banner, Box Butte, Cheyenne, Dawes, Deuel, Kimball, and Perkins, all above three thousand feet in elevation.

Cheyenne and Scotts Bluff counties have borne the brunt of four of the most destructive storms Nebraska has ever had, and throughout a period of twenty-seven years these two counties have been struck by more hailstorms than any other part of the state. The official hailstorm record of Cheyenne and Scotts Bluff counties is given below:

County	***Date***	***Estimated Damage***
Cheyenne	July 2, 1953	$6,100,000[a]
Cheyenne	May 26, 1952	600,000
Cheyenne	June 23-24, 1952	1,300,000
Cheyenne	July 13, 1952	150,000
Cheyenne	June 5-25, 1951	3,000,000
Cheyenne to Banner	Aug. 16, 1927	200,000[a]
Scotts Bluff and Sioux	June 25, 1951	3,000,000[a]
Scotts Bluff	Sept. 22, 1948	520,000
Scotts Bluff	June 28-29, 1947	1,500,000

Scotts Bluff and Sioux	July 17, 1944	3,000,000[a]

[a] Part of this loss was in other counties.

A severe storm in the eastern part of the state on July 16, 1920, extending from Antelope County to the Platte River, destroyed practically all vegetation in a path one to six miles wide. On August 29, 1952, a hailstorm in North Platte was so destructive that insurance companies paid an estimated $800,000 on property damage.

An excessively damaging storm moved north of Central City, York County, to the Kansas Line south of Wymore on August 8, 1917. Hailstones were reported "as big as your fist," and others the size of baseballs. In a house in York, hail blew through a window screen, and one hailstone crashed through the window pane and a thick cloth shade. An hour later the owner of the house found a hailstone as large as a hen egg on the bed. Hail marks on the side of the house were so close together there was not space enough to lay a finger between them. High up on the window of the railway station at York there was a smooth hole two inches in diameter in the window pane. Eaves projected above this window four or five feet over the sidewalk. The hailstone must have been blown by an exceedingly violent wind. The tile roof on the Federal Building in York was so badly shattered that three sides had to be replaced.

Great numbers of chickens were killed and young pigs and calves fatally injured. Horses and cattle were pounded and bruised until their bodies were swollen and bleeding from lacerations. Fruit, leaves, and branches were stripped from many trees. Fodder, millet, and prairie hay were beaten to the ground. More than 225,000 acres of corn sustained a 50 per cent loss. Reporting facilities were not adequate to estimate the total damage from this storm.

The Cheyenne County storm of July 2, 1953, which also hit Kimball and Banner counties, was the worst in Nebraska's history. The area involved is all above four thousand feet in elevation. The hail was accompanied by high winds that added to its destructiveness. Loss to crops was $6,000,000 and to other property, $100,000. The storm began in Wyoming and left a path of devastation one hundred miles long and eight to fifteen miles wide. It was estimated that three million bushels of wheat were destroyed.

A violent hailstorm on June 20, 1881, covered a wide territory and seemed to concentrate upon Alexandria, in Thayer County, and Fairbury, in Jefferson County. According to the Omaha *Bee* of October 25, 1929, the storm came with a suddenness that left no time for people to prepare for it. The accounts stated that "great rocks of ice were driven through the air" by the force of the wind and that sidings of houses were split into kindling. Six inches of water fell in less than an hour. Livestock, driven to frenzy by the pounding hailstones, underwent terrific beating. At Alexandria, not only were sidings of houses broken but "pieces of ice" actually pierced the sidings and roofs and pelted the inmates. One report stated that "the hail went through roofs and sidings, breaking dishes and smashing furniture." Accompanied by a tornado-like wind, the hail leveled crops, stripped trees of their foliage, and bruised and battered human beings unfortunate enough to be caught in its fury. No estimate of the total damage was made.

Nebraska has the distinction of reporting the largest hailstones of authentic record. These fell on July 6, 1928, at Potter, in Cheyenne County. The co-operative observer there, Mr. H. Stevens, who had served with complete reliability for seven years, reported that these hailstones measured generally 10 to 14 inches in circumference and 3.2 to 4.5 inches in diameter, but that a few were 17 inches in circumference, With an approximate diameter of 5.4 inches, and weighed a pound and a half. The only other recorded hailstones approaching this size fell in a terrific storm at Dallas, Texas, May 8, 1926, when trustworthy sources reported stones 8 to 12 inches in circumference, weighing twenty-two ounces, and made up of five to eight concentric layers of ice.

Since it is doubtful that updraft winds could have been strong enough to support a hailstone 5.4 inches in diameter and weighing a pound and a half, such as those that fell in the Potter storm, the theory is advanced that updrafts might have existed that were strong enough to delay its fall and that the stone grew in size while falling. As a hailstone passes through that portion of the cloud which is colder than freezing, it must continually pick up super-cooled droplets and occasionally snow as well. Sublimation, also, might possibly add to the size of the hailstones for some distance below the cloud base.[15]

Some Especially Damaging Nebraska Hailstorms

Estimated

Location	*Date*	*Damage*
Chase County	June 12, 1953	$ 205,000
Adams County	June 25, 1953	500,000
Kimball, Banner, and Cheyenne counties	July 2, 1953	6,100,000
Dixon County	Aug. 5, 1953	200,000
Cheyenne County	May 26, 1952	600,000
Morrill County	June 19, 24, 1952	806,000
Clay County	June 23, 1952	500,000
Cheyenne County	June 23-24, 1952	1,300,000
Deuel County	June 26, 1952	675,000
Cheyenne County	July 13, 1952	150,000
Boone County	July 17, 1952	660,000
North Platte and vicinity	Aug. 29, 1952	800,000
Cheyenne County	June 5 & 25, 1951	3,000,000
Furnas and Redwillow counties	June 8, 1951	488,000
Scotts Bluff and Sioux counties	June 25, 1951	3,000,000
Merrick County	Aug. 8, 1951	900,000
Dawson County	Aug. 8, 1950	500,000
North Platte and vicinity	Aug. 29, 1950	300,000
Chase County	May 19 & 23, 1949	2,365,000
Hitchcock County	May 19, 1949	805,000

Garden and Deuel counties	May 22, 1949	512,000
Perkins County	May 23, 1949	811,000
Haigler and vicinity	June 14, 1948	1,800,000
Cuming County	June 16, 1948	1,300,000
Redwillow County	June 21, 1948	2,400,000
Scotts Bluff County	Sept. 22, 1948	520,000
Scotts Bluff County	June 28-29, 1947	1,500,000
Box Butte County	July 21, 1947	3,000,000
Scotts Bluff and Sioux counties	July 17, 1944	3,000,000
Custer County to Gage County	June 20, 1935	1,100,000
Cedar and Knox counties	July 11, 1933	600,000
Lincoln County	Aug. 5, 1932	500,000
North Platte and vicinity	Aug. 5, 1932	500,000
Wheeler County to Boone County	Aug. 6, 1932	500,000
Geneva and vicinity	June 18, 1929	500,000
Banner County to Cheyenne County	Aug. 16, 1927	200,000
Antelope County to Platte River	July 16, 1920	[a]
Merrick County to Gage County	Aug. 5, 1917	[a]
York County to the Kansas line	Aug. 8, 1917	[a]
Thayer and Jefferson counties	June 20, 1881	[a]

[a] Severe but damage not estimated.

NEVADA

Hail losses in Nevada are rare. In four recent years the losses paid on damage to insured crops was only $2,341. About half of this was for damage to wheat. The average rate for crop insurance is $2.52, one of the lowest in any state (Table VI in Chapter V). In twenty-five years the only Nevada loss of consequence reported to the Weather Bureau was $39,000, caused by a hailstorm on July 21, 1943, in Fernley and the surrounding area.

NEW ENGLAND

Noteworthy storms of this area are discussed under individual New England states, listed in general alphabetical order in this chapter.

Some Especially Damaging New England Hailstorms

Location	*Date*	*Estimated Damage*
Boston and Middlesex County, Mass.	June 10, 1952	$ 500,000
Parts of Rhode Island to Hartford, Conn.	July 17, 1951	200,000
Connecticut Valley (Mass., Conn.,	July 20,	[a]

Vt., and N. H.)	1949	
Aroostook and Penobscot counties, Maine	July 31, 1947	250,000
Hartford, Conn., and vicinity	June 8, 1946	600,000
Hampshire County, Mass.	Aug. 23, 1946	150,000
Marlboro, Mass.	Aug. 14, 1938	[a]
Parts of Connecticut and Massachusetts	Aug. 16, 1930	1,500,000
Hartford, Conn., and vicinity	Aug. 1, 1929	1,000,000
North-central Connecticut	Aug. 5, 1927	365,000
Lawrence, Mass., and vicinity	July 17, 1924	75,000
Hartford County, Conn.	Aug. 31, 1920	2,000,000

[a] Severe but damage not estimated.

NEW HAMPSHIRE

The hail risk in New Hampshire is comparatively small. From 1944 to 1953 only two hailstorms were reported in the state, neither severe. The actual damage from hail in the state has not been computed separately but is included in the totals for the

New England area. (Figure 1 in Chapter II).

The loss ratio over the seventeen years ending with 1953 has averaged $1.63. The insurance rate for full coverage of crops is $5.20 (Table VI in Chapter V). Apples constitute the main loss for insured crops. Tobacco suffers little damage, but the rate on tobacco is much higher than on other crops, running as high as $10.44.

Very few heavily damaging storms appear on the state’s record. On July 20, 1949, a storm did great damage along the Connecticut Valley, reaching Merrimack County, New Hampshire, before it finally died out, but the damage there seems to have been very light. Another hailstorm on July 17, 1924, especially destructive at Lawrence, Massachusetts, extended to Salem, New Hampshire, and destroyed practically all crops in the vicinity.

See hailstorms tabulated under New England.

NEW JERSEY

Damage from hail in New Jersey is usually light. In the ten years ending with 1953 the state’s hail losses totaled only $112,300. Over an eighteen-year period the loss ratio of crop insurance has averaged $1.70. The average insurance rate is $3.81 (Table VI in Chapter V). Losses from crop damage average only $8,182 annually. Almost half of this involves damage to the tomato crop and about one-fifth is for damage to peaches. Both crops are easily damaged, even by light hail.

The most destructive hailstorm reported in the state in twenty-five years occurred June 7, 1926, in Cumberland County. Truck gardens, fruit, and plant beds were destroyed over a path three to four miles long. The loss was estimated at $150,000.

Some Especially Damaging New Jersey Hailstorms

Location	***Date***	***Estimated Damage***
Camden, Hunterton, and Burlington counties	July 19, 1951	$ 26,000
Bound Brook and vicinity	May 17, 1948	50,000
Cumberland County	June 7, 1926	150,000
Princeton to Freehold (near)	June 12, 1918	30,000
Gloucester, Camden, Burlington, and Atlantic counties	July 12, 1918	8,000

NEW MEXICO

In New Mexico the hail risk is high but actual hail damage is comparatively low, largely because the population is scattered and much of the land is unproductive. In the ten years ending with 1953 only seventy-nine hailstorms were reported, twelve of which were severe. It is very probable that many hailstorms that strike the desert areas have not been reported. Hail losses for the ten years totaled $4,061,100. Hailstorms in New Mexico occur mainly in the months of June, July, and August, between 1:00 P.M. and 7:00 P.M. (Tables III and IV in Chapter III).

The loss ratio of crop insurance has averaged $7.70 over a period of nineteen years (Table VI in Chapter V). The average insurance rate for full coverage is $13.31 and is exceeded only by that of Wyoming and Colorado. Because of the high rates necessary, practically all crop insurance policies carry the 10 or 20 per cent deductible clause. The greatest hail risk and, consequently, the highest rates are in the eastern section of the state. In Colfax, Lea, and Roosevelt counties the loss ratio, computed on the basis of full coverage, averages $12.41 to $18.50. Over 80 per cent of insured losses has been to wheat and 10 per cent to cotton.

In a twenty-nine-year period New Mexico reported thirteen hailstorms that caused losses of $100,000 or more each, and one of these resulted in damage that amounted to $500,000. This storm struck Roswell and vicinity on May 20, 1951, with excessive damage to roofs, greenhouses, and plants in the city. Eight hundred acres of crop land were hit. Roswell reported destructive hail four times in the eight years preceding 1954. One on May 12, 1950, damaged crops in the vicinity to the extent of $190,000, and damage to roofs in the city itself amounted to $50,000. Another Roswell hailstorm, on the evening of May 16, 1947, caused a loss of $300,000 to nine thousand acres of cotton and five hundred acres of small grains. The path of the storm was two miles wide and thirty miles long. Hail accumulated to depths of four to five inches over much of the area. The fourth Roswell hailstorm occurred on June 2, 1946, with total damage amounting to $200,000.

On August 20, 1953, hail at Estancia and vicinity, in Torrence County, brought losses of $200,000, mainly to crops. A hailstorm at Portales, on the afternoon of June 18, 1951, resulted in another $200,000 loss to row crops, wheat, and alfalfa. Other property damage amounted to $75,000.

Some Especially Damaging New Mexico Hailstorms

Location	***Date***	***Estimated Damage***
Dona Ana County	June 11, 1953	$100,000
Estancia and vicinity	Aug. 20, 1953	200,000
Roswell and vicinity	May 20, 1951	500,000
Colfax County	June 11-12, 1951	130,000
Portales and vicinity	June 18, 1951	275,000
Roswell and vicinity	May 12, 1950	240,000
Clayton and vicinity	Sept. 10, 1950	80,000
Tucumcari	June 15, 1948	250,000
Portales and vicinity	May 4, 1949	125,000
Cimarron	Aug. 20, 1949	100,000
Roswell and vicinity	May 16, 1947	300,000
Roswell and vicinity	June 2, 1946	200,000
Las Vegas and vicinity	June 22, 1939	250,000
Ft. Hancock (near)	Sept. 12, 1925	200,000

NEW YORK

New York, with its wide-spread acreages of vegetables and fruit and its dense population, offers excellent targets for hail, but fortunately its hailstorms are rare and their paths cover a smaller area than in almost any other part of the country, averaging only a mile in width and five miles in length.

In the decade ending with 1953 only nineteen hailstorms were reported, and only five of them were severe. Nearly all occurred in the three summer months and in the afternoon (Tables III and IV in Chapter III). In a twenty-nine-year period twenty storms resulted in losses ranging from $100,000 to $750,000 each. Most of them were in the southern and western parts of the state.

