Snow

The United States is one of the snowiest countries in the world. On average 100 to 120 storms deposit significant amounts of snow. About 15% of these storms deposit more than 6 to 12 inches of snow at a time. Approximately 70% of all snow falls between December and February. Snow removal costs local and state governments approximately $2 billion a year. Part of that cost is the use of approximately 8 million tons of salt on streets and highways.

Several regions in the United States have their own characteristic type of snowfall. In the Western Mountain region (the Rockies) snow constitutes 60% to 75% of the annual precipitation. In the Great Plains snow contributes only about 20% of the annual precipitation. Alaska and the Upper Midwest each get about 30 to 80 inches of snow a year. However, the difference is that it snows frequently in small amounts in Alaska and the snow stays on the ground. In comparison, in the Midwest snow usually falls sporadically in large amounts and melts before it snows again.

Single cities can have massive snow removal bills. Rochester, New York, spends approximately $3.7 million a year, and Buffalo, New York, had to pay $5 million for snow removal in 1995.

How Does Snow Form?

Three conditions are commonly needed for snow to fall: high air moisture, upward movement of warm air, and cold ambient temperatures (although theoretically it can snow at any temperature as long as sufficient moisture is in the air). Several typical weather patterns are conducive to snowfall. Different weather patterns predominate in different regions of the United States.

Orographic lifting occurs in the western United States. Here the movement of warm air occurs along the slopes of the Rocky Mountains, and the pattern of snowfall coincides with the contours of the mountains.

Frontal systems that produce snow typically are divided into two types:

Cold fronts: In the eastern United States cold fronts elevating warm air result in heavy snowfalls, usually of short duration. “Alberta Clippers” are an example of these.

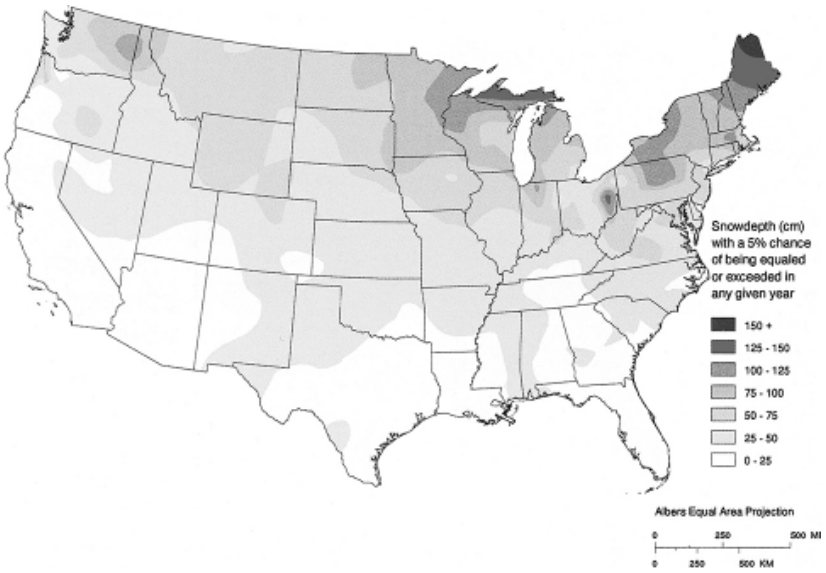
Warm fronts: In the southern United States warm Gulf air rises slowly as it moves northward. This typically results in a lighter snowfall of longer duration. The “Pineapple Express” and “Nor’easters” are examples of these systems.

Convergence systems can produce snow throughout the United States but are typically seen in some places more than others. In convergent systems air flowing to the center of a low-pressure system is displaced upward as the air reaches the center. As the air moves up, snow is formed and precipitates. “Four Corner Lows” and “Panhandle Lows” are examples of these.

Convection systems occur when cold air is at high altitudes into which warm air ascends. As the warm air ascends, it reaches a point where it becomes buoyant and precipitation occurs. Convection systems typically occur near warm bodies of water.

Lake effect snow occurs in the area east of the Great Lakes. The principal cause of lake effect snow is moisture saturation of the air without lifting. The high moisture content then precipitates as snow. Lake effect snow occasionally occurs in the evaporation zone of power plants’ cooling towers.

Other weather patterns that can cause snow include jet streams and cold air damming.



Distribution of snowfall in the United States 1961 to 1990. (From Federal Emergency Management Agency: *Multi-hazard identification and risk assessment: a cornerstone of the national mitigation strategy*, Washington, DC, 1997, FEMA.

