Winter Weather Forecasting 101: Liquid-To-Snow Ratios Explained

A snowflake is magical and mesmerizing. Every snowflake that falls is different in shape, size, orientation, and density. Though, I’m sure you’ve questioned at some point why during different winter storms and events that produces snow, why does the snow have a weight to it that varies during each experience? This is where we discuss the term snow-liquid ratio.

Snow Liquid Ration (SLR) – What is it?

First, it’s important to understand what the flake is composed of. It’s a combination of air (nitrogen, oxygen, etc.), water (liquid form), and ice. Next, It’s a ratio of the amount of water contained within the flake to the depth of snow that falls. In other words, how much snow will accumulate on the ground with a given amount of liquid equivalent water. If you were to take snow, melt it down to its pure liquid form, how much melted snow equals a certain amount of water.

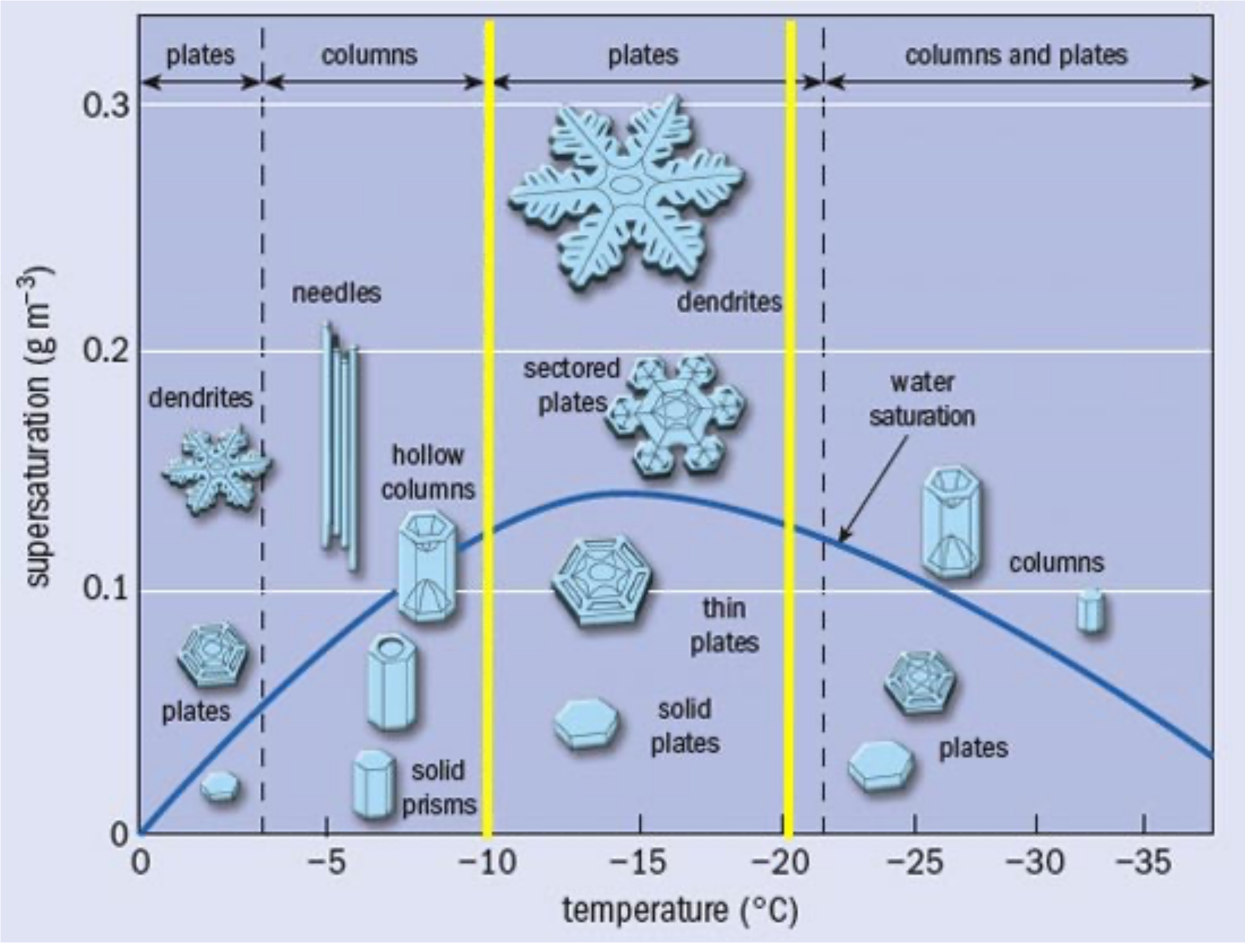
If you’re a big snow or winter fan, I’m sure you’ve heard of the old “rule of thumb” 10:1 liquid snow ratio. In this example, it means that if you measured exactly 10” of snow, it would melt down to precisely 1” of liquid water. A lower SLR (i.e., 6:1, 7:1)implies a heavier, denser snow (wet) while a higher SLR (i.e., 12:1, 15:1) means a fluffier and lighter snow (dry). We use the traditional 10:1 ratio as a reference or baseline when forecasting snowfall since figuring out the type of snow ratio will have large implications.