Experience of hail insurance companies indicates that the hail risk to crops is comparatively small. The loss ratio for insured crops averaged only $2.15 over a seventeen-year period (Table VI in Chapter V). The average rate of crop insurance for the state as a whole is $3.73. Over 50 per cent of losses to insured crops has been to apples and 10 per cent to the grape crop. Tobacco is one of the high risk crops, with a loss ratio of $4.98 and an insurance rate of $8.03. Counties having the highest loss ratio are: Broome County, $4.45; Chemung County, $3.92; Columbia, $5.31; Ulster, $4.99; and Greene, $9.42.

The most destructive New York hailstorm occurred in central and southern Wayne County, near Lake Ontario, on the afternoon of July 23, 1946, with losses totaling $750,000. Orchards and vegetables on muck land were especially damaged. Another severe storm struck Otsego County, near Niagara Falls, August 16, 1951. The crop loss was $500,000. The hailstones, some as large as baseballs, were driven by a high wind. In Gilbertsville, alone, twenty-five hundred window panes were broken.

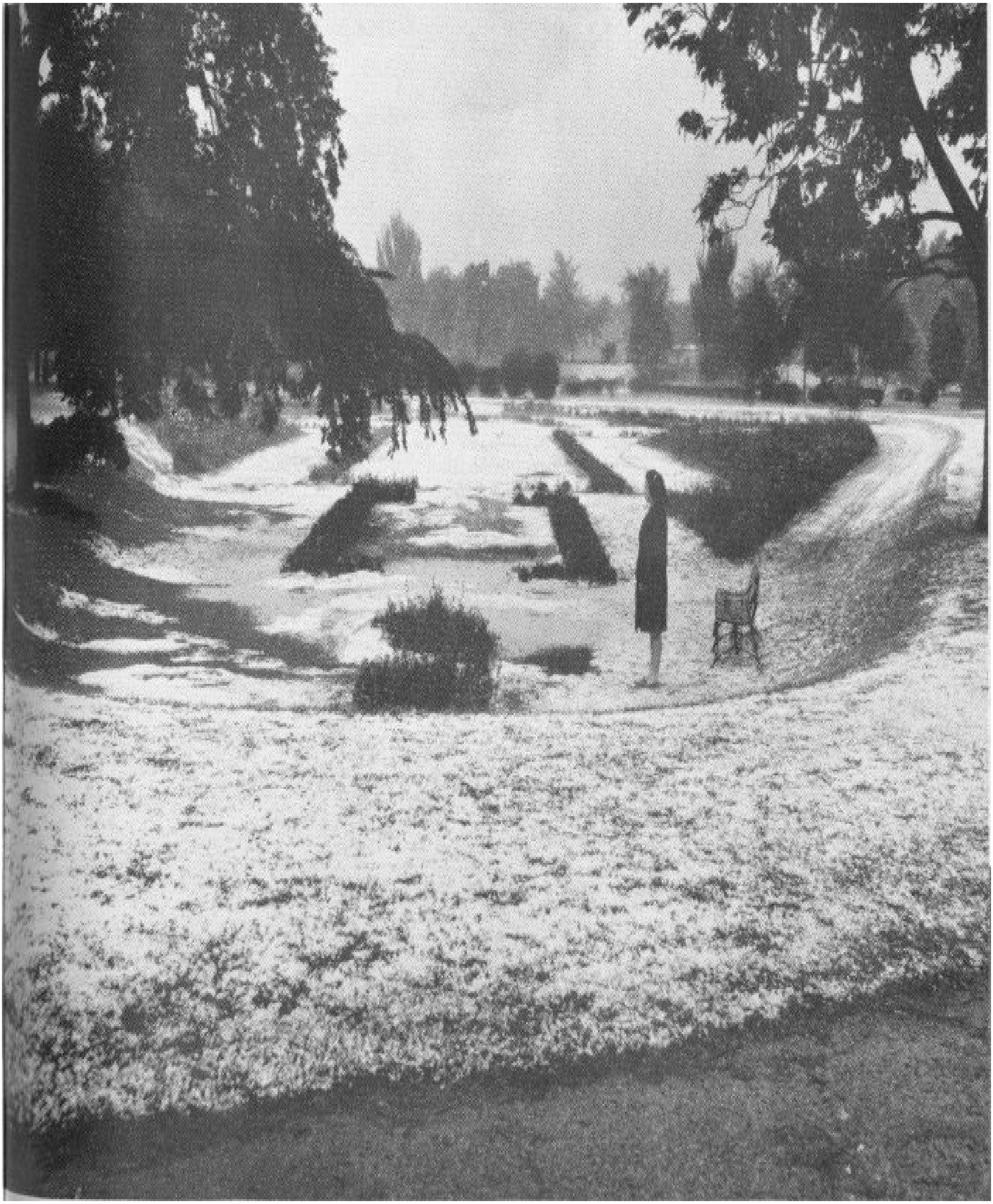
Four hailstorms have struck rather close to New York City but not in the city itself. Two of these were in Rockland County, the first on July 10, 1939, with a loss of $90,000; the second one on July 21, 1926, with damage amounting to $102,000. One hailstorm occurred in the vicinity of the city on May 23, 1925, damaging the area to the extent of $250,000. In Orange and Ulster counties a hail loss on June 29, 1925, amounted to $200,000.

Some Especially Damaging New York Hailstorms

Location	***Date***	***Estimated Damage***
Otsego County	Aug. 16, 1951	$500,000
Genesee County	July 11, 1947	250,000
Rockland County	July 21, 1946	102,000
Wayne County	July 23, 1946	750,000
Wayne County	Sept. 29, 1946	100,000
Niagara County	Sept. 1, 1940	205,000
Rockland County	July 10, 1939	90,000
Genesee County to Schuyler County	Aug. 1, 1935	500,000
Au Sable Chasm into Clinton County	Aug. 4, 1935	250,000

Buffalo and vicinity	June 15, 1934	100,000
Oswego County	July 12, 1934	500,000
Swormville	July 15, 1934	105,000
Lodi and vicinity	Aug. 13, 1933	100,000
Troy to Glens Falls	June 19, 1930	100,000
Marathon (near)	Aug. 7, 1927	100,000
Albany County	Aug. 29, 1927	500,000
Ontario County	June 26, 1926	300,000
New York City and vicinity	July 25, 1925	250,000
Esopus, Marlboro, and Cornwall	June 29, 1925	200,000
Linwood and vicinity	July 25, 1925	250,000
North-central part of the state	Aug. 19, 1925	115,000

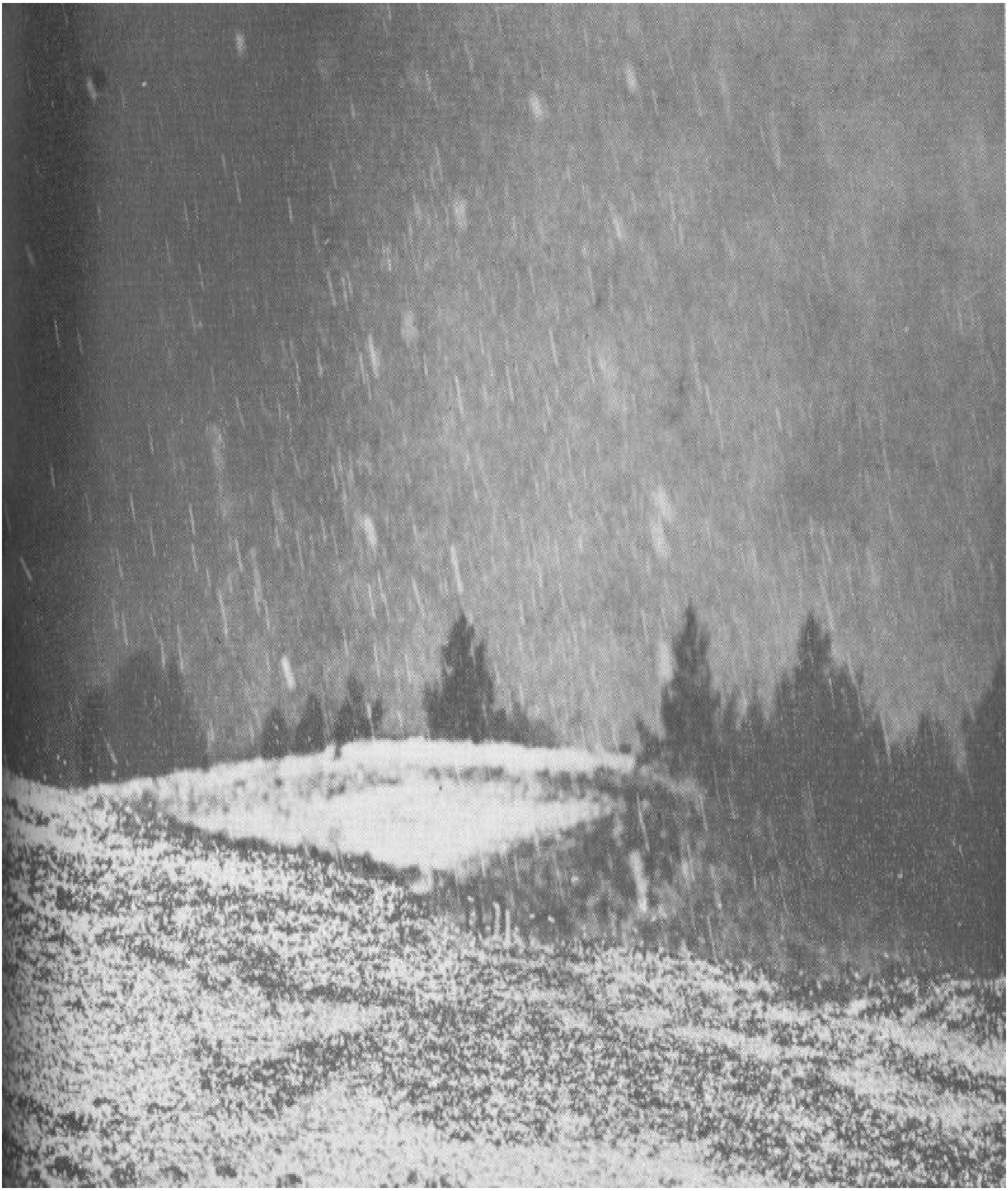
Scenic Falls of Hail



A cover of hail in the famous sunken gardens of Denver, Colorado, August 26, 1944. This storm resulted in a million-dollar loss to Denver and the vicinity. Courtesy U. S. Weather Bureau.

Hailstones as big as baseballs rained on Memphis, Tennessee, in a freak twenty-minute storm causing extensive damage on March 26, 1944. Courtesy "Acme Photo."

Hail near Ada, Oklahoma, May 24, 1940. Level ground was covered six to eight inches deep, with drifts five feet deep in places. Highways were blocked by the *accumulation.*



Hailstorm in the Himalayas, 1924. India is noted for its deadly and damaging hailstorms. Here we see one in action. Courtesy U. S. Weather Bureau.

Hail at Conchas Dam, New Mexico, April 19, 1937. Hailstones in this storm were from one-half to an inch and a quarter in diameter and covered the ground as thickly as heavy snow.

Hailstones at Aurora, Illinois, May 1, 1933. Some of these stones weighed half a pound and were seven and one-half inches long. Courtesy Alice M. Holden.

NORTH CAROLINA

Losses from hail damage in North Carolina average three times that of any other state east of the Mississippi River, and these losses are fifty times greater than tornado losses in the state. Only six other states have reported heavier damage from hail. It is not the high incidence of hail in this state that causes this excessive loss but the fact that North Carolina is our chief tobacco-producing state and tobacco is a particularly vulnerable crop.[16] It is a heavy insurance risk, for two reasons. It has an extremely high value per acre and is especially susceptible to hail damage because of its broad, spreading leaves. The average path of a hailstorm in North Carolina is two miles wide and nineteen miles long, an area of thirty-eight square miles. The value of a tobacco field within such an area can run as high as $500 per acre.

Consequent to such conditions of risk, a high proportion of the tobacco crop is always insured. The average annual risk covered by insurance in North Carolina is $40,012,438, exceeding that of any other state. The average annual loss for insured crops is $1,064,957, exceeded only in Kansas (Table VI in Chapter V). The loss ratio over a thirty-year period in the state averaged $2.60 and the rate of insurance averaged $4.76 (Table VI in Chapter V). In a few counties it runs as high as $5.24 to $7.08. Over a period of thirty years 98 per cent of the losses to insured crops represented damage to tobacco.

Hail occurs in almost every part of the state. In the thirty-three years ending with 1953 forty-two hailstorms brought losses of at least $100,000 each, and in three of them, losses exceeded

$1,000,000 each. Thirty-two of these storms were reported during the last ten years of the period, when a closer network of reporting stations enabled the Weather Bureau to obtain more comprehensive coverage. A total of 187 hailstorms was recorded from 1944 to 1953, ninety per cent of which struck in May, June, July, and August, just as tobacco was developing (Table IV in Chapter III). The hail loss for the ten-year period amounted to $31,715,516.

The most damaging hailstorm in North Carolina occurred on the afternoon of July 30, 1952, with losses totaling $1,732,000. Its path encompassed one hundred and fifty square miles in Buncombe, Guilford, Ashe, Alleghany, Alexander, Davie, Rockingham, Granville, Forsyth, Caswell, Cumberland, Sampson, Wilson, and Beaufort counties. Another hailstorm, extending from Beaufort County to Pitt County between 4:00 P.M. and 7:00 P.M. of June 27, 1951, caused losses of $1,150,000, the second greatest loss in the state's history. Damage to crops, mainly tobacco, amounted to $1,100,000. The heaviest destruction was in Pitt County.

On April 28, 1921, in Anson County, hailstones ranging from the size of hen eggs to that of baseballs destroyed gardens, grain fields, and trees. Pine trees in the path of the storm were so badly damaged that they had to be cut for lumber. Losses from this storm were not estimated.

One of the most destructive of North Carolina storms struck between 3:00 P.M. and 5:00 P.M. on June 14, 1951, in the north-central part of the state with a loss of $1,020,000 over an area of two hundred square miles. Crop damage, mainly to tobacco, amounted to $1,000,000 of this loss. The counties hit were

Franklin, Nash, Caswell, Person, Wake, and Wilson. Another damaging hailstorm, in the eastern part of the state, swept over much of Bertie, Halifax, and Northampton counties on June 1, 1953, covering an area of eighty square miles. The heaviest damage was to cotton in Northampton County. Total losses amounted to $655,000.

