

= Hail =

Hail is a form of solid precipitation . It is distinct from American sleet (called ice pellets outside of the United States) , though the two are often confused . It consists of balls or irregular lumps of ice , each of which is called a hailstone . Sleet (ice pellets) falls generally in cold weather while hail growth is greatly inhibited during cold surface temperatures .

Unlike graupel , which is made of rime , and ice pellets , which are smaller and translucent , hailstones consist mostly of water ice and measure between 5 millimetres (0 @. @ 2 in) and 15 centimetres (6 in) in diameter . The METAR reporting code for hail 5 mm (0 @. @ 20 in) or greater is GR , while smaller hailstones and graupel are coded GS .

Hail is possible within most thunderstorms as it is produced by cumulonimbi , and within 2 nautical miles (3 @. @ 7 km) of the parent storm . Hail formation requires environments of strong , upward motion of air with the parent thunderstorm (similar to tornadoes) and lowered heights of the freezing level . In the mid @- @ latitudes , hail forms near the interiors of continents , while in the tropics , it tends to be confined to high elevations .

There are methods available to detect hail @- @ producing thunderstorms using weather satellites and weather radar imagery . Hailstones generally fall at higher speeds as they grow in size , though complicating factors such as melting , friction with air , wind , and interaction with rain and other hailstones can slow their descent through Earth 's atmosphere . Severe weather warnings are issued for hail when the stones reach a damaging size , as it can cause serious damage to human @- @ made structures and , most commonly , farmers ' crops .

= = Definition = =

Any thunderstorm which produces hail that reaches the ground is known as a hailstorm . Hail has a diameter of 5 millimetres (0 @. @ 20 in) or more . Hailstones can grow to 15 centimetres (6 in) and weigh more than 0 @. @ 5 kilograms (1 @. @ 1 lb) .

Unlike ice pellets , hailstones are layered and can be irregular and clumped together . Hail is composed of transparent ice or alternating layers of transparent and translucent ice at least 1 millimetre (0 @. @ 039 in) thick , which are deposited upon the hailstone as it travels through the cloud , suspended aloft by air with strong upward motion until its weight overcomes the updraft and falls to the ground . Although the diameter of hail is varied , in the United States , the average observation of damaging hail is between 2 @. @ 5 cm (1 in) and golf ball @- @ sized (1 @. @ 75 in) .

Stones larger than 2 cm (0 @. @ 80 in) are usually considered large enough to cause damage . The Meteorological Service of Canada issues severe thunderstorm warnings when hail that size or above is expected . The US National Weather Service has a 2 @. @ 5 cm (1 in) or greater in diameter threshold , effective January 2010 , an increase over the previous threshold of ¾ -inch hail . Other countries have different thresholds according local sensitivity to hail ; for instance grape growing areas could be adversely impacted by smaller hailstones . Hailstones can be very large or very small , depending on how strong the updraft is : weaker hailstorms produce smaller hailstones than stronger hailstorms (such as supercells) .

= = Formation = =

Hail forms in strong thunderstorm clouds , particularly those with intense updrafts , high liquid water content , great vertical extent , large water droplets , and where a good portion of the cloud layer is below freezing 0 ° C (32 ° F) . These types of strong updrafts can also indicate the presence of a tornado . The growth rate is maximized where air is near a temperature of ? 13 ° C (9 ° F) .

= = = Layer nature of the hailstones = = =

Like other precipitation in cumulonimbus clouds , hail begins as water droplets . As the droplets rise

and the temperature goes below freezing , they become supercooled water and will freeze on contact with condensation nuclei . A cross @-@ section through a large hailstone shows an onion @-@ like structure . This means the hailstone is made of thick and translucent layers , alternating with layers that are thin , white and opaque . Former theory suggested that hailstones were subjected to multiple descents and ascents , falling into a zone of humidity and refreezing as they were uplifted . This up and down motion was thought to be responsible for the successive layers of the hailstone . New research , based on theory as well as field study , has shown this is not necessarily true .

The storm 's updraft , with upwardly directed wind speeds as high as 110 miles per hour (180 km / h) , blows the forming hailstones up the cloud . As the hailstone ascends it passes into areas of the cloud where the concentration of humidity and supercooled water droplets varies . The hailstone ' s growth rate changes depending on the variation in humidity and supercooled water droplets that it encounters . The accretion rate of these water droplets is another factor in the hailstone ' s growth . When the hailstone moves into an area with a high concentration of water droplets , it captures the latter and acquires a translucent layer . Should the hailstone move into an area where mostly water vapour is available , it acquires a layer of opaque white ice .