Variables That Affect Snow Ratios

1. Temperature & Moisture

First-and-foremost, a snowflake is created through a process called heterogenous nucleation. There must be some type of particle or substance (i.e., clay, aerosol, dust) for water vapor to condense onto, thereby creating the crystal. Moisture in this context is represented more by relative humidity. We need sufficient moisture to reach saturation in order for a snowflake to be created. However, too much moisture aloft may mean a lower ratio and you'll understand why.

Temperature by far is the biggest factor when it comes to snow liquid ratios. Temperatures matter from the time a snowflake is created within the snow-bearing cloud, through the depth of the column it travels through, and at the surface. Below is a prominent diagram used to explain what type of crystal develops at a specific moisture and temperature range. Those beautiful, perfect snowflakes you may have seen in close-up images or when holding a few in your glove as they fall are called dendrites. That is the specific type of image you may envision when you hear or think snow. These flakes are quintessential – when they accumulate, they build up uniformly and are light. Between the two yellow vertical lines is what is known as the "Dendritic Growth Zone" – the area we observe where ice crystals are 100% present and where dendrites form due to sufficient saturation and temperatures colder than -10*C. The "DGZ" is between typically -12 to -18*C.



The colder the temperature between the surface up to the cloud where snowflakes are falling, the higher the snow ratio will be. The only caveat can be if it's too cold believe it or not, this can result in poor ratios. This means if temperatures are colder than -20*C where flakes are being produced, there's little to no sufficient water vapor to produce snow. Though if temperature warm throughout the depth of the layer the flake falls through, the ratio will end up being higher especially if air temperatures are marginal.