On June 25, 1938, hail in Wayne, Greene, Pitt, and Nash counties resulted in a loss of $500,000. Many growers reported their tobacco crops a complete loss. Cotton and corn were also damaged. A storm moving from Virginia into Rockingham County on August 26, 1946, brought a $900,000 loss, mainly to corn and tobacco, over a forty-mile path in Rockingham and Guilford counties. A hailstorm, the damage of which was confined to city property, struck Asheville on June 18, 1936. Hailstones measuring two to three inches in diameter damaged windows, street lamps, automobiles, and roofs to the extent of $10,000.

Some Especially Damaging North Carolina Hailstorms

Location	***Date***	***Estimated Damage***
Beaufort to Sampson County	May 19, 1953	$ 165,000
Pender County	May 21, 1953	132,000
Carteret County to Robeson County	May 31, 1953	172,000
Bertie, Halifax, Northampton counties	June 1, 1953	655,000
Brunswick County to Wilson	June 13,	515,000

County	1953	
Warren County	June 19, 1953	210,000
Pamlico County to Graham County	July 3, 1953	310,000
Buncombe County to Wilkes County	April 13, 1952	110,000
Robeson and Pitt counties	June 5, 1952	500,000
Pitt County to Cumberland County	June 9, 1952	100,000
Alleghany County to Harnett County	June 28, 1952	200,000
Edgecombe County to Davidson County	July 14, 1952	130,000
Durham County to Yadkin County	July 15, 1952	120,000
Hoke and Robeson counties	July 22, 1952	100,000
Bertie County to Wilson County	July 23, 1952	367,000
Bertie County to Yadkin County	July 29, 1952	260,000
Buncombe County to Beaufort County	July 30, 1952	1,732,000
Rockingham County	Aug. 18, 1952	525,000
North-central area of the state	June 14, 1951	1,020,000

North-central area of the state	June 26, 1951	626,000
Beaufort County to Pitt County	June 27, 1951	1,150,000
Forsyth County	July 18, 1951	270,000
Surry County	July 19, 1951	204,000
Iredell County	May 26, 1950	350,000
Franklin County	July 15, 1950	180,500
Forsyth County	Aug. 21, 1950	100,000
Yadkin County	Aug. 21, 1950	462,000
Cleveland County, near Shelby	June 19, 1947	500,000
Wake and Chatham counties	June 20, 1947	100,000
Vance County	July 14, 1947	100,000
Apex and vicinity	May 27, 1946	100,000
Gibsonville to Cedar Grove	Aug. 26, 1946	900,000
Wayne, Greene, Pitt, and Nash counties	June 25, 1938	500,000
Edgecombe, Wilson, and Greene	Aug. 2,	100,000

counties	1937	
Guilford County	May 14, 1935	300,000
Cumberland County to Wayne County	July 9, 1930	150,000
Scotland, Robeson, and Pitt counties	May 12, 1927	100,000
Chowan County to Lenoir County	June 21, 1925	250,000
Iredell County to Mecklenburg County	June 14, 1924	250,000
Vance County	Sept. 1, 1924	250,000
Princeton and vicinity	May 13, 1922	500,000
Anson County	April 28, 1921	[a]

[a] Severe but damage not estimated.

NORTH DAKOTA

North Dakota, with its great wheat and barley crops, ranks fifth among the states in hail damage (Table II in Chapter II). The average annual hail loss for the state over the ten-year period ending with 1953 was $3,443,400, fifty times the loss from tornadoes. Apparently, most of the state’s losses from hail have been from storms of limited extent, many of which were not reported. In the same ten-year period only fifteen hailstorms were reported, nine of which were severe. Nearly all occurred in June, July, and August, when wheat and barley were either reaching their full growth or approaching harvest (Table IV in Chapter III). Total damage for the period was $34,434,000.

The loss ratio in North Dakota averaged $2.96 over a twenty-seven-year period. This is less than for South Dakota or Montana but greater than that of Minnesota. The average rate of insurance in the state as a whole is $6.27 (Table VI in Chapter V). Over 60 per cent of losses to insured crops has been to wheat and 13 per cent to barley.

As in all midwestern states that extend to the High Plains area, the risk of hail in North Dakota increases with elevation from east to west. In the extreme eastern counties the loss ratio ranges from $0.87 to $1.30. In the middle section it rises to between $3.05 and $5.74 and in the western counties as high as $10.00 to $16.00. Insurance rates in that area, for full coverage, range between $10.00 and $16.00 and even higher in some localities. For this reason much crop-hail insurance is written with a 10 or 20 per cent deductible clause.

North Dakota Counties Having a High Hail Risk [a]

County	***Loss Ratio***	***Insurance Rate (Full Coverage)***
Bowman	$ 8.54	$12.80
Divide	10.28	12.65
Billings	5.85	12.07
Dunn	5.45	10.36

Golden Valley	16.40	12.00
McKenzie	14.10	11.59
Mountrail	6.46	10.10
Slope	9.33	13.71
Williams	6.50	11.59

[a] All of these counties are in the western part of the state, with elevations near or above three thousand feet.

The most damaging hailstorm in the history of North Dakota struck Bismarck and vicinity about 5:00 P.M. on July 26, 1949, devastating a path five to ten miles wide from Mandan to McKenzie. Hailstones up to two and a half inches in diameter were driven by high winds. There was heavy damage to automobiles and buildings. Almost every house in the northern part of Bismarck had some damage to windows, roofs, and sidings. Losses in the city itself totaled $1,000,000. The crop loss was not estimated.

On July 1, 1952, McKenzie County suffered hail losses amounting to $400,000, of which $250,000 was to crops. The storm path was six to eight miles wide and twenty to thirty miles long, extending from Watford City to the vicinity of Alexander. Crops in the area were completely destroyed. A hailstorm twenty miles northeast of Dickinson on July 19, 1953, resulted in a loss of $100,000. A farmer measured twenty-two inches of hail in ditches after the storm.

Some Especially Damaging North Dakota Hailstorms

Estimated

Location	*Date*	*Damage*
Dickinson (near)	July 19, 1953	$ 100,000
McKenzie County	July 1, 1952	400,000
Emmons, Logan, and McIntosh counties	July 16, 1951	100,000
McHenry County	July 28, 1951	[a]
Morton and Dunn counties	Aug. 16, 1951	[a]
Marmarth and vicinity	Aug. 26, 1951	[a]
Mountrail County to McHenry County	July 14, 1950	17,000
Bismarck and vicinity	July 26, 1949	1,000,000
Grant County	May 28, 1949	150,000

[a] Severe but damage not estimated.

OHIO

Hail risk over Ohio is comparatively light. Damages for the 1944-53 period totaled only $529,550. Only fifteen hailstorms were recorded for the state in that period, and only three were severe. Most of them occurred in the afternoon between May 1 and September 30 (Tables III and IV in Chapter III). The paths of these storms were exceptionally long, averaging thirty-two miles.

Over a twenty-year period the loss ratio for crop insurance has averaged $0.92, which is one of the lowest in the country. The average insurance rate for all crops is $2.67 (Table VI in Chapter V). Twenty-three per cent of all losses to insured crops has been to corn, 18 per cent to vegetables, 11 per cent to wheat, and 10 per cent to tobacco. Ohio produces a wide variety of truck and fruit crops, which generally take a higher insurance rate than corn and wheat. Some crops on which the risk is especially high are apples and other tree fruits, berries, vine crops, and tobacco. The loss ratio for insured tobacco averages $1.37 and the average insurance rate on it is $4.62.

In twenty-two years only five especially damaging hailstorms have been reported. The most destructive of these struck the northwestern, central, and south-central parts of the state on July 7, 1932, with losses amounting to $800,000. Crops sustained most of this damage. Two storms three days apart, on May 23 and 26, 1951, caused a loss of $425,000 in the vicinities of Waynesville and Middletown. Loss to crops, mainly hay, wheat, and corn, totaled $300,000.

Some Especially Damaging Ohio Hailstorms

Location	***Date***	***Estimated Damage***
Waynesville and Middletown	May 23 & 26, 1951	$425,000
Ashtabula	June 24, 1951	55,000

Adams County	July 28, 1950	[a]
Erie County	July 22, 1938	100,000
Northwestern and central areas	July 7, 1932	800,000

[a] Severe but damage not estimated.

OKLAHOMA

Oklahoma ranks ninth among the states in hail damage. In the ten years ending with 1953 its hail losses totaled $29,256,725, an average of $2,925,672 per year (Table II in Chapter II). This is approximately twice as great as the state's tornado damage. Hail damage in Kansas is almost four times that of Oklahoma, while Texas, on the basis of relatively equal areas, shows considerably less damage from hail than does Oklahoma. During the 1944-53 period, Oklahoma reported 230 hailstorms, and 34 of them were classed as severe. Eighty per cent of these storms occurred in April, May, and June, with 40 per cent in May, just when the wheat crop was most susceptible to hail damage. Most of them struck between 3:00 P.M. and 10 P.M., although several severe storms were reported between 10:00 P.M. and 6:00 A.M. (Tables III and IV in Chapter III).

For a period of thirty years ending in 1953 the loss ratio in Oklahoma averaged $3.89, which is higher than that of most states (Table VI in Chapter V). The average crop-hail insurance rate for the state as a whole is $5.86. Ninety per cent of losses to insured crops has been to wheat and 4 per cent to oats and cotton. Hailstorm losses to corn have been relatively small.

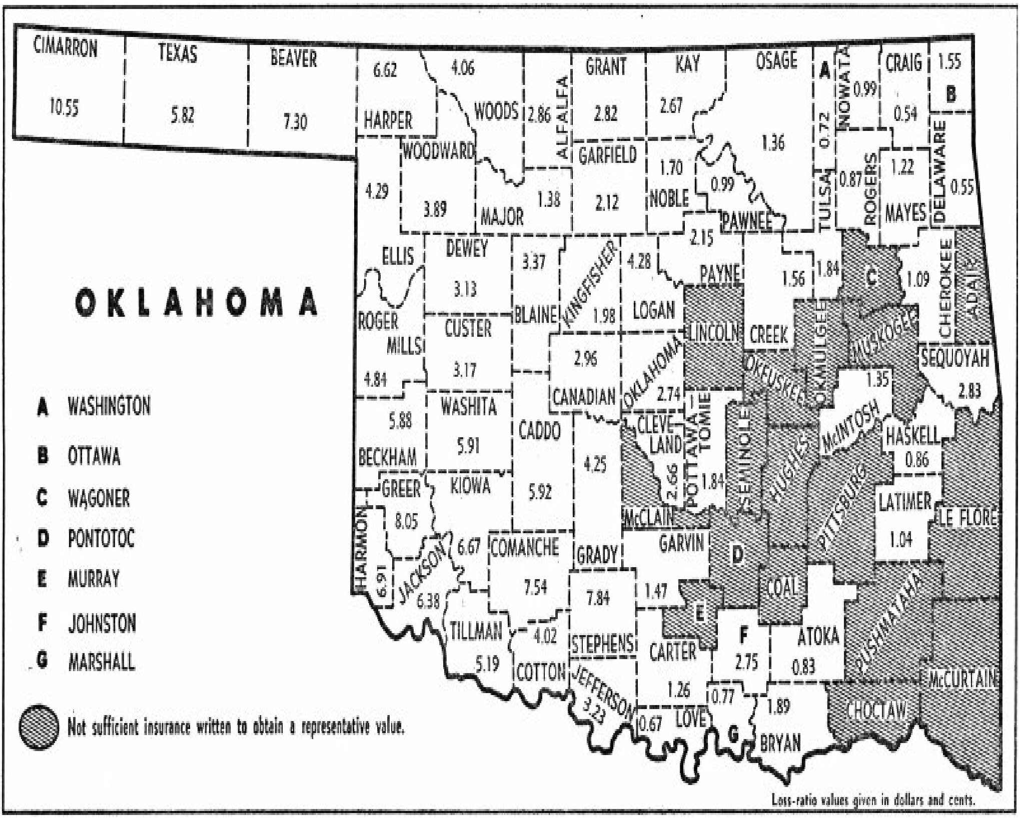


FIG. 12.—*Crop Hail Risk Over Oklahoma During the Thirty-Year Period Ending with 1953. In many parts of the extreme western area, 8 to 10 per cent of the crops, chiefly wheat, is hailed out annually.*
(*Data compiled by the Crop-Hail Insurance Actuarial Association, Chicago Illinois.*)

Oklahoma’s hail risk increases with regularity from east to west as elevations increase (Figure 12). Along the eastern border the loss ratio is little more than $1.00 for each $100 of crop insurance written. West of the line from Kay County to Tillman County, which is roughly the thousand-foot contour line, the loss ratio ranges well above $2.00. In the western tier of counties south of the panhandle, where elevations rise to two thousand feet, the loss ratio increases to between $4.00 and $6.00 or more. In the panhandle, where elevations are between three thousand and four thousand feet and even higher, the loss ratio is well above $10.00. Crop insurance rates increase in proportion to the loss ratio, ranging from $3.00 for full coverage in the eastern third of the state to between $6.00 and $12.00 in the western part, including the panhandle. Here most policies carry the 10 per cent or the 20 per cent deductible clause.

In a thirty-one-year period ending with 1953, fifty hailstorms in Oklahoma caused losses of $100,000 or more each. Ten of these caused damage amounting to $1,000,000 or more each. The most destructive hailstorm on record in the state occurred late in the evening of May 31, 1949, in Jackson, Greer, and Kiowa counties, with an estimated loss of $2,500,000. Kiowa County took the brunt of the storm, with heavy damage over an area of one hundred square miles.

Oklahoma City has had eight severe hailstorms. Since no other place in the state has reported anything like this number, it is considered very likely that many severe storms in other areas of the state have not been reported (Table V in Chapter III). The most damaging hailstorm in Oklahoma City was on the evening of September 18, 1923. Losses amounted to $1,000,000. It was especially severe in the northwestern and western parts of the city. Hailstones as big as hen eggs, driven through windows by high winds, damaged woodwork and floors fifteen to twenty feet from the windows. Weather boarding was dented as if by a hammer, and shingles were split apart. Another Oklahoma City hailstorm, late in the evening of September 12, 1950, resulted in a total loss of $987,000, chiefly in the southern part of the city. Damage was most severe in the Capitol Hill section and adjacent suburban areas. Some four thousand homes, three hundred business houses, and seven hundred and fifty automobiles suffered severe damage.