Furthermore , the hailstone ' s speed depends on its position in the cloud ' s updraft and its mass . This determines the varying thicknesses of the layers of the hailstone . The accretion rate of supercooled water droplets onto the hailstone depends on the relative velocities between these water droplets and the hailstone itself . This means that generally the larger hailstones will form some distance from the stronger updraft where they can pass more time growing . As the hailstone grows it releases latent heat , which keeps its exterior in a liquid phase . Because it undergoes ' wet growth ' , the outer layer is sticky (i.e. more adhesive) , so a single hailstone may grow by collision with other smaller hailstones , forming a larger entity with an irregular shape .

The hailstone will keep rising in the thunderstorm until its mass can no longer be supported by the updraft . This may take at least 30 minutes based on the force of the updrafts in the hail @-@ producing thunderstorm , whose top is usually greater than 10 km high . It then falls toward the ground while continuing to grow , based on the same processes , until it leaves the cloud . It will later begin to melt as it passes into air above freezing temperature .

Thus , a unique trajectory in the thunderstorm is sufficient to explain the layer @-@ like structure of the hailstone . The only case in which multiple trajectories can be discussed is in a multicellular thunderstorm , where the hailstone may be ejected from the top of the " mother " cell and captured in the updraft of a more intense " daughter " cell . This , however , is an exceptional case .

= = = Factors favoring hail = = =

Hail is most common within continental interiors of the mid @-@ latitudes , as hail formation is considerably more likely when the freezing level is below the altitude of 11 @,@ 000 feet (3 @,@ 400 m) . Movement of dry air into strong thunderstorms over continents can increase the frequency of hail by promoting evaporational cooling which lowers the freezing level of thunderstorm clouds giving hail a larger volume to grow in . Accordingly , hail is less common in the tropics despite a much higher frequency of thunderstorms than in the mid @-@ latitudes because the atmosphere over the tropics tends to be warmer over a much greater altitude . Hail in the tropics occurs mainly at higher elevations .

Hail growth becomes vanishingly small when air temperatures fall below ? 30 ° C (? 22 ° F) as supercooled water droplets become rare at these temperatures . Around thunderstorms , hail is most likely within the cloud at elevations above 20 @,@ 000 feet (6 @,@ 100 m) . Between 10 @,@ 000 feet (3 @,@ 000 m) and 20 @,@ 000 feet (6 @,@ 100 m) , 60 percent of hail is still within the thunderstorm , though 40 percent now lies within the clear air under the anvil . Below 10 @,@ 000 feet (3 @,@ 000 m) , hail is equally distributed in and around a thunderstorm to a distance of 2 nautical miles (3 @.@ 7 km) .

= = Climatology = =

Hail occurs most frequently within continental interiors at mid @-@ latitudes and is less common in the tropics , despite a much higher frequency of thunderstorms than in the mid @-@ latitudes . Hail is also much more common along mountain ranges because mountains force horizontal winds upwards (known as orographic lifting) , thereby intensifying the updrafts within thunderstorms and making hail more likely . The higher elevations also result in there being less time available for hail to melt before reaching the ground . One of the more common regions for large hail is across mountainous northern India , which reported one of the highest hail @-@ related death tolls on record in 1888 . China also experiences significant hailstorms . Central Europe and southern Australia also experience a lot of hailstorms . Popular regions for hailstorms are southern and western Germany , northern and eastern France and southern and eastern Benelux . In south @-@ eastern Europe , Croatia and Serbia experience frequent occurrences of hail .

In North America , hail is most common in the area where Colorado , Nebraska , and Wyoming meet , known as " Hail Alley " . Hail in this region occurs between the months of March and October during the afternoon and evening hours , with the bulk of the occurrences from May through September . Cheyenne , Wyoming is North America 's most hail @-@ prone city with an average of nine to ten hailstorms per season .

= = Short @-@ term detection = =

Weather radar is a very useful tool to detect the presence of hail @-@ producing thunderstorms . However , radar data has to be complemented by a knowledge of current atmospheric conditions which can allow one to determine if the current atmosphere is conducive to hail development .