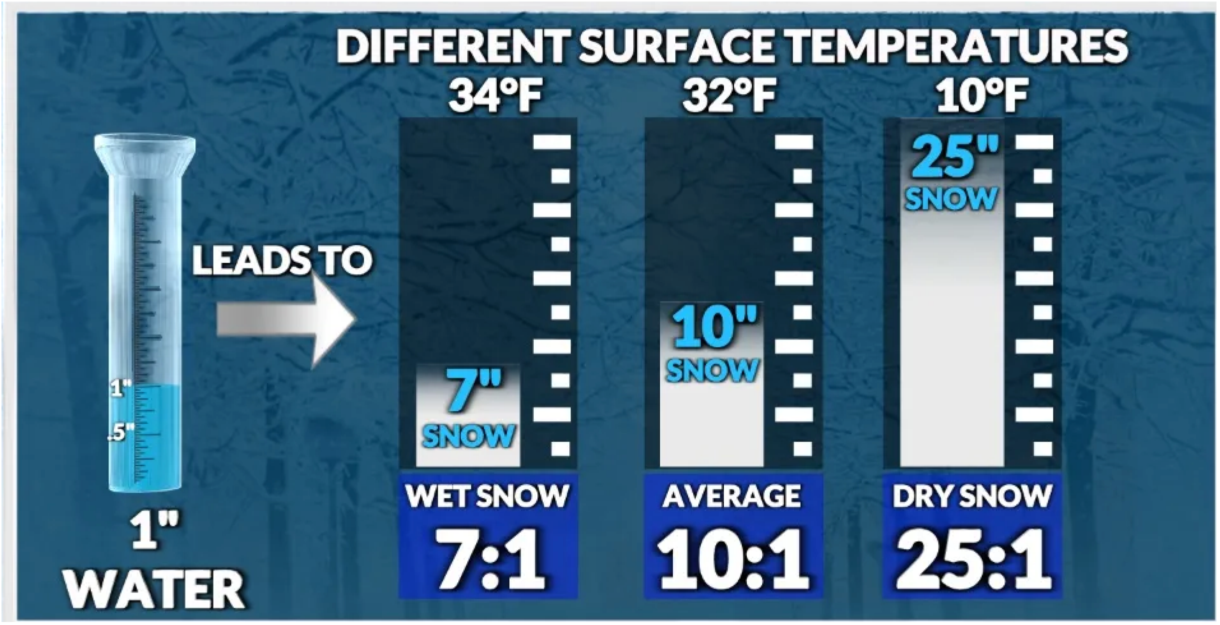
Lastly, specific type of storm tracks often provides clues in forecasting the snow to water ratios. An origination in the Gulf will typically have more liquid water as it tracks up the East Coast or into the Midwest, which in this case would result in a lower SLR. An Alberta clipper, however, originating from an inherently colder place will end up producing higher a SLR.

2. Amount of Ice

Visualize the development of a snowflake at its infancy. It now must travel downwards to the ground (in this case, to the left as temperatures increase). As the snowflake grows and temperature rises, it begins to collect liquid water; however, the water is *supercooled* (water that exists in its liquid state below 0*C or 32*F). So that flake now encounters other flakes, merging and becoming “sticky” since moisture is abundantly present as it clashes and collects onto the flake. It grows bigger until it finally hits the ground where the surface temperatures hover around the freezing mark. That snow now, if melted to pure water, would reveal a low SLR below 10:1. It’d be that heavy, dense, and “backbreaking” snow you shovel.

On the contrary, lets imagine the snowflake leaves the snow-producing cloud and the temperature remains within that range of -12*C to -18*C all the way down to the ground. While likely the snowflake encountered other nearby flakes, crystals remained the prevalent type within this temperature range. The surface temperature in this case let’s say was in the mid-upper 20’s. That SLR now was undoubtedly above 10:1, and the snow you’d feel would be light and fluffy.

A fantastic visual created from KNWA FOX 24 reveals how surface temperatures correlate with snow ratios, and how sensitive snowflakes are to the type of air temperature. We see that when temperatures that are marginal, it results in low snowfall totals because the SLR is low. 1” of liquid water, at a temperature around to above freezing, produces only about 7” of snow. However, on a cold, frigid day with an arctic air mass, temperatures are in the teens or 20’s. This produces much more snowfall because the SLR is higher, and this implies it’s effective at accumulating snow quickly.