A terrific hailstorm, accompanied by high winds, struck in the Lawton-Fort Sill area on the late afternoon of March 13, 1953. In Lawton, losses amounted to $750,000. There were more than thirteen thousand insurance claims filed in the city. Extensive damage to aircraft occurred in the Fort Sill area. Total losses from the storm were estimated at $1,900,000. A month later, on April 14, between 5:00 P.M. and 7:55 P.M., a hailstorm moving in a southeasterly direction from Blaine County to Cleveland County, caused a loss of $1,500,000, of which $800,000 was to crops and $700,000 to other property. Calumet, El Reno, Mustang, Norman, and Tuttle were in the storm's path. Damage in El Reno was estimated at $300,000. Crop damage was mostly to wheat and other fall-sown crops in Canadian County.

Three days later, on April 17, 1953, between 6:30 P.M. and 8:00 P.M., a storm of hail, snow, rain, sleet, and some glaze moved through Kay, Creek, Tulsa, Osage, Rogers, and Washington counties with a loss of $50,000 to crops and $1,000,000 to other property. There were several areas of complete crop destruction, including a strip extending east and west just north of Ponca City, with the heaviest crop damage in western Kay County in an area around Nardin. In and near Tulsa there was extensive damage to windows, roofs, automobiles, aircraft, and hangars. There were between six thousand and ten thousand claims for insurance, totaling over $1,000,000. This was one of the few severe hailstorms accompanied by snow, sleet, and glaze.

Another million-dollar hail loss occurred in Harmon County on the early morning of June 7, 1937. More than three inches of hail covered the ground in low places. Hail in gullies accumulated to depths of several feet. More than a thousand acres of wheat, sixty thousand acres of cotton, and ten thousand acres of grain sorghums were a total loss.

There was a spectacular fall of heavy hail near mid-day on June 10, 1950, in Harper, Dewey, and Custer counties in a path eight to thirty miles wide and one hundred miles long. Losses amounted to $710,000, of which $650,000 was to wheat and other crops. The heaviest hail fell near Fay, Custer County, where an area half a mile wide and a mile long was swept completely clean. Cattle, chickens, rabbits, and many other animals were killed. At Aledo, Custer County, hail stripped the bark from trees. Damage to houses amounted to $60,000. At Mutual, hail on the ground accumulated to a depth of four inches.

One of the heaviest falls of hail ever reported in Oklahoma was from Seminole to Ada on May 20, 1940. It was six to eight inches deep on level ground, with drifts five feet deep. Traffic was blocked on Highway 99 from Konawa to Ada until highway graders could remove the accumulation. Vegetation and trees presented a midwinter appearance. No adequate estimate of the damage could be made.

Some Especially Damaging Oklahoma Hailstorms

Location	***Date***	***Estimated Damage***
Lawton and Fort Sill areas	Mar. 13, 1953	$1,900,000
Blaine County to Cleveland County	April 14, 1953	1,500,000
Kay County to Washington County	April 17, 1953	1,050,000
Washita County	June 5, 1953	105,000
Stephens County	June 5, 1953	675,000
Lawton and vicinity	April 30, 1952	1,500,000
Blaine and Kingfisher counties	April 30, 1952	204,800
Beckham County and Washita County	May 22-23, 1952	1,313,000
Kingfisher and Logan counties	May 23, 1952	2,045,000
Beckham and Washita counties	May 23, 1952	100,000
Alfalfa County	June 4, 1952	251,450
Grant, Garfield, and Kay counties	Aug. 5-6, 1952	1,600,000
Kay County	May 19,	200,000

	1951	
Alfalfa County	June 20-21, 1951	400,000
Cimarron and Texas counties	June 21, 1951	400,000
Beaver, Harper, and Woodward counties	June 23-24, 1951	618,000
Stillwater and vicinity	April 2, 1950	925,000
Pottawatomie County	April 2, 1950	343,000
Harper County to Custer County	June 10, 1950	710,000
Enid and vicinity	June 27, 1950	400,000
Oklahoma City	Sept. 12, 1950	987,000
Tillman County	May 8, 1949	500,000
Altus and vicinity	May 18, 1949	390,000
Gould and vicinity	May 18, 1949	410,000
Jackson, Greer, and Kiowa counties	May 31, 1949	2,500,000
Tillman County	May 12, 1948	300,000
Ellis, Harper, and Woodward counties	June 8, 1948	250,000
Oklahoma City	May 16, 1943	750,000

Altus	Oct. 22, 1943	250,000
Custer County	April 10, 1940	260,000
Seminole to Ada	May 20, 1940	[a]
Weatherford	July 1, 1940	300,000
Ottawa and Craig counties	Aug. 24, 1939	500,000
Washita County	May 6, 1938	255,000
Arnett and vicinity	June 14, 1938	500,000
Harmon County	June 7, 1937	1,250,000
Burlington, Cherokee, and Helena	June 9, 1937	350,000
Oklahoma City	Feb. 23, 1936	[a]
Lawton and vicinity	June 3, 1936	298,000
Ardmore	Oct. 6, 1936	300,000
Okmulgee County	March 11, 1935	200,000
Guthrie	March 23, 1935	125,000
Ponca City	April 17, 1935	500,000
Braman and vicinity	April 17, 1935	750,000
Major County to Washita County	May 12, 1930	450,000

Cotton and Jefferson counties	Aug. 22, 1930	325,000
Harper County	June 20, 1928	850,000
Westville and vicinity	June 1, 1927	360,000
Blaine County	July 10, 1927	200,000
Tillman County	Sept. 13, 1925	500,000
Stephens, Garvin, and Comanche counties	Oct. 14, 1925	750,000
Oklahoma City	Sept. 18, 1923	1,000,000
Oklahoma City	March 22, 1917	9,500
Oklahoma City	March 22, 1915	[a]
Oklahoma City	April 12, 1911	[a]
Oklahoma City	April 25, 1909	[a]

[a] Severe but damage not estimated.

OREGON

Hail is more frequent along the coastal zone of Oregon than in almost any other part of the country, but it is small hail that does little damage. Most of it falls in the winter season. In the middle and eastern parts of the state, hail is much less frequent. The hailstones are generally no more than one-half inch in diameter but capable of causing real damage to tree fruits in the limited areas in which these are grown. The total damage to fruit has been comparatively small but, owing to the high value of these crops per acre, the possibility of small or moderately large hail pitting or bruising the fruit, thus making it unfit for market, causes much anxiety on the part of growers. Ninety per cent of Oregon's losses to insured crops has been to wheat, 3 per cent to tree fruits, and 5 per cent to peas and beans.

In the ten years ending with 1953 five hailstorms were reported, three of which were severe (Table IV in Chapter III). Hail damage over that period totaled $1,141,000. The heaviest losses to insured crops occurred in 1947. The average loss ratio for the state over a twenty-six-year period is $0.74, one of the lowest in the country. The average rate for crop-hail insurance is $2.05, but this rate varies with different crops. For tree fruits it is $3.89; for bush berries, $4.96; and for strawberries, $4.20.

Two outstanding hailstorms occurred in 1948. The most destructive of these was on August 4, near Pendleton and Adams, in Umatilla County. Hailstones as large as apricots destroyed eight thousand acres of wheat. Damage was estimated at $250,000. The second storm was four days later, on August 8, near Bonneville. It resulted in severe damage to wheat, potatoes, and hay over a path twenty miles long. Hailstones up to an inch in diameter caused losses estimated at $100,000.

PENNSYLVANIA

Hailstorms have not been numerous in Pennsylvania nor particularly damaging. During the thirty-three years ending with 1953 only ten damaging storms were reported, none of which caused losses exceeding $500,000. In the last ten years of that period only six hailstorms out of a total of thirty were severely damaging. More than a third of this total number of hailstorms occurred in the month of May (Table IV in Chapter III).

Insurance company data reveal that over a seventeen-year period the loss ratio has averaged $2.44. The insurance rate for the state as a whole averages $4.42 (Table VI in Chapter V). This indicates a hail risk to crops greater than that of Ohio or New York but considerably less than that of West Virginia. Approximately 60 per cent of losses to insured crops has been to apples and 14 per cent to tobacco.

A hailstorm accompanied by high winds struck Meadville, Pennsylvania, and vicinity on June 26, 1950, between 2:30 P.M. and 6:00 P.M. It was almost as severe as any ever reported in the United States. Some of the hailstones measured five and a half inches in diameter and weighed thirteen ounces. Windows were broken in more than a third of Meadville’s homes. Two thousand panes were broken in greenhouses, incurring a loss of $6,000. Two hundred panes were smashed at the sewage plant. A Blooming Valley farmer picked up a bushel basket of hailstones that averaged eight and one-half inches in circumference. As these large hailstones struck the ground they bounced ten feet into the air without breaking. Two persons were injured by them. No estimate was made of the storm's total damage.

On June 13, 1936, a hailstorm in the eastern part of Adams County caused damage amounting to $300,000. It was especially severe in Abbotstown, East Berlin, and Orrtanna. In some places hail accumulated in drifts eighteen inches deep and remained for twenty-four hours. Near Uniontown, in Fayette County, on the afternoon of May 11, 1951, hailstones bombarded New Salem, breaking hundreds of windows and battering automobiles, roofs, trees, and gardens. As large as four inches in circumference, these hailstones drifted a foot deep in places. A hailstorm near West Chester, Chester County, on August 31, 1922, left drifts three feet deep and seventy feet long. Some of the hailstones washed into a level field and covered more than an acre to a depth of twelve inches. The total damage was not estimated.

Some Especially Damaging Pennsylvania Hailstorms

Location	***Date***	***Estimated Damage***
Uniontown	May 11, 1951	[a]
Meadville and vicinity	June 26, 1950	[a]
Spring Grove	June 28, 1946	$ 26,000
Carlisle and vicinity	Aug. 4, 1943	500,000
Wilkes-Barre and vicinity	July 6,	350,000

	1942	
Greene County to Westmoreland County	May 23, 1938	75,000
Adams County	June 13, 1936	300,000
Lock Haven (near)	July 22, 1933	100,000
Chester County	June 25, 1924	275,000
West Chester (near)	Aug. 31, 1922	[a]

[a] Severe but damage not estimated.

RHODE ISLAND

In the small area of Rhode Island, hail damage has not been very extensive, and the total is not known. For the eighteen years ending with 1953 losses to insured crops amounted to only $20,816. From 1944 to 1953 only one hailstorm was reported. It was a boundary-crossing storm from Connecticut on July 17, 1951, incurring losses of $200,000, but apparently most of its damage was in Connecticut.

Experience of crop insurance companies shows a rather high loss ratio for Rhode Island, but this is due to the fact that most of the hail risk is on apple and tomato crops, which are easily damaged by hailstones of almost any size. The rate for crop insurance is $5.66. Seventy-six per cent of losses has been to apples and 23 per cent to tomatoes.

SOUTH CAROLINA

South Carolina produces only about 16 per cent as much tobacco as North Carolina. Consequently, its hail losses are only a fraction of those of its sister state. During the 1944-53 decade, South Carolina reported only eighteen hailstorms of varying intensity, of which three were classed as severe. More than half of these storms occurred in April and May (Table IV in Chapter III). Hail losses over the period totaled $1,900,500. North Carolina's losses for the same period amounted to $31,715,516.

The average loss ratio for South Carolina over a twenty-nine-year period is $2.46, with an average insurance rate of $4.28 (Table VI in Chapter V). These averages are comparable with those of North Carolina and Georgia. The loss ratio for tobacco insurance averages $3.38. Seventy-four per cent of losses to insured crops has been to tobacco and 25 per cent to cotton.

In the thirty-four years ending with 1953 fourteen South Carolina hailstorms have caused losses of at least $100,000 each. In only one did the damage amount to as much as $1,000,000. This occurred in Spartanburg County on April 24, 1952. It struck the Inman area at 6:00 P.M. in a path three miles wide and ten miles long. About one thousand carloads of peaches were destroyed. There was also damage to wheat and cotton. The second most damaging storm hit Ridge Spring and vicinity, in Saluda County, about 4:00 A.M. of April 13, 1953. Between seven hundred and eight hundred acres of peaches were ruined. Loss was estimated at $400,000.

Beaufort, Berkeley, and Dorchester counties were struck by a violent hailstorm on May 27, 1946, with an estimated damage of $126,000. All of Beaufort County was in the path of the storm, with the greatest damage in a six-mile strip from Pritchardville to Frogmore. Losses to crops, mainly tobacco, amounted to $75,000. In the McBeth and Bowman area in Berkeley County, between Reevesville and Harleyville, there was much damage to tobacco, but the loss was not estimated and is not included in the total given.

A loss of $100,000 was the result of a hailstorm eight miles north of Columbia on May 10, 1932, in which 175 plantations sustained heavy damage. Wheat suffered a 60 per cent loss and oats, 80 per cent. In another hailstorm at Columbia, on April 30, 1924, thousands of window panes and skylights in cotton mills and other buildings were broken by hailstones up to two inches in diameter. This was the worst hailstorm in the history of the city. Heavy rain accompanied the hail. Damage was set at $60,000.

Some Especially Damaging South Carolina Hailstorms

Location	***Date***	***Estimated Damage***
Ridge Spring	April 13, 1953	$ 400,000
Spartanburg County	April 24, 1952	1,000,000

Beaufort, Berkeley, and Dorchester counties	May 27, 1946	126,000
Olanta and vicinity	May 18, 1943	100,000
Greenville County	June 25, 1940	150,000
Loris and vicinity	June 24, 1938	100,000
Philadelphia, Darlington County	June 11, 1937	140,000
Sumter County	June 19, 1937	196,000
Newberry County	June 30, 1937	175,000
Lee County	June 30, 1937	200,000
Spartanburg, Marion, and Clarendon counties	May 9, 1932	101,500
Columbia (near)	May 10, 1932	100,000
Spartanburg County	Aug. 29, 1929	200,000
Columbia	April 30, 1924	60,000
Sumter and Clarendon counties	June 8, 1919	260,000

SOUTH DAKOTA

South Dakota’s hail losses from 1944 to 1953 totaled $5,297,100. This is so much less than losses reported in North Dakota and Nebraska that there seems to be a question as to whether the official network of reporting stations in South Dakota has been sufficient to furnish records of all important storms. Insurance company experience indicates that South Dakota’s hail losses have at least approached those in the states to the north and south of it. Over a period of twenty-seven to thirty years, average annual losses from hail to insured crops totaled $531,856 in North Dakota, $596,600 in Nebraska, and $606,116 in South Dakota (Table VI in Chapter V). Since the principal losses in each of these states were to wheat and corn it would seem that losses in South Dakota were actually much greater than were reported.