Snowfall

Snow forecasts are made by the National Weather Service (NWS). Snowfall is measured at national weather stations. The prediction of snowfall from radar weather detection systems can be difficult because snow often falls in narrow bands that have large differences in temperatures. Predicting annual snowfall also is not very accurate because the amount of snow that can fall at any one site can vary by as much as 300% from year to year. Local forecasting is the single most important source of information for being prepared to deal with snowstorms. Local estimation of the total amount of snow that is likely to fall in a season is the most useful parameter for businesses, including livestock operations, because this allows them to anticipate needed resources.

Snowstorms usually last only for a few hours, but record storms can last for several days. Snow often accumulates at a rate of 0.5 inch per hour. If it falls at a higher rate, communities are disrupted. Snow falling at more than 1 inch per hour leads to rapid disruption, and more than 2 inches per hour invariably stops community activities altogether. Lake effect snow can fall at tremendous rates, reaching 5 to 7 inches per hour, and is often accompanied by lightning and thunder. Higher rates are most likely measurement errors caused by drifting.

Common tracks and development areas (double circles) for snow-producing storm systems affecting the contiguous 48 United States. (Modified from Doeksen NJ, Judson A: The snow booklet: a guide to the science, climatology and measurement of snow in the United States, Ft Collins, Colo, 1996, Colorado State University.)

Physical Properties of Snow

Determining the amount of snow that falls is important to be able to predict avalanches, snow melts, flooding, and other aspects of snow management such as the need for snow removal equipment. The major factors meteorologists measure are the following:

- Amount of precipitation
- Total accumulation (old and new snow)
- Water equivalent (snow density)

Measurement of snowfall is not an exact science, nor is the depth of snow predictive of the problems that come from it. Difficulties in measurement arise because snow melts when it lands, settles as it sits, and often is easily redistributed.

The density of snow can vary considerably from day to day. Water has a density of 1, and ice 0.92. Therefore ice is only 92% as dense as water. Snow density is typically 0.04 to 0.11 (4% to 11% of the density of water) but in extreme cases can range from 0.01 to 0.40. The weight of snow can be calculated from its density. For example, snow that has a density of 0.12 would have to be 8 feet deep to be as heavy as 1 foot of water. This is equivalent to saying that 12 feet of snow would exert approximately 5 lb per square inch. The more dense snow is, the more ice it has in it. If the density is above 0.10, snow becomes sticky and difficult to shovel. High-density snow typically falls at higher ambient temperatures such as those that occur in the fall and spring. Low-density snow, “wild snow,” is light and fluffs up when walked through. Low-density snow, the skier’s delight, usually falls at low ambient temperatures.

The density of snow is less than that of water because it contains a lot of air. This property also makes it a good insulator, which is why Inuit people in the far north of North America use snow to build their homes. Under thick snow the ground temperature stays at about freezing (32º F or 0º C), which allows ground vegetation to survive for prolonged periods and guards crops against winter kill. This is important in regions that have prolonged periods of cold weather, such as Alaska.

Fresh snow reflects over 90% of sunlight, making it a hazardous environment in which to work without appropriate eye protection (sunglasses) and protective clothing to prevent sunburn. Wet snow is less reflective (approximately 60%).

Snow dissipates through either melting or evaporation. Melting occurs when the ambient temperature increases or when it rains. Typically snow melts at about 1 inch of water content per day (equivalent to 6 inches of snow depth). Maximum rates of 2 to 3 inches of water content per day (equivalent of 12 to 18 inches of snow depth) have been recorded. Evaporation occurs in low-humidity environments. Evaporation lowers the temperature of the snow and slows the evaporation process.

Problems Resulting from Snowfall

The total amount of snow that falls is less important as a predictor of the likely problems that will arise than is how well prepared a community, individual businesses, and families are to deal with the snow. For example, in the Gulf Coast states and southeastern United States even small amounts of snow can be disruptive because of the rare occurrence of snow-related problems and an associated low level of preparedness.