3. **Wind**

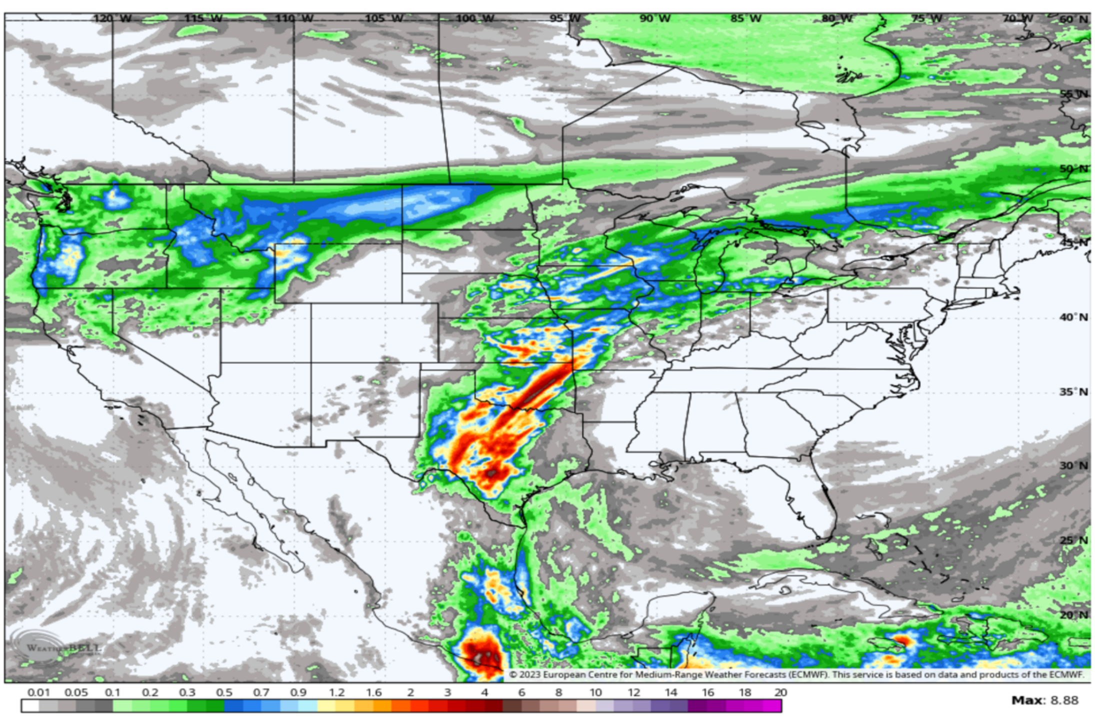
If the conditions are windy with potent gusts during snowfall, it can lead to the fracturing of snowflakes. As the flake falls, the higher winds cause splintering and breaking of the structures of the flakes. It also causes other flakes to violently clash into each other, ultimately resulting in poorer ratios once the snow finally makes it to the ground.

The temperatures could be ideal in a certain situation where dendrites are the dominant type. However, persistent windy conditions with strong gusts now can produce a more granular type of snow. There's less air in between the flakes, so it's "tighter". In this case, the snow that piles up occurs at an ineffective rate. This point proves how much factors into the type of ratio results, and why forecasting snow can be quite difficult.