In the ten years ending with 1953 thirty-four hailstorms were reported in South Dakota, four of them severe. Practically all occurred from 1:00 P.M. to 10:00 P.M. in June, July, and August, when corn and wheat were especially susceptible to hail damage. Hail between midnight and noon is very rare in this state (Tables III and IV in Chapter III).

Over a twenty-seven-year period the loss ratio of crop insurance averaged $3.80, with an average insurance rate of $6.99. These are higher than the corresponding figures for North Dakota, Nebraska, Iowa, and Minnesota. On the average, 41 per cent of losses to insured crops has been to wheat and 19 per cent to corn. As in other midwestern states, the loss ratio and hail insurance rate increase as elevations rise from east to west. In the extreme eastern and southeastern counties, where elevations are not much above one thousand feet, the loss ratio is between $1.25 and $2.50. In the extreme western counties it increases to between $7.00 and $13.00 in many areas. Insurance rates for full coverage increase from an average of $5.00 or $6.00 in the extreme eastern counties to $15.00 in the extreme western areas, where much crop insurance is written with deductible clauses to lower the rate.

In a twenty-year period ending with 1953, South Dakota reported twelve especially damaging hailstorms, most of which were in the eastern part of the state. The most destructive of these was on June 24, 1952, with losses totaling $3,500,000. The loss to crops was $500,000. The storm path was two to five miles wide and fifty miles long, extending through or touching Hand, Beadle, Kingsbury, Miner, and Jerauld counties. Hail up to three inches in diameter fell in three separate narrow strips. Huron and several small towns, Virgil, Iroquois, Howard, Wessington Springs, Fort Thompson, and Gannvalley, were in the path of the storm. The greater part of the damage was to automobiles and buildings. In Huron the storm lasted thirty minutes, with hailstones as large as ten inches in circumference. Poultry and livestock were killed and there were many instances of injury to people. Damage in Huron amounted to $1,000,000.

Another hailstorm, on August 12, 1952, struck Beadle, Jerauld, and Sanborn counties. Total damage amounted to $105,000, with a loss of $100,000 to crops. The hail fell over an area from Alpena and Forestburg to Artesian and in many places stripped field crops completely.

Rapid City, in the famous Black Hills area and with an elevation of 3,231 feet, has had two damaging hailstorms. The first one occurred from 5:10 P.M. to 5:15 P.M. on July 5, 1891, with a loss of $150,000. Some hailstones were reported to be six inches in diameter. Windows and plate glass in the business section of town suffered heavy damage. All growing grain along Rapid Creek and Spring Creek was destroyed over an area extending several miles. Sixteen horses were killed by hailstones and several others blinded. The second storm in Rapid City occurred thirty-three years later, on July 18, 1924. Hail fell to an approximate depth of four inches. Damage was placed at $150,000 in the city itself, and there was heavy damage to crops and trees throughout the storm area. When it was over, residents shoveled the ice blanket off the sidewalks. The sun came out shortly after the storm, and a heavy white mist formed over the accumulation of hail on the ground.

Some Especially Damaging South Dakota Hailstorms

Location	***Date***	***Estimated Damage***
Hand and Beadle counties to Jerauld County	June 24, 1952	$3,500,000
Beadle and Jerauld counties to Sanborn County	Aug. 12, 1952	105,000
Spink, Hand, and Beadle counties	Aug. 7, 1951	64,000
Western areas of the state	July 12, 1948	500,000
Day County	Aug. 4, 1940	150,000
Hanson County to Minnehaha County	June 7, 1939	500,000

Andover and vicinity	July 11, 1938	100,000
Eastern and central areas of the state	Aug. 6, 1938	100,000
Winner	June 7, 1933	200,000
Bowdle to Broadland	June 20, 1930	150,000
Southeastern counties	June 11, 1929	310,000
Rapid City and vicinity	July 18, 1924	150,000
Rapid City and vicinity	July 5, 1891	150,000

TENNESSEE

The hail risk over Tennessee is comparatively light. The state has had few really damaging storms. Out of twenty-three hailstorms reported from 1944 to 1953, only three were severe. The months of greatest frequency are June, July, and August (Tables III and IV in Chapter III). Hail damage over that period amounted to $4,542,000.

Over a twenty-one-year period the loss ratio for the state averages $1.50. The average insurance rate is $3.14 per $100 of insurance written. The loss ratio in Tennessee is lower than it is in Kentucky but about the same as in Mississippi and Alabama. Eighty-five per cent of all losses to insured crops has been to tobacco and 5 per cent to cotton. The hail risk varies little over the state, although some crops, especially tobacco, take a higher insurance rate than others.

In thirty-one years only eight excessively damaging storms have been reported, and only one of these caused losses greater than $400,000. This hailstorm, the most destructive in the state's history, struck Memphis, Lynville, Columbia, Jackson, Medina, and other points in the southwestern part of the state on March 26-27, 1944, with a loss of $2,000,000. The greater part of the damage was to roofs, windows, greenhouses, automobiles, airplanes, and utilities. The second most damaging storm, on November 2, 1945, extended from Millington to a point north of Munford and Brighten. Crop damage amounted to $300,000, out of a total loss of $400,000. A hailstorm occurred in Roane and Loudon counties on May 11, 1926, with extensive damage to peach orchards. The strawberry crop, valued at $8,000, was almost a total loss. Damage, mostly to crops, amounted to $150,000.

Some Especially Damaging Tennessee Hailstorms

Location	***Date***	***Estimated Damage***
Montgomery County	Sept. 1, 1951	$ 100,000[a]
Shelby and Tipton counties	Nov. 2, 1945	400,000
Memphis and southwestern areas	May 26-27, 1944	2,000,000
Weakley County to Carroll County	Mar. 2, 1940	100,000
Roane and Loudon counties	May 11, 1926	150,000

Montgomery and Henry counties	Aug. 19, 1926	100,000
Clairborne County	July 14, 1924	[b]
Jefferson County to Cooke County	July 14, 1924	50,000

[a] Much additional damage to tobacco crops not included.

[b] Severe but damage not estimated.

TEXAS

Texas ranks first among the states in tornado damage, but its average annual hail losses from 1944 to 1953 are almost 50 per cent greater than losses from tornadoes. In this ten-year period hail damage in Texas totaled $31,858,275, putting it sixth among the states in hail losses (Table II in Chapter II). However, on the basis of relatively equal area, it would be in about tenth place.

During the same ten-year period 227 hailstorms have been reported in the state, and 48 of them were severely damaging. Seventy-four per cent occurred in May, June, and July, and most of them between 3:00 P.M. and 9:00 P.M. (Tables III and IV in Chapter III).

The average loss ratio for Texas is $5.67 for a thirty-eight-year period (Table VI in Chapter V). The average rate for full insurance coverage is $6.89. These averages are considerably higher than in most states. Sixty-nine per cent of all losses to insured crops has been to wheat and 14 per cent to cotton. Over much of the state the hail risk is comparatively small. This includes the extreme southern part, south of Latitude 28°, along the Gulf Coast to the eastern part of the state. In these regions the loss ratio is as low as $0.40 to $1.00 and rates for crop insurance are near $4.00. The greatest hail risk is in the panhandle and the area south of it, where elevations are from three thousand to four thousand feet. Here the loss ratio ranges as high as $10.00 to $14.00, while rates for full coverage insurance are from $14.00 to $18.00. In the thirty years ending with 1953 thirty-three Texas hailstorms resulted in damages of $100,000 or more each, and twelve of them caused losses of at least $1,000,000 each.

The first violent hailstorm ever reported in America is believed to have been in Texas. The Fourteenth Annual Report of the Bureau of Ethnology contains the following extract from the *Coronado Expedition, 1540-1542*.[17] The best evidence indicates that Coronado was probably somewhere in Texas at the time.

“While the army was resting in this ravine, as we have related, a tempest came up one afternoon with a very high wind and hail, and in a very short space of time a great quantity of hailstones, as big as bowls, or bigger, fell as thick as raindrops, so that in places they covered the ground to a depth of two or three spans or more deep. (A span is nine inches) And one hit the horse—or I should say, there was not a horse that did not break away, except two or three which the negroes protected by holding large sea nets over them, with the helmets and shields which all the rest wore; and some of them dashed up onto the sides of the ravine so that they got them down with great difficulty. If this had struck them while they were upon the plain, the army would have been in great danger of being without its horses, as there were many which they were not able to cover. The hail broke many tents, and battered many helmets, and wounded many of the horses, and broke all the crockery of the army, and the gourds, which was no small loss, because they do not have any crockery in this region. They do not make gourds, nor sow corn, nor eat bread, but instead raw meat—or only halfcooked—and fruit."

San Antonio has reported five very damaging hailstorms; Dallas, three; and Amarillo, two. The fact that these three cities, where Weather Bureau officials have been on full-time duty for years, have recorded more occurrences of damaging hail than have other places in the state indicates that many storms have gone unreported.

The most destructive of the San Antonio storms was between 9:00 P.M. and 10:00 P.M. on May 16, 1946. Hail struck the city in a path four miles wide. The hailstones, some as large as baseballs, caved in skylights, battered thousands of roofs, neon signs, and windows, and punched holes through the tops, hoods, and fenders of automobiles. The loss from this storm was estimated at $2,000,000.

On the late evening of May 15, 1945, a hailstorm struck Austin, damaging homes, greenhouses, business property, aircraft, and automobiles to the extent of $455,000. A second storm with similar damage occurred almost three years later, on March 16, 1948, with an even greater loss of $800,000.

The most terrific storm ever to hit Dallas occurred May 8, 1926 covering a path one to fifteen miles wide from some twenty-five miles north of Dallas to more than twenty-five miles southeast of the city. Reliable reports collected by the Weather Bureau indicated that the largest hailstones were eight to twelve inches in circumference and consisted of as many as eight concentric layers. Some of them weighed as much as twenty-two ounces. Composition, tile, and shingle roofs were shattered. Skylights, plate glass, windows, automobiles, and street cars sustained terrific damage. According to Weather Bureau reports, some sections of the city appeared to have been riddled by machine gun fire. Scores of persons were injured, and a few horses and other animals were reported killed. Crops in the vicinity were completely destroyed. Total damage amounted to $875,000.

Amarillo's most violent hailstorms occurred in recent years. The most severely damaging one was a prelude to a tornado which struck Amarillo on May 15, 1949. Damage was especially heavy in the eastern part of the city, where hailstones fell for half an hour preceding the tornado. In a large housing project all exposed windows were broken, and hail even penetrated the outer layer of composition siding and tore holes in it two and a half inches wide. The hail loss was estimated at $212,000.

On the afternoon of August 10, 1951, hail destroyed about twelve thousand acres of cotton in the vicinity of Dean, Texas, twenty-one miles west of Lubbock. Total damage from the storm amounted to $1,500,000. A terrific hailstorm struck Del

Rio and vicinity shortly after midnight on April 19, 1949, with complete devastation to the fruit crops of the area. Damage to automobiles alone amounted to $300,000, and total losses were estimated at $1,525,000.

An exceptionally heavy fall of hail, but without any damage at all to crops or other property, occurred near Ballinger, Texas, on May 16, 1917. The storm struck an area where there were no crops nor even buildings of any sort. The hail, accompanied by a terrific downpour of rain, washed from hillsides into tremendous drifts. One accumulation of water-borne hail covered two acres to a depth of three feet. Four days later it was still a foot deep and did not entirely disappear until seven days after the storm. Heavy hail in the vicinity of Memphis, in Hall County, on July 16, 1950, caused a crop loss of $1,500,000. Twenty-five thousand acres of cotton and fifteen thousand acres of feed crops took most of the damage.

Some Especially Damaging Texas Hailstorms

Location	***Date***	***Estimated Damage***
Zavala County to Dimmit County	March 11, 1953	$ 165,000
Hunt County	April 11, 1953	265,000
San Antonio	April 23, 1953	200,000
Swisher County	June 18, 1953	500,000
Montague County	April 3, 1952	500,000

Amarillo	May 9, 1952	90,000
Oldham County	May 9, 1952	306,000
Abilene	May 24, 1951	825,000
Wichita Falls	June 6, 1951	1,000,000
Hockley County	Aug. 10, 1951	1,500,000
Borger	May 27, 1950	300,000
Greenville	May 29, 1950	400,000
Austin County	June 5, 1950	1,000,000
Hall County	July 16, 1950	1,500,000
Del Rio and vicinity	April 19, 1949	1,525,000
Amarillo	May 15, 1949	212,000
Lipscomb County	May 22, 1949	1,080,000
Austin	March 16, 1948	800,000
Childress and Hall counties	April 21, 1947	1,258,000
Hockley County	Oct. 8, 1947	1,800,000
San Antonio	May 16, 1946	2,000,000
Austin and vicinity	May 15, 1945	455,000
San Antonio	April 2, 1944	1,005,000
Parmer and Castro counties	June 14, 1942	750,000
Mercedes and vicinity	March 24, 1941	420,000
Paris	April 22, 1941	550,000

Waco and vicinity	May 7, 1939	450,000
San Antonio	April 6, 1938	120,000
Dallas County	April 8, 1938	1,000,000
San Antonio	March 5, 1935	1,005,000
Dallas County and Hunt County	April 25, 1933	478,000
Cleburne	May 17, 1930	500,000
Dallas County to Lamar County	May 8, 1926	875,000
Grayson and Smith counties	May 10, 1926	1,713,000
Corpus Christi	May 10, 1924	15,000
Dimmitt County	July 3, 1934	500,000
Ballinger	May 16, 1917	[a]

[a] No damage to crops or other property.

UTAH

Because Utah is so sparsely settled and so little acreage is under cultivation, many of its hailstorms cause little or no damage. Consequently, many of them go unreported. In the ten years ending with 1953 only two hailstorms were recorded as severe. Both of these were in the Salt Lake City area, where irrigation is extensively practiced and where the value per acre of crops produced is very high. No other area of the state has reported a damaging hailstorm.

