Hail Formation and Effects

Hail is one of the many weather phenomena that a storm chaser faces. When we're in pursuit of a storm, and catch some hail, there are a multitude of thoughts; most of which begin with the phrase, "Uh oh."

Uh oh. How big is it going to get?
Uh oh. How long is it going to last?
Uh oh. We screwed our angle of approach.
Uh oh. We're closer than we thought to the danger zone.
Uh oh. We're in the danger zone.
Uh oh. Do I have glass coverage?

Mid-latitude thunderstorms can grow to be 16-18 km (10-11 miles) tall. Although the surface may be fairly warm, the freezing level (0°C or 32°F) typically occurs at about 4 km (2.5 miles) up... meaning that the upper 75% of the storm is maintained at or below freezing temperatures. The strong updrafts in a developing thunderstorm or supercell can reach 160kph (100mph), bringing large amounts of moisture and debris into the storm. The debris (aerosols, dust, dirt, insects) act as nuclei for the water to collect on, creating a tiny raindrop. As the new raindrop travels upward in the updraft, it collects more water droplets... a process called coalescence. The larger the drop becomes, the more efficiently it collects other drops.

So far, only raindrops have been produced. To produce ice, the droplets must continue traveling upward beyond the freezing level. At this level, it is possible to have solid particles (snowflakes or ice crystals), spongy ice-water particles (graupel), or supercooled water droplets (below freezing, but still liquid). With one of these particles as a nucleus, other frozen particles can collect on it and form larger frozen particles. For example, snowflakes, ice crystals, or other graupel might adhere to the walls of a graupel particle, making it bigger. As the new particle continues traveling upward, the environment becomes even colder, forcing all remaining water to freeze.

At some point, the mass of the ice particle and the gravitational pull on it are balanced and the ice particle reaches the top of its journey... it falls back toward the ground, still collecting more mass on its way. The return trip downward is a good point to introduce the two types of hail growth: dry growth and wet growth. If the hailstone (an ice particle larger than about 1mm or 0.04") is still in the very cold portion of the cloud (colder than -40°C or -40°F), it will undergo dry growth. This means that the hail stone itself has a hard, dry, icy coating and grows by collecting other "dry" particles... this process is not very efficient.

However, in the region of the thunderstorm where temperatures are between -40°C (-40°F) and 0°C (32°F), the hailstone can undergo wet growth. Wet growth involves the latent heat of fusion. To explain this, start with ice. To melt the ice, heat must be extracted from the environment and added to the ice. This added energy turns the ice into water. On the other hand, when water freezes and becomes ice, energy is released to the environment. The amount of energy required to make this transformation is called the latent heat of fusion. So, back to the hailstone. If it collects a supercooled water droplet and the droplet freezes on contact, and this layer becomes clear if the freezing is very fast and somewhat opaque if the freezing is slow (as oxygen bubbles incorporated into the layer). It releases energy to the environment... in this case, to the hailstone. Every supercooled droplet the stone collects releases energy, and eventually, the effect is large enough that the hailstone's surface begins to melt! Now that the hailstone has a wet coating, it collects other particles (water, supercooled water, snowflakes, ice crystals, graupel) very efficiently.

If the percentage of liquid in the hailstone becomes too great, some of the water will shed off of the stone (because of a balance of air drag and surface tension) leaving a smaller, lighter stone in its place. At this point, the hailstone (whether it shed water or not) could still be light enough to be caught by the updraft again and start the growth process all over. This repeats until the hailstone is too heavy for the updraft to support and it falls out of the cloud. As it falls, it travels into warmer air, allowing it to melt slightly. Even so, the largest hailstones can reach 15cm (6") in diameter, weigh 3.5 pounds, and hit the ground at 180kph (110mph). All of this from an updraft and a piece of dust. If you slice a hailstone in half, you can see the layers that chart its lifespan...many times clear layers altering with frostier, more opaque ones. I believe the record count of layers was recorded by NSSL as 24. There are other records much more dramatic.

Hail accounts for the destruction of 1% of the worlds crops. Damage can be severe enough to kill livestock and create millions of dollars worth of damage to homes. Hail can also kill humans as well as damage cars and other vehicles in the path. The appearance of hail in a storm can be of a greenish tint to the gray cloud mass of the storm. In the US, there are about 4800 hailstorms every year, which, combined with property damage, equates to 1 billion dollars a year in this country alone. The largest hailstone recorded in this country was in Coffeyville, Kansas, and was 17.5 inches in circumference. When you consider that quarter sized hail require an updraft of nearly 40 MPH to sustain it, this is a rather impressive size. However, the heaviest recorded hailstone was in northern India. In was born from the March 10, 1939 storm and weighed a full 7.5 pounds.

Just as there is a tornado alley, there is a hail alley. This covers a portion of our country including E. Colorado, Nebraska, and Wyoming. Other areas of high hail instances are northern India. The common thread seems to be mid-latitude areas on the downwind side of a mountain chain. The lowest instances of hail in this country are on the Pacific coast, and in Florida.

Knowing the dynamics of a storm can help you to estimate where a hail shaft may exist in a particular storm. It is usually between the sections of the storm known as the downdraft and the updraft. When using computer programs to track storms, dBz, A logarithmic expression for reflectivity factor, is often used to determine the probability of hail within a storm. Z is the amount of radar beam energy that is back scattered by a target and detected as a signal (or echo). The higher the z, the more energy is being scattered back by the target, or the greater the intensity of the precipitation. So many other factors can affect reflectivity, such as distance, angle of beam, width of beam, the size and type of the precipitation; that dBz cannot verify conclusively the presence of size of hail in a storm. Values of 50 or above usually do occur when hail is present, though.

Despite the fact that hail is extremely dangerous and damaging, it has been used by chaser as a known precursor of an even more danger severe weather event... the tornado. The hail shaft, as mentioned, most often exists in the portion of the storm very near to where a tornado would form. Amazing how one severe weather event can be the warning bell for yet another. However, penetration of a hail shaft has been enough to send many seasoned chasers into either an about face, or searching for immediate shelter.

If you have the capability of tracking the storm, and understand the dynamics of thunderstorm development, a seasoned chaser can almost always avoid the hail shaft. A NOAA weather radio can be a helpful tool also to prevent yourself from getting caught. Should all else fail, all you can do is seek shelter under a sturdy shelter until the storm passes.

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