Modern radar scans many angles around the site . Reflectivity values at multiple angles above ground level in a storm are proportional to the precipitation rate at those levels . Summing reflectivities in the Vertically Integrated Liquid or VIL , gives the liquid water content in the cloud . Research shows that hail development in the upper levels of the storm is related to the evolution of VIL . VIL divided by the vertical extent of the storm , called VIL density , has a relationship with hail size , although this varies with atmospheric conditions and therefore is not highly accurate . Traditionally , hail size and probability can be estimated from radar data by computer using algorithms based on this research . Some algorithms include the height of the freezing level to estimate the melting of the hailstone and what would be left on the ground .

Certain patterns of reflectivity are important clues for the meteorologist as well . The three body scatter spike is an example . This is the result of energy from the radar hitting hail and being deflected to the ground , where they deflect back to the hail and then to the radar . The energy took more time to go from the hail to the ground and back , as opposed to the energy that went direct from the hail to the radar , and the echo is further away from the radar than the actual location of the hail on the same radial path , forming a cone of weaker reflectivities .

More recently , the polarization properties of weather radar returns have been analyzed to differentiate between hail and heavy rain . The use of differential reflectivity (<formula>) , in combination with horizontal reflectivity (<formula>) has led to a variety of hail classification algorithms . Visible satellite imagery is beginning to be used to detect hail , but false alarm rates remain high using this method .

= = Size and terminal velocity = =

The size of hailstones is best determined by measuring their diameter with a ruler . In the absence of a ruler , hailstone size is often visually estimated by comparing its size to that of known objects , such as coins . Using the objects such as hen 's eggs , peas , and marbles for comparing hailstone sizes is imprecise , due to their varied dimensions . The UK organisation , TORRO , also scales for both hailstones and hailstorms . When observed at an airport , METAR code is used within a surface weather observation which relates to the size of the hailstone . Within METAR code , GR is used to indicate larger hail , of a diameter of at least 0 @-@ 25 inches (6 @-@ 4 mm) . GR is derived from

the French word grêle . Smaller @-@ sized hail , as well as snow pellets , use the coding of GS , which is short for the French word grésil .

= = = Hail records = = =

Megacryometeors , large rocks of ice that are not associated with thunderstorms , are not officially recognized by the World Meteorological Organization as " hail , " which are aggregations of ice associated with thunderstorms , and therefore records of extreme characteristics of megacryometeors are not given as hail records .

Heaviest : 1 @.@ 02 kg (2 @.@ 25 lb) ; Gopalganj District , Bangladesh , 14 April 1986 .

Largest diameter officially measured : 7 @.@ 9 inches (20 cm) diameter , 18 @.@ 622 inches (47 @.@ 3 cm) circumference ; Vivian , South Dakota , 23 July 2010 .

Largest circumference officially measured : 18 @.@ 74 inches (47 @.@ 6 cm) circumference , 7 @.@ 0 inches (17 @.@ 8 cm) diameter ; Aurora , Nebraska , 22 June 2003 .

Terminal velocity of hail , or the speed at which hail is falling when it strikes the ground , varies . It is estimated that a hailstone of 1 centimetre (0 @.@ 39 in) in diameter falls at a rate of 9 metres per second (20 mph) , while stones the size of 8 centimetres (3 @.@ 1 in) in diameter fall at a rate of 48 metres per second (110 mph) . Hailstone velocity is dependent on the size of the stone , friction with air it is falling through , the motion of wind it is falling through , collisions with raindrops or other hailstones , and melting as the stones fall through a warmer atmosphere . As hail stones are not perfect spheres it is difficult to calculate their speed accurately .

= = Hazards = =

Hail can cause serious damage , notably to automobiles , aircraft , skylights , glass @-@ roofed structures , livestock , and most commonly , farmers ' crops . Hail damage to roofs often goes unnoticed until further structural damage is seen , such as leaks or cracks . It is hardest to recognize hail damage on shingled roofs and flat roofs , but all roofs have their own hail damage detection problems . Metal roofs are fairly resistant to hail damage , but may accumulate cosmetic damage in the form of dents and damaged coatings .