Insurance companies show an average loss ratio of $1.44 over a period of twenty-six years. The average rate for crop insurance is $3.23. These averages are among the lowest found anywhere in the country but still not as low as in Illinois, Indiana, and Ohio (Table VI in Chapter V). Seventy-five per cent of all losses to insured crops has been to wheat and 18 per cent to fruit crops.

In the thirty-four years ending with 1953 only three damaging hailstorms were reported, and all of them were in or near Salt Lake City. The most destructive of these occurred in Salt Lake City and vicinity on August 19, 1945. It was accompanied by violent winds and by rains of cloudburst proportions in the mountains near the city. This wind and rain destruction was included in the estimated losses, which amounted to $500,000.

The most spectacular Utah hailstorm on record struck Lehi and vicinity, about twenty-five miles south of Salt Lake City, August 9, 1920. The path of greatest destruction was a mile wide and two miles long, extending from northwest to southeast over the northern portion of Lehi. In an area three-fourths of a mile wide and a quarter mile long, hailstones accumulated on the ground to a depth of several inches. There was complete destruction of fruit, potatoes, beets, corn, and other crops. Poultry and small animals perished by the hundreds. Teams ran away, causing additional damage and injury. Roofs and fabric tops of automobiles were riddled. Greenhouses were totally destroyed, with an estimated seven thousand panes of glass broken. A partial estimate of damage was set at $50,000, but the total loss was much greater.

Some Especially Damaging Utah Hailstorms

Location	*Date*	*Estimated Damage*
Utah County	June 23, 1948	$250,000
Salt Lake City and vicinity	Aug. 19, 1945	500,000
Lehi and vicinity	Aug. 9, 1920	50,000[a]

[a] Partial estimate of damage.

VERMONT

Hail losses in Vermont have been comparatively light. In the ten years ending with 1953 only two hailstorms were reported and neither was severely damaging. Vermont's hail losses have been tabulated with those of the New England area, but for the eighteen years ending with 1953 a partial listing of losses to insured crops in the state totalled $55,257. Practically all of these losses involved damage to apples. Experience of insurance companies shows an average loss ratio of only $2.18 for the state as a whole, and the average rate for crop insurance is $4.80. Vermont produces a comparatively small amount of tobacco, but that crop carries an insurance rate of $10.45.

No outstanding hailstorms have been reported in the state. Although a very destructive storm on July 20, 1949, along the Connecticut Valley, reached a few areas in Vermont, the damage there seems to have been light.

VIRGINIA

Virginia, ranking third in the production of tobacco, has greater hail losses than any other state east of the Mississippi River except North Carolina, Tennessee, and Illinois. For the ten years ending with 1953 Virginia's losses totaled $3,741,626, an average of $374,162 per year. This is five times greater than the losses from tornadoes. Damage to tobacco comprises more than 98 per cent of all losses to insured crops in the state. In this ten-year period 101 hailstorms were reported, 11 of which were classed as severe. All but two of them occurred in the four-month period, May, June, July, and August (Table IV in Chapter III). Over a period of thirty years, Virginia shows an average loss ratio of $3.34 and an average insurance rate of $6.13, both well above the averages for most states (Table VI in Chapter V).

Fifteen hailstorms resulting in losses of from $100,000 to more than $500,000 each were reported in the twenty years ending with 1953. The storm paths were comparatively short and narrow and were well distributed over the state. The most destructive of these storms passed over Winchester on June 19, 1944, with losses totaling $560,000, of which $510,000 comprised damage to fruit crops alone. This was only one of four damaging hailstorms that have struck in Frederick County.

A severe storm in Rockingham, Augusta, and Albemarle counties on May 17, 1950, caused a loss of $200,000. Hail fell at Alton, Batesville, White Hall, Covesville, and Dale Enterprise. Besides damage to buildings, poultry, and small grains, more than one hundred acres of peaches and five

hundred acres of apples sustained heavy losses. On the afternoon of May 9, 1949, Albemarle County suffered hail damage to the extent of $300,000. Crops were cut to pieces over an area twelve miles square, and an estimated two hundred thousand bushels of fruit were destroyed. Another hailstorm on July 14, 1934, caused damage amounting to $125,000 to the tobacco crop in Pittsylvania County over a path three to five miles wide and thirty miles long.
Many fields of tobacco were a total loss.

Some Especially Damaging Virginia Hailstorms

Location	***Date***	***Estimated Damage***
Halifax and vicinity	Aug. 8, 1953	$200,000
Pittsylvania County	July 29, 1952	236,000
Henrico County	May 3, 1951	102,000
Frederick and Clarke counties	May 11, 1951	101,000
Bristol, Washington County	July 19, 1951	102,000
Rockingham, Augusta, and Albemarle counties	May 17, 1950	200,000
Frederick County	May 18, 1950	100,000
Albemarle County	May 9, 1949	300,000
Richmond County	May 21,	100,000

	1948	
Frederick and Clarke counties	Aug. 30, 1945	110,000
Winchester and vicinity	June 19, 1944	560,000
Greensville County to Patrick County	Aug. 2, 1937	260,000
Stuarts Draft to Staunton, Augusta County	June 8, 1935	100,000
Pittsylvania County	July 14, 1934	125,000
Rockingham County	Aug. 9, 1934	260,000

WASHINGTON

Hail is very frequent in extreme western Washington, especially in the southwestern part, but the hailstones are usually small and in the nature of graupel. Washington's total hail damage has averaged less than that of any other state west of the Mississippi River, except Nevada. In the ten years ending with 1953 only three hailstorms were reported, two of which were severe. Losses during that period amounted to $383,500.

The records of insurance companies show that the hail risk in the state is very light, except to the fruit crop. Even small hail is likely to bruise fruit enough to make it unmarketable. The loss ratio on crop insurance has averaged only $0.44, with an average insurance rate of $1.81. These are among the lowest averages for any of the states. The loss ratio on fruits runs much higher, however. On apples it is $3.48; on other tree fruits, $3.26; and on berries, $3.18. Fifty per cent of losses to insured crops has been to wheat and 24 per cent to tree fruits.

Some Especially Damaging Washington Hailstorms

Location	***Date***	***Estimated Damage***
Selah, Yakima County	June 14, 1948	$300,000
Columbia County	July 18, 1941	75,000
Yakima and vicinity	June 21, 1938	25,000
Yakima and Wenatchee, vicinities	June 12, 1935	65,000
Yakima	June 14, 1928	300,000
Douglas County	Sept. 5, 1925	200,000

WEST VIRGINIA

Hailstorms occur often in West Virginia, but they seem to have done relatively little damage to areas of heavy crop production. In the ten years ending with 1953 only twenty-eight hailstorms were reported in the state, six of which were severe. Losses reported totaled only $131,525, an average of $13,152 per year. Losses to insured crops during the eighteen years ending with 1953 averaged $15,707 annually (Table VI in Chapter V). Ordinarily, the losses to insured crops are only a fraction of total losses.

The hail risk to crops is rather high, as indicated by the loss ratio average of $4.97 and an insurance rate of $8.13 (Table VI in Chapter V). Seventy-five per cent of losses to insured crops involves apples and 23 per cent, peaches. In some localities the full coverage rate on cherries and other fruits is as high as $10 per $100 of insurance. Many policies are written with a 10 per cent deductible clause.

The only outstanding hailstorm reported in West Virginia was in the northern part of Preston County on July 18, 1926. It caused extensive damage to buildings and crops, with losses estimated at $200,000.

WISCONSIN

Hail losses in Wisconsin are about the same as in Michigan but much less than those in Minnesota, Iowa, and Illinois. In the 1944-53 decade there were forty-two hailstorms reported in Wisconsin, seven of which were classed as severely damaging. Losses for the period totaled $1,619,950.

Hail risk to crops other than tobacco is comparatively small. The loss ratio over a nineteen-year period has averaged $2.69 for all crops. The ratio for grain crops is only $1.24. The insurance rate per hundred dollars of risk averages $4.71

(Table VI in Chapter V). There is little variation between loss ratio and insurance rates over the state. Wisconsin produces a great amount of tobacco. More than 66 per cent of losses to insured crops involves damage to tobacco, while only 8 per cent of losses is to grain crops. The loss ratio on tobacco averages $6.55 and the average insurance rate for that crop is $9.90.

In the thirty-three years ending with 1953 sixteen hailstorms were reported to have caused losses of $100,000 or more each. The most damaging of these was on May 9, 1934, from 12:30 P.M. to 1:30 P.M. Its path was several miles wide and extended from Watertown, Jefferson County, through Hubbleton, Waukesha, and Oconomowoc into Milwaukee, a distance of forty-four miles. There was wide destruction of crops and heavy damage to roofs and automobiles. Losses amounted to $2,000,000. The second most damaging storm was on August 13, 1929, from La Crosse County to Rock County, with a loss of $900,000. La Crosse, Vernon, Monroe, Columbia, Dane, and Rock counties were in its forty-five mile path. There was severe damage to corn, tobacco, greenhouses, and buildings of all kinds.

Another severe hailstorm, on August 24, 1945, struck Rusk, Chippewa, and Clark counties in a path forty miles long that passed through Weyerhauser, Holcomb, and Stanley. Damage amounted to $880,000. Hailstones as large as hen eggs piled up twelve to eighteen inches deep in some places. There were great losses to wheat, corn, and cranberries, with the usual damage to windows, roofs, automobiles, and poultry. Two severe hailstorms occurred on July 14, 1934, one from Waushara County to Green County, with a loss of $150,000, and the other in Langlade County, with damages amounting to $250,000. In the Langlade County storm 10 to 60 per cent of all crops in its path were destroyed. Crop losses were estimated at $150,000.

Some Especially Damaging Wisconsin Hailstorms

Location	***Date***	***Estimated Damage***
Outagamie, Brown, and Shawano counties	July 25, 1950	$ 100,000
Dodge, Washington, and Milwaukee counties	June 7, 1948	100,000
Sharon (near)	June 16, 1948	150,000
Vernon and Crawford counties	Aug. 29, 1948	250,000
La Crosse County	Aug. 29, 1948	110,000
Weyerhauser to Clark County	Aug. 24, 1945	880,000
Trempealeau County to Winnebago County	June 18, 1944	100,000
Watertown to Milwaukee	May 9, 1934	2,000,000
Langlade County	July 14, 1934	250,000
Waushara County to Green Lake County	July 14, 1934	150,000

Dane County	Aug. 20, 1930	100,000
Dane County	Sept. 1, 1930	200,000
La Crosse County to Rock County	Aug. 13, 1929	900,000
Walworth County to Racine County	Sept. 9, 1925	150,000
Crawford and Dane counties	Aug. 1, 1922	500,000
Wausau and vicinity	May 22, 1921	150,000

WYOMING

Wyoming, like Colorado and New Mexico, has a high hail risk but comparatively small losses. In the ten years ending with 1953 these losses totaled only $2,486,040, less than those of any other state between the Continental Divide and the Mississippi River. But the loss ratio for hail insurance averages $8.27 per $100 of full coverage insurance. This is higher than that of any other state except Colorado (Table VI in Chapter V). The seeming discrepancy between actual losses and the loss ratio is accounted for by the fact that the state is thinly settled, that there are few sizable towns and cities, and that a great deal of the land produces little except scanty pasture. Wyoming’s hail losses, nevertheless, are about fifteen times greater than its losses from tornadoes.

Ninety-two per cent of losses to insured crops is to wheat, 3 per cent to barley, and 2 per cent to sugar beets and truck crops such as beans, peas, and other vegetables, all grown on irrigated land. The average rate for hail insurance, computed for full coverage, is $12.56 (Table VI in Chapter V). Practically all crop insurance is written with a 10 per cent deductible clause.

From 1944 to 1953 forty-five hailstorms were reported in Wyoming, and ten of these were severe. Seventy-three per cent of them occurred in June and July (Table IV in Chapter III), usually in the afternoon or early evening (Table III in Chapter III). It is very likely that many severe hailstorms, striking in sparsely settled areas and causing practically no damage, are not reported at all. Cheyenne, Wyoming, has reported more hailstorms than any other place in the United States. In a forty-four-year record Cheyenne has had three hundred and eighty falls of hail, an average of almost nine times per year. Next in frequency is North Head, Washington, with an average of seven falls annually. (Figure 2). In the twenty-eight years ending with 1953, Wyoming reported eleven hailstorms that caused losses of $100,000 to $500,000 each. Nearly all of them were in the southeastern part of the state, and Cheyenne was struck by three of the eleven.

The most destructive storm at Cheyenne was on June 11, 1944. Lasting twenty-five minutes, from 3:55 P.M. to 4:20 P.M., it damaged the city to the extent of $500,000. Some of the larger stones measured eight and one-half inches in circumference. Consisting of many layers of ice, they were shaped like a doorknob and were rough on the outside. Neon signs, windows, roofs, and automobiles sustained most of the damage. Three days later, on the evening of June 14, another hailstorm struck Cheyenne, causing similar damage with losses estimated at $140,000. Some of the hailstones were nearly two inches in diameter. In places they accumulated to a depth of two and a half inches. A storm much earlier in Cheyenne's history occurred on June 14, 1926, causing another loss of $140,000.

On June 17, 1950, Riverton, in Fremont County, suffered a hail loss of $200,000, mostly in damage to crops and buildings at the State Prison Farm. Excessive crop damage was caused by two hailstorms in Laramie County. The first one was on June 21, 1951, at Pine Bluffs, with damages estimated at $105,000. The second storm, on September 6 of the same year, covered an area eight miles wide and forty miles long in the eastern part of the county. Losses were mainly to crops but there was heavy damage also to livestock, buildings, and automobiles. The total loss was set at $175,000.

Some Especially Damaging Wyoming Hailstorms

Location	***Date***	***Estimated Damage***
Platte and Goshen counties	July 2, 1953	$100,000
Pine Bluffs and vicinity	June 21, 1951	105,000
Laramie County	Sept. 6, 1951	175,000
Riverton	June 17, 1950	200,000
Wheatland and vicinity	July 5, 1950	100,000
Converse and Niobrara	June 17,	100,000

counties	1948	
Laramie County	July 14, 1948	100,000
Douglas and vicinity	Aug. 1, 1948	401,100
Cheyenne	June 11, 1944	500,000
Cheyenne	June 14, 1944	140,000
Cheyenne and vicinity	June 14, 1926	140,000

VII. Hailstorms in Other Countries

Since the purpose of this book is to offer a comprehensive survey of hailstorms in the United States primarily, the discussion of such storms in other parts of the world is intended to give only a general summary of the frequency and severity of hail in other countries, with a few examples of some of the more destructive storms.