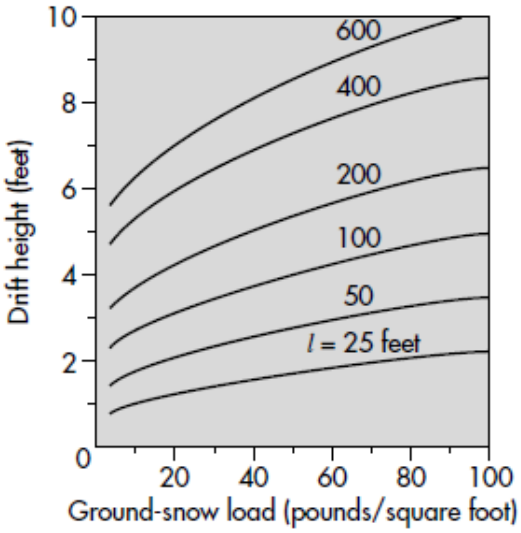


FIG. 5-4 Relationship of drift height and ground snow load. The drift height is proportional to the length of the roof upon which the snow falls. (Modified from O'Rourke MJ: Snow load on buildings, *Am Sci* 85:64-70, 1997.)

Avalanches

Avalanches typically occur on slopes of 25 to 60 degrees. However, they can occur on slopes as low as 5 degrees. They occur most commonly after snowfalls of at least 4 inches and can weigh up to 50 tons per square yard. Between 1900 and the end of 1995 more than 900 persons were killed as a result of avalanches. Recently the death rate has been increasing as a result of renewed interest in snow-related leisure activities. Local forecasts are the most reliable source of information on the possibility of avalanches. Significant numbers of wildlife are also killed each year by avalanches. Estimates are that 10% to 20% of mountain caribou deaths in Canada result from avalanches.

Avalanches are divided into two types: (1) Loose snow starts to move from a single point and

spreads outward. These avalanches usually are limited in size. (2) The more dangerous type of avalanche results from the rupture of slabs of bonded snow. These avalanches are typically 10 to 100 feet wide, but some have been up to a mile wide.

Another factor that determines an avalanche's impact is the type of snow involved. Wet snow usually moves at a slower speed, whereas dry snow can move at more than 100 mph.

Avalanches usually occur at the same location and take the same path each winter, which has important implications for wildlife and skiers. Avalanches clean chutes free of trees, allowing elk, moose, and mountain goats to graze there. These species take advantage of the easier access to vegetation where avalanches have fallen in the spring. Although the chutes cleared by avalanches make up only 5% of the landscape, bears spend 50% to 60% of their time eating, resting, and breeding there.

FIG. 5-5 Typical distributions of snow on roofs with different wind speeds. **A,** In calm conditions snow forms a uniform layer. **B,** If wind blows, the snow will drift. (Modified from O'Rourke MJ: Snow load on buildings, *Am Sci* 85:64-70, 1997.)

Building Collapses

Snow rarely settles uniformly. Snowdrifts usually occur if the wind blows more than 10 mph. Two main reasons exist for uneven distribution of snow on buildings. The most important reason is wind that causes snow to drift until it settles in an area where the turbulence is low. Common sites where the snow turbulates are on the lower of two roofs, roofs lower than surrounding trees, and the downwind side of gable roofs. Three fourths of damage from snow to buildings is to those with two-level roofs. Examples of these are shopping mall veterinary practices and businesses that have added extensions (e.g., to increase kennel boarding space or to house additional livestock). The redistribution of snow occurs as much of the snow settles on the lower deck. Building collapse can be prevented by constructing buildings strong enough to withstand the weight of the snow. Alternatively, buildings should be constructed in a way to lower the probability of snow drifting on the roofs.

The other main reason for uneven distribution of snow is thermal. Snow melts as it passes into a warm area of air and precipitates. This is a common problem with roofs that have insufficient insulation and can be prevented by adding insulation. Damage from snow to buildings is also caused by snow that has already settled and that then begins to melt. The higher parts of a roof are usually the warmest, so that is where the snow melts first. The water flows down the roof to the eaves, which usually are much colder. The runoff then freezes and eventually forms a small ice dam and icicles, which increases the weight on the eaves and can lead to rupture and building collapse. This is a relatively common problem in structures that have poor insulation and long eaves, such as livestock barns. Appropriate reinforcement of the eaves is the best approach to

prevent damage from melting snow.

In snow-prone areas buildings are categorized according to their public use and have to be built according to standards for each category. The building is intended to be strong enough to withstand the greatest snowfall expected to occur within a given time period. This is referred to as the mean recurrence interval (MRI). Public buildings, such as city halls, fire stations, and hospitals, have to be built to withstand a 100-year MRI. Buildings of average public importance, such as shopping malls and homes, are constructed to 50-year MRI standards. Agricultural buildings are constructed to 25-year MRI standards. Mitigation for animal care industries includes ensuring that buildings that house animals are built to appropriate standards. Veterinary hospitals and animal shelters should consider upgrading their construction standards so that they can function as critical facilities during severe snow weather.