Hail is one of the most significant thunderstorm hazards to aircraft . When hailstones exceed 0 @.@ 5 inches (13 mm) in diameter , planes can be seriously damaged within seconds . The hailstones accumulating on the ground can also be hazardous to landing aircraft . Hail is also a common nuisance to drivers of automobiles , severely denting the vehicle and cracking or even shattering windshields and windows . Wheat , corn , soybeans , and tobacco are the most sensitive crops to hail damage . Hail is one of Canada 's most expensive hazards . Rarely , massive hailstones have been known to cause concussions or fatal head trauma . Hailstorms have been the cause of costly and deadly events throughout history . One of the earliest known incidents occurred around the 9th century in Roopkund , Uttarakhand , India , where 200 to 600 nomads seem to have died of injuries from hail the size of cricket balls . The largest hailstone in terms of diameter and weight ever recorded in the United States fell on July 23 , 2010 in Vivian , South Dakota ; it measured 7 @.@ 9 inches (20 cm) in diameter and 18 @.@ 62 inches (47 @.@ 3 cm) in circumference , weighing in at 1 @.@ 94 pounds (0 @.@ 88 kg) . This broke the previous record for diameter set by a hailstone 7 inches diameter and 18 @.@ 74 inches circumference (still the greatest circumference hailstone) which fell in Aurora , Nebraska in the United States on June 22 , 2003 , as well as the record for weight , set by a hailstone of 1 @.@ 67 pounds (0 @.@ 76 kg) that fell in Coffeyville , Kansas in 1970 .

= = Accumulations = =

Narrow zones where hail accumulates on the ground in association with thunderstorm activity are known as hail streaks or hail swaths , which can be detectable by satellite after the storms pass by . Hailstorms normally last from a few minutes up to 15 minutes in duration . Accumulating hail storms

can blanket the ground with over 2 inches (5 @. @ 1 cm) of hail , cause thousands to lose power , and bring down many trees . Flash flooding and mudslides within areas of steep terrain can be a concern with accumulating hail .

Depths of up to 18 in (0 @. @ 46 m) have been reported . A landscape covered in accumulated hail generally resembles one covered in accumulated snow and any significant accumulation of hail has the same restrictive effects as snow accumulation , albeit over a smaller area , on transport and infrastructure . Accumulated hail can also cause flooding by blocking drains , and hail can be carried in the floodwater , turning into a snow @-@ like slush which is deposited at lower elevations .

On somewhat rare occasions , a thunderstorm can become stationary or nearly so while prolifically producing hail and significant depths of accumulation do occur ; this tends to happen in mountainous areas , such as the July 29 , 2010 case of a foot of hail accumulation in Boulder County , Colorado . On June 5 , 2015 , hail up to four feet deep fell on one city block in Denver , Colorado . The hailstones , described as between the size of bumble bees and ping pong balls , were accompanied by rain and high winds . The hail fell in only the one area , leaving the surrounding area untouched . It fell for one and a half hours between 10 p.m. and 11 : 30 p.m. A meteorologist for the National Weather Service in Boulder said , " It 's a very interesting phenomenon . We saw the storm stall . It produced copious amounts of hail in one small area . It 's a meteorological thing . " Tractors used to clear the area filled more than 30 dump @-@ truck loads of hail .

Research focused on four individual days that accumulated more than 5 @. @ 9 inches (15 cm) of hail in 30 minutes on the Colorado front range has shown that these events share similar patterns in observed synoptic weather , radar , and lightning characteristics , suggesting the possibility of predicting these events prior to their occurrence . A fundamental problem in continuing research in this area is that , unlike hail diameter , hail depth is not commonly reported . The lack of data leaves researchers and forecasters in the dark when trying to verify operational methods . A cooperative effort between the University of Colorado and the National Weather Service , for the summer of 2016 , is in progress . The joint project 's goal is to enlist the help of the general public to develop a database of hail accumulation depths .

= = Suppression and prevention = =

During the Middle Ages , people in Europe used to ring church bells and fire cannons to try to prevent hail , and the subsequent damage to crops . Updated versions of this approach are available as modern hail cannons . Cloud seeding after World War II was done to eliminate the hail threat , particularly across the Soviet Union ? where it was claimed a 70 to 98 percent reduction in crop damage from hail storms was achieved by deploying silver iodide in clouds using rockets and artillery shells . Hail suppression programs have been undertaken by 15 countries between 1965 and 2005 .