Hoyt Lemons, who has made extensive investigations of hailstorms, states that they occur most frequently in the continental interiors at middle latitudes, diminishing seaward and becoming less frequent also as they approach the equator and the poles.[18]

Dry subtropical areas, such as the regions near the Mediterranean Sea, the middle and northern Pacific coastal region of the United States, and the western coast of British Columbia have the greater part of their hail during the winter months. Humid subtropical regions, such as the southern part of the United States adjacent to the Gulf of Mexico, have a late spring and early summer maximum of hailstorms. Other inland areas in the temperate zone have the most frequent and the most severe hail in the summer months, the season when crops are most susceptible to its damage.

Hailstorms are rare at low latitudes, the equatorial zone, although some subtropical regions occasionally have hail which ranks in severity with that of the middle latitudes.

Hailstorms have been known to occur over large bodies of water in low latitudes.

There have been reports of hailstones of great size in many parts of Africa, both north and south of the equator. Hann, in his *Lehrbuch der Meteorologie*, mentions an extremely violent hailstorm in the Sahara Desert.[19] At Pilgrims Rest, in the Transvaal, hail falling on the metal roof of a power plant produced such a din that it drowned out the noise of the turbines. In 1936 nineteen persons in the northern Transvaal were killed by hail. In French West Africa, 321 hailstorms were recorded from 1921 to 1934. The areas where these occurred were generally in the rugged regions of high altitude. During that period only one hailstorm was observed along the coast. Hail rarely falls in the French Sudan or along the Ivory Coast, except in the northern part, and it is just as rare in Mauritania, with the exception of the mountainous area around Atar. Two or three occurrences of hail have been noted in the Niger Colony and in widely scattered areas of Senegal. Hail in this region is not of great consequence, because the storms are not intense nor of long duration.

Several tropical islands of the Caribbean and Pacific areas occasionally experience hail, but the hailstones are small. More severe hail, however, sometimes occurs at high altitudes in this region. Visher states that from 1908 to 1917 ten hailstorms were officially reported in the northern part of Australia, from latitude 13° to 16° S.[20] Several of these storms occurred within 14 degrees of the equator and all of them were at sea level. The chief localities affected were Brock’s Creek, Burrundie, Pine Creek, and Bonrock. Queensland, Australia, 17° 30′ S., had one hailstorm a few years prior to 1920, while Townsville, on the seacoast, 19° 30′ S., had three, two of which were severely damaging. Mackay, Rockhampton, and other seaports between 20 degrees and the tropics have had several hailstorms. The areas subject to hail in the Northern Territory of Australia are almost all crossed by the heat equator twice each year.

On November 20, 1880, a severe hailstorm occurred at sea level in the Fiji Islands, on the island of Rambi, 16° 30′ S. Hail fell also near Bua, 17° 20′ S., on May 16, 1886, and another storm struck Suva, 18° 10′ S., in May, 1918. In some of the Fiji storms, the hailstones were larger than pigeon eggs. Cornthwaite reports three hailstorms in low-lying districts in Panama, latitude 9 degrees, during a twelve-year period.[21] Panama, like northern Australia, is crossed by the heat equator twice yearly.

It is believed that the infrequency of hail near sea level in the tropics is due to the great height of the freezing level in the upper atmosphere. Only occasionally will the updrafts in thunderstorms have sufficient force to carry water droplets to altitudes high enough for hail formation, and even if hailstones are formed, they must fall for so great a distance that they are likely to melt or evaporate before they reach the ground.

Hail falls rather frequently in high latitudes in or near the Polar regions, but it is usually small hail, or graupel—not true hail in the literal sense of the word. At Nome, Alaska, 64° 30′ N. and twenty-eight feet above sea level, six occurrences of hail were reported in the eight-year period ending with 1938. At Sitka, Alaska, 57° N. and ninety feet above sea level, hail fell twenty-four times in the five years ending with 1917.

There are reports of hail in the upper Yukon district of northern Canada, near the Arctic Circle. In Canada hail is not as frequent or as damaging as in adjacent areas of the United States. Canadian hailstorms occur no oftener than two or three times a year, except along the southern Pacific Coast, where hail often falls from two to five times annually during the winter or early spring. But in this coastal region it is mainly small hail, causing little or no damage. It is the same type of hail that occurs along the western coast of the United States. In the inland regions of Canada, the prairie provinces, hail falls during the warm months and sometimes causes severe damage to wheat. In southern Ontario tobacco is often damaged extensively by hail. From 1934 to 1937 insurance data in the province of Ontario showed a loss ratio of almost 94 per cent on tobacco.

Some very damaging hailstorms have occurred in the prairie provinces. About twenty-five years ago in the vicinity of Stanraer, in Saskatchewan Province, a hailstorm caused great destruction to wheat. The storm swept as far as the Saskatoon district, where damage to crops approximated 100 per cent. The Vanscoy area, fifteen miles from Saskatoon, suffered the most damage. Acres of grain were flattened to the ground. At Elston, three horses were killed, and in the vicinity of Rosetown, the storm devastated a strip fifteen miles long and six to ten miles wide, leveling crops and causing heavy damage to buildings.

The *Leader Post*, of Regina, reported that hail caused heavy damage to three hundred thousand acres of crops in eastern

Saskatchewan on June 26, 1933. The greatest destruction was in the vicinities of Summerberry, Qu'Apelle, Wide Awake, Ellisboro, Grenfell, Broadview, Moose Valley, and south of Kipling and Pelly. The hail strip was some forty miles long and two to twelve miles wide in places north of Grenfell and Summerberry. In that district more than two hundred thousand acres of crops suffered heavy damage. Many farmers reported 100 per cent losses. Some of the hailstones in the Grenfell area were as large as a man's fist, and the accumulation of hail was four inches deep in places.

In the province of Ontario a hailstorm of unusual intensity struck Kemptville, about thirty miles south of Ottawa, June 26, 1952. An account in the *Ottawa Citizen* gives vivid details of this storm:

"Stones pounded down as big as 4½ inches in diameter. This hailstorm, the Ottawa Valley's biggest in 50 years, bombarded Kemptville on the afternoon of June 26 and missed Ottawa by a thunder clap, Rockliff meteorologists said.

"Thunder was heard at Uplands weather station at 1:30 P.M., just as the storm was threading its way southeast from Renfrew into the Kemptville area.

"During the 15 minute deluge there an estimated 5,000 windows were broken, 500 dogs, cats and fowl were killed, 200 automobiles severely damaged, almost 100 metal roofs punctured and 15 acres of demonstration and experimental crops ruined. Damage estimated in the district ranged up to $500,000.

“Only three persons were injured, none seriously. The storm began at Renfrew and turned to hail as it swooped down from the northwest to Kemptville. The hail extended to Mountain, five miles east of Kemptville and then turned to rain again as high winds whipped it down to Prescott and across the St. Lawrence River to Ogdensburg.

“The hailstorm at Kemptville was followed by a torrential rain. Hail smashed 1,700 panes of glass in buildings and greenhouses at the Kemptville Agricultural School. Officials said apple, potato, cabbage and tomato crops were smashed to pulp, destroying a year of experimental work by government experts.

“Windows on the north and west sides of almost all buildings were shattered in an instant. Broken branches crashed to streets to mix with thousands of glass slivers and the bouncing stones of ice. Windshields were smashed and bodies badly dented on 200 parked cars along the main street at the time of the storm. On convertible cars canvas roofing was ripped to shreds.

“A wholesale tobacco truck was badly battered and its entire load ruined. A florist’s new $7,000 greenhouse was demolished. At McKeens Hotel thirty panes of glass were smashed, many in the dining room where the last luncheon guests had just left. Huge panes of stained glass windows at St. Paul’s Presbyterian Church were pounded to shreds. Rev. M. N. McDonald, Church Rector, who spent 14 years on the hail ridden prairies, said he had never seen a storm like this one.

“A new aluminum roof on the Oxford on Rideau Co-Operative was a sieve after the storm. More than 200 windows were broken in the Finnerty block of business offices and apartments.

“Louis J. Burof of Detroit, a tourist who had spent a large part of his life traveling across North America, was amazed. ‘I’ve seen plenty of hailstones and big ones, too, but when these things started coming I was amazed. The stones were the largest I’ve ever seen. They were as big as goose eggs,’ he said.

“Barney Marshall, a garage owner, huddled under an awning when trapped outside with his daughter. They fled to cover when the awning was rent to shreds above their heads. A Commercial Credit traveler from Ottawa said he had to walk through hailstones a foot deep to reach his car, which was a lumpy mess though it had been smooth and shiny ten minutes before. Even the reinforced steel frame was twisted.

“First intimation of the hailstorm came when motorists limped into Ottawa from Kemptville yesterday afternoon. Pedestrians gawked as their dappled cars rolled through downtown streets.

“Most of the hailstones were roughly spherical in shape and about the size of soft balls. Many remained in shaded spots hours after the storm, but by then they were only the size of golf balls.

“Lawns were left dented after the stones melted. Persons inside buildings at the time of the storm said it sounded like the rattling of a barrage of heavy calibre bullets. Then the windows went and persons huddled in corners as the stones bounded into offices, homes and shops.”

In Mexico, hail has never been reported at places of low elevation, such as Obispo, Veracruz, and Tampico, but in the interior, hail often occurs from one to seven times a year. The plateau of Mexico has the greatest frequency of hail. Mexico City averages five or six falls of hail annually; Puebla, seven; Morelia, four; and Guanajuato, three.

A violent hailstorm in the Gulf of Mexico, about eighty miles southeast of Galveston, on the night of March 17-18, 1906, is described by an officer of the British ship *Jamaican*.[22] "The approach of the storm was heralded by a loud hissing sound. Stones up to the size of walnuts and oranges, some 2½ inches in diameter, fell with such force as to dent the binnacles and chip paint on rails and other places. The ship stopped and men sought shelter. The First Officer sustained a severe bruise from a stone striking his neck. The helmsman received a scalp wound."

Severe hailstorms sometimes occur in England. The Quarterly Journal of the Royal Meteorological Society, July, 1920, gives an account of a damaging hailstorm at 1:45 A.M. of July 16, 1918, in Surrey. The worst damage extended from the Isle of Wight to Lowestoft. At one point in the path all but two panes of glass in a greenhouse were smashed, together with most of the glass in frames. In some places the hail was two to three inches deep on the ground. Over level areas it was almost an inch deep. Plums and apples were beaten off the branches and what fruit was left on the trees was badly bruised. Some of the hailstones were shaped like "buns," with jagged protuberances sometimes nearly an inch long, and many stones measured two inches in diameter. Windows in the County Council Boy's

High School were smashed, and the building was unusable after the storm because of a deluge of rain through broken skylights. In some areas everything that grew was destroyed. At the Cane Hill Asylum, damage to glass and crops was estimated at a thousand pounds. In one house along Brighton Road, hail coming through a broken window actually accumulated in a heap on the floor. At the Red House on the Sanderstead Road large hailstones came down through chimneys of a residence, about thirty stones in each room. In a corn field masses of ice were found the next day.

In some parts of Europe, hail is more frequent than it is anywhere in the United States. Paris, France, has an annual hail frequency of ten days and Württemburg averages thirteen days a year on which hail falls. The highest frequency in the United States is between nine and ten days annually, at Cheyenne, Wyoming. In the Mediterranean area, where most of the hail falls during the winter months, from December through February, the annual hail frequency average at Athens is two days; at Malta, nine days; and at Beirut, seven days. In Paris, hail is more frequent than thunderstorms in the winter season but much less frequent in summer. March is its month of greatest frequency. In the middle latitudes of Europe, the hail season is late spring and summer.

An early hailstorm at Leipzig, Germany, on August 27, 1860, was described as follows by Moritz Hauptmann, the eminent musical critic and teacher:[23]

“The hailstones were as large as hen’s eggs—that is no exaggeration—you could have shoveled together a heap of them. It was reported that in the space of five minutes Leipzig was damaged to the extent of two and a half millions. The school buildings and houses in our neighborhood were so damaged that masons and glaziers were in requisition from far and near.

“The damage was only partially repaired on September 5 when two thousand houses were still roofless. Great havoc was done to skylights of the Museum. La Roche’s Napoleon, Schrader’s Frederick II, and the regicide Cromwell all had holes punched in their heads. Anyhow, the hailstorm was an impartial politician.”

At Budapest, Hungary, on the evening of June 13, 1922, a hailstorm left the ground covered with hailstones of a great variety of shapes. Some were spherical and others radial in structure. One hailstone had a large air bubble in the center. Some had prongs two-tenths of an inch long. On one particular stone the prongs were three-tenths of an inch in length. Italy had a severe hailstorm in July, 1945, with some hailstones the size of lemons and others so large that a man could not span them with both hands. Trees were stripped, and people and horses seriously injured.

In India, the hail record is more nearly complete than in most countries, because, at least until recent years, the government remits the land tax in part or in whole for the area affected. This practice makes it necessary for a revenue officer to visit the scene of destruction and make a detailed report to file with the collector of revenue. Almost all of India’s hailstorms occur during the northeast or dry monsoon. Very few are recorded in the season of the southwest or wet monsoon. The months of greatest frequency during the period

1883-97, with the number of storms occurring in each are as follows: December, 57; January, 91; February, 112; March, 241; April, 203; and May, 72.

Hail is quite frequent in Central India and Rajputana but comparatively rare in Burma, especially lower Burma. It seldom occurs south of latitude 16 degrees. The largest hailstones of authentic record in India measured ten to thirteen inches in circumference and weighed nine to thirteen ounces. Hailstones ranging from eight to ten inches in circumference and weighing two to four ounces commonly occur. Reports of hailstones of fantastic size have been frequent in India, such as the story of one that was "as big as a millstone" and another that weighed seven and one-half pounds. These are probably instances in which hailstones froze into one large piece on the ground, or just examples of sheer exaggeration. Such reports have never been verified.