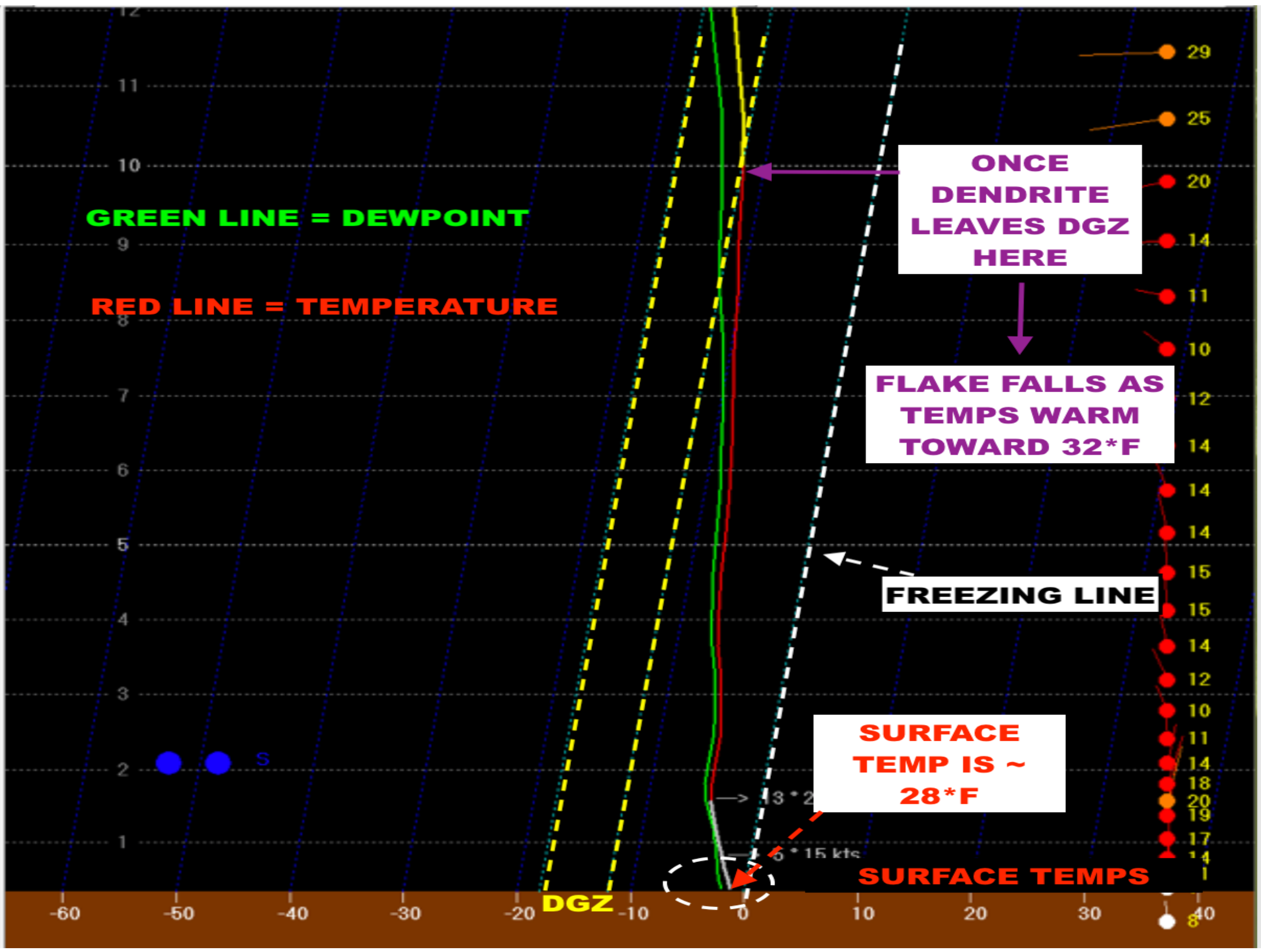
Forecasting Snow Totals

It's not an easy task, as there are many challenges. Other than the many factors that go into trying to get a solid estimate on how much snow will end up accumulating for a forecast, the tools that are at our disposal can't capture every single change that may arise from the surface up to the cloud. Numerical weather prediction in this case takes what falls, melts it down to liquid equivalent, and spits out a value based on its algorithm. However, it could be based on assumptions that are erroneous since more is happening aloft that the model isn't capturing. Now, there are also some models that try to utilize specific temperatures from the ground to the cloud and other complicated factors (i.e., vertical motion) to predict how much snow accumulates. Others may even try to decipher between pure snow versus freezing rain and sleet. They've come along way, but it's important to know they're just used as tools and guidance to help meteorologist make a forecast.