There are records of more people being killed by hailstones in India than in any other country. Lack of adequate shelter in primitive living conditions could be the reason for this. The greatest loss of life from a single hailstorm occurred April 30, 1888, in the Moradabad and Beheri districts, when 246 persons perished from hailstone injuries. Two of the most violent hailstorms of recent years in India struck on March 17 and 18, in 1939, in the Nirmal Taluk district in the state of Hyderabad. The report of this was furnished by the assistant engineer of the public works department at Nirmal and is believed to be authentic.[24] The storm damaged seventeen villages over an area of thirty square miles. Hail accumulated more than an inch in depth and required two days to melt. High winds accompanied the storm. Leaves were stripped from trees and tile roofs were smashed to bits. It was estimated that the two storms damaged 700 tiled roofs, 1,400 thatched homes, 2,000 acres of *thabi* crops and 800 acres of *rabi* crops. A total of 1,000 sheep and 200 cattle were killed. Dead fish floated on the surface of ponds.

Hail occasionally falls in many parts of the Philippines, at both high and low elevations. Very little damage results because the hailstones are almost invariably small and the principal crops of the island are not particularly liable to hail damage, with the exception of tobacco.

Selga reports five hailstorms in Manila, one on May 18, 1923; one on June 30, 1924; another on August 18, 1881; and one some time in April, 1887.[25] No serious damage resulted from any of these, the stones being comparatively small in each case. The most severe hailstorm recorded in the Philippines was at Indang, in the province of Cavite, on May 16, 1927. Hail fell in such quantities that the town plaza was covered white. The stones ranged from two-fifths of an inch to two inches in diameter, causing heavy damage to corn, tomato plants, *obi*, truck crops, and tree fruits.

On Easter Sunday, April 3, 1926, a hailstorm occurred at a surprisingly low altitude in the Philippines. This was at Mindanao, practically at sea level. Some of the stones were as large as hazelnuts, and they continued to fall for almost an hour. Hail has occurred in the Philippines at the following places, all at low altitudes: Libak, La Paz, Tuguegarao, Nueva, Magalang, Angeles, San Luis, Santa Maria, Montalban, Imus, Ternate, Laguna, Tarabucan, Cebu, and Fort Pikit. In almost every instance the hailstones were small, the largest one being listed as “the size of the end of your thumb.”

Some very severe hailstorms have occurred in China. The *Bulletin* of the American Meteorological Society gives a dispatch from Nanking telling of two hundred persons being killed and thousands injured in a severe hailstorm in the western part of Honan Province on Sunday, June 19, 1932. Extremely large hailstones, the report said, fell for two hours, destroying houses, crops, and trees throughout an area containing four hundred villages.

A destructive hailstorm struck Puerto Rico about 2:00 P.M. on April 12, 1903, extending from Aguas Buenas, 18° 15′ N., along the valley of the Bairo River, across the Loiza, and up the valley of the Gurabo. There was extensive damage to uncut tobacco. Hailstones were from an inch to an inch and a quarter in diameter, some disk-shaped. The following day another storm in the valley of the Loiza River covered the ground with hailstones.

On February 14, 1906, between midnight and 1:00 A.M., a very severe hailstorm occurred in the Bahama Islands. It struck Governor’s Harbor on the island of Eleuthera, latitude 23° N., about sixty miles from Nassau. Lasting for fifteen minutes, the hail damaged buildings, trees, and crops. Many birds were killed. Hailstones in some places accumulated to a depth of six inches.

Appendix
The Most Destructive Hailstorms of the United States

The individual state tabulations in this book include many hailstorms that resulted in comparatively little damage. In some states hail damage is infrequent and not excessive, as compared to losses in such states as Kansas and Montana, where million-dollar hail losses occur rather frequently.

The tabulation below is a summary of excessive hail damage throughout the United States, with a listing of only those storms that resulted in losses of at least five hundred thousand dollars. Until little more than a decade past, Weather Bureau facilities were insufficient to afford comprehensive coverage of storms in all localities. Consequently, comparatively fewer storms were recorded for the earlier years included in this tabulation.

Damage estimates given are on the basis of monetary value of property at the time of the storm. The decrease in the purchasing power of the dollar in recent years, together with the increase in actual prices on commodities as compared to values in earlier years, makes it difficult to approximate losses prior to 1947 with the present dollar value.

Losses from the Most Destructive Hailstorms of the United States

Date	Location	Estimated Damage
1954		
Aug. 1	Washington, Republic, and Clay counties, Kan.	$ 2,140,000[a]
1953		
March 13	Lawton and Ft. Sill areas, Okla.	1,900,000[b]
April 17	Kay County to Washington County, Okla.	1,050,000[a]
June 7	Thomas and Trego counties, Kan.	2,500,000[a]
June 21	Wichita, Kan. (and vicinity)	9,180,000[b][c]
July 2	Kimball, Banner, and Cheyenne counties, Neb.	6,000,000[a]
July 5	Western Iowa	4,250,000[a]
Aug. 1	Gratiot County, Mich.	500,000[a]
1952		
April 24	Spartanburg County, S. C.	1,000,000[a]
April 30	Lawton, Okla. (and vicinity)	1,500,000[b]
May 22-23	Beckham and Washington counties, Okla.	1,313,000[a]
May 23	Kingfisher and Logan counties, Okla.	2,045,000[a]
June	Hand and Beadle counties, S. D.	

24		3,500,000[b]
June 26	Northeastern Colorado	2,060,000[a]
July 30	Beaufort County to Buncombe County, N. C.	1,732,000[a]
Aug. 1	Boyle County, Ky.	810,000[a]
Aug. 5-6	Grant, Garfield, and Kay counties, Okla.	1,600,000[a]
1951		
April 28	Placer and Amador counties, Calif.	1,000,000[a]
May 29-30	Wallace County to Kearny County, Kan.	6,215,000[a]
June 6	Wichita Falls, Tex.	1,000,000[b]
June 14	Northeastern North Carolina	1,020,000[a]
June 19	McCallsburg to Cedar Rapids, Iowa	2,250,000[a]
June 21-22	Sherman County to Reno County, Kan.	5,716,000[a]
June 23	Sedgwick County to Allen County, Kan. (including Wichita)	14,340,000[b][c]
June 25	Scotts Bluff and Sioux counties, Neb.	3,000,000[a]
June 27	Beaufort County, N. C.	1,150,000[a]
Aug.	Hockley County, Tex.	1,500,000[a]

10

1950

March 15	Tangipahoa Parish, La.	1,000,000[a]
March 21	Panama City, Fla.	2,000,000[b]
July 1	Brady, Mont. (and vicinity)	1,500,000[a]
July 1	Manhattan, Kan. (and vicinity)	2,512,000[b]
July 2	Scott County, Kan.	1,750,000[a]
July 16	Hall County, Tex.	1,500,000[a]
Sept. 15	Joplin, Mo. (and vicinity)	2,000,000[b]
Sept. 18	Phoenix, Ariz. (and vicinity)	680,000[b]
Sept. 21	Cass County, Ind.	1,000,000[b]
Dec. 2	St. Louis, Mo. (and vicinity)	4,000,000[b]
1949		
April 19	Del Rio, Tex. (and vicinity)	1,525,000[a]
May 18	Sherman and Cheyenne counties, Kan.	2,375,000[a]
May 19, 23	Chase County, Neb.	2,365,000[a]
May	Greeley County to Ford County, Kan.	

23		2,500,000[a]
May 26	Bismarck, N. D. (and vicinity)	1,000,000[a]
May 31	Jackson, Greer, and Kiowa counties, Okla.	2,500,000[a]
1948		
April 8	Union County to Bradley County, Ark.	1,100,000[b]
May 30	Denver, Colo. (and vicinity)	3,800,000[b]
June 13, 16	Cheyenne, Sherman, and Decatur counties, Kan.	4,450,000[a]
June 14	Morgan and Scott counties, Ill.	1,076,500[a]
June 21	Red Willow County, Neb.	2,400,000[a]
Aug. 17	Whiteside County, Ill.	2,000,000[a]
1947		
June 25-26	Kingman County, Kan.	2,250,000[a]
June 29	Phillips County, Colo.	2,000,000[a]
July 21	Box Butte County, Neb.	3,000,000[a]
1946		
May 10	Mesa County, Colo.	1,000,000[a]

May 16	San Antonio, Tex.	2,000,000[b]
July 23	Wayne County, N. Y.	750,000[a]
1945		
May 20	South-central part of Minnesota	1,000,000[a]
May 29	Cairo, Ill. (and vicinity)	1,000,000[b]
June 26	Russell County, Kan.	2,000,000[a]
Aug. 11	Chouteau County, Mont.	6,000,000[a]
Aug. 19	Salt Lake City, Utah (and vicinity)	500,000[b][c]
1944		
April 2	San Antonio, Tex.	1,005,000[b]
April 8, 19	Sacramento Valley, Calif.	2,000,000[a]
May 26-27	Memphis and southwest part of Tennessee	2,000,000[b]
June 19	Winchester, Va. (and vicinity)	500,000[a]
July 14	Lyons and Osceola counties, Iowa	1,500,000[a]
July 17	Scotts Bluff and Sioux counties, Neb.	3,000,000[a]
Aug. 26	Denver, Colo. (and vicinity)	1,000,000[b]

Oct. 9	Richland County, Mont.	2,530,000[a]
Oct. 9	McCone County, Mont.	1,500,000[a]
1943		
June 16	Pawnee County to Reno County, Kan.	2,000,000[a]
July 18	Pipestone County, Minn.	1,615,000[a]
July 21	Allen County, Ind.	1,000,000[a]
Aug. 2	Stillwater and Yellowstone counties, Mont.	2,000,000[a]
1942		
June 12	Republic and Washington counties, Kan.	2,000,000[a]
July 30	Chouteau County, Mont.	1,500,000[a]
1941		
April 3	Polk County, Fla.	1,000,000[a]
1938		
April 8	Dallas, Tex.	1,000,000[b]
1937		
June 7	Harmon County, Okla.	1,250,000[a]
1935		
March 5	San Antonio, Tex.	1,005,000[b]
June	Custer County to Gage County, Neb.	1,100,000[a]

20		
1934		
May 9	Watertown to Milwaukee, Wis.	2,000,000[b]
Aug. 18	Central Minnesota	500,000[a]
1930		
Aug. 16	Parts of Connecticut and Massachusetts	1,500,000[a]
1929		
Aug. 1	Hartford, Conn. (and vicinity)	1,000,000[a]
1927		
May 28	St. Louis, Mo. (and vicinity)	1,000,000[b]
June 2	Barton County to Stafford County, Kan.	2,000,000[a]
July 13	Weld County, Colo.	1,000,000[a]
1926		
May 8	Dallas, Tex.	875,000[b]
May 10	Grayson and Smith counties, Tex.	1,713,000[a]
1925		
Aug. 18	Poweshiek County to Lee County, Iowa	5,000,000[a]

[a] Damage mainly to crops.

[b] Damage mainly to property other than crops.

[c] Wind damage included but mainly hail damage.

Footnotes

[1] C. M. Botley, “Shape of Hailstones,” *Quarterly Journal* of the Royal Meteorological Society (1937), 337.

[2] C. D. Reed, “Dry Hailstones,” *Bulletin* of the American Meteorological Society (January, 1937), 27-28.

[3] F. A. Berry, E. Bollay, and N. R. Beers, *Handbook of Meteorology* (New York, McGraw-Hill Book Company, 1945), 712.

[4] H. W. Byers, *General Meteorology* (New York, McGraw-Hill Book Company, 1940), 578-79.

[5] W. J. Humphreys, *Physics of the Air* (New York, McGraw-Hill Book Company, 1940), 359-60.

[6] H. W. Byers, *General Meteorology* (Rev. ed., New York, McGraw-Hill Book Company, 1944), 578-79.

[7] F. E. Lloyd in *Transactions* of the Royal Society of Canada, Section III (September, 1916).

[8]
T. E. W. Schumann, “The Theory of Hail Formation,” *Quarterly Journal* of the Royal Meteorological Society (January, 1938), 3-17.

[9]
Technical Note 2734, National Advisory Committee for Aeronautics, Washington, D. C. (September, 1952), 21.

[10]
Lt. Col. E. J. Fawbush and Maj. R. C. Miller, “A Method of Forecasting Hailstone Size at the Earth’s Surface,” *Bulletin* of the American Meteorological Society (June, 1953), 235-44.

[11]
F. C. Bates and D. S. Foster, U.S.W.B., “A Hail Forecasting Technique,” unpublished.

[12]
Bulletin of the American Meteorological Society (August-September, 1924).

[13]
Charles D. Reed, “Twenty Years of Hail Damage in Iowa,” *Climatological Data of Iowa* (July, 1943).

[14]
Wayne L. Decker, “Hail Damage Frequency,” *Transactions* of the American Geophysical Union (April, 1952), 204-10.

[15]
C. F. Brooks, “Hailstones That Grow in Size While

Falling," *Bulletin* of the American Meteorological Society (June, 1946), 358.

[16] *Agricultural Statistics* of the United States Department of Agriculture (1953), 107.

[17] Part I (1892-93), 506-507.

[18] Hoyt Lemons in *Bulletin* of the American Meteorological Society (February, 1942), 61-68.

[19] Julius von Hann, "Hagelwetter," *Lehrbuch der Meteorologie*, (3rd ed., Leipzig, Chr. Herm. Tauchnitz, 1915), 708-25.

[20] S. S. Visher, "Hail in the Tropics," *Bulletin* of the American Meteorological Society (July-August, 1922), 117-18.

[21] H. C. Cornthwaite in U.S.W.B. *Monthly Weather Review*, Vol. XXVII, p. 723.

[22] U.S.W.B. *Monthly Weather Review* (May, 1906), 226.

[23] *Quarterly Meteorological Journal* of the Royal

Meteorological Society (London, April, 1918), 97.

[24] P. S. Hariharan, “Sizes of Hailstones,” *Indian Journal of Meteorology and Geophysics* (Delhi, January, 1950), 73.

[25] Migual S. J. Selga, “Hail in the Philippines,” (Manila Bureau of Printing, 1929).

[26] August-September, 1932.

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Transcriber's Notes

- Retained publication information from the printed edition: this eBook is public-domain in the country of publication.
- Silently corrected a few typos.
- Abbreviated state and month names in some table captions, to reduce width of table.
- In the text versions only, text in italics is delimited by _underscores_.

[The end of *Hailstorms of the United States* by Snowden D. Flora]