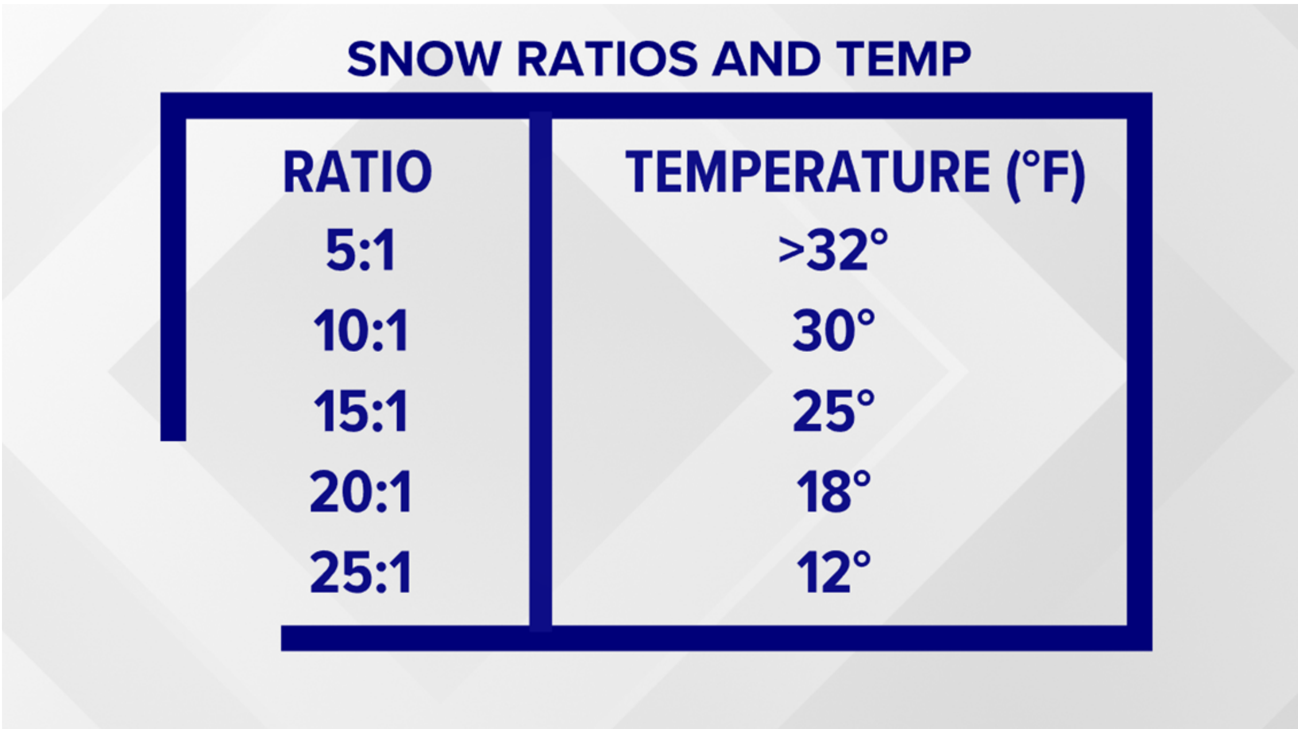
In this example, I'll be introducing a skew-t or sounding. This is a vertical representation of the atmosphere, and how temperature, moisture, and wind vary with increasing height. Don't be fearful of it at first glance, as it's easy to read and for simplistic sake, I've annotated the most important components for this example. First, let's take a total precipitation forecast from a computer model. Down on the precipitation graphic, the legend reveals the amount of precipitation as it's color-coded. If you were forecasting snow totals, you'd locate the general area you're interested in. Find the consensus maybe from other computer models regarding how much total precipitation will fall and next we compare this to a sounding.



Next, we now want to pull up the sounding for the area. Below is a skew-t from BUFKIT (analysis tool kit developed for snowfall forecasting). We see here the DGZ (dashed yellow lines where they encompass -12 to -18*C), the freezing line (dashed white), the temperature (red line), dewpoint (green), wind on the right-hand side, and brown represents the surface temperatures. In this vertical representation, once a flake leaves that -12 to -18*C range, it falls toward the ground. However, you notice that as it goes down, the red line is shifting more toward the right, so temperatures are warming. We remain totally below freezing the whole way down. At the surface, we have a temperature that is approximately 28 to 29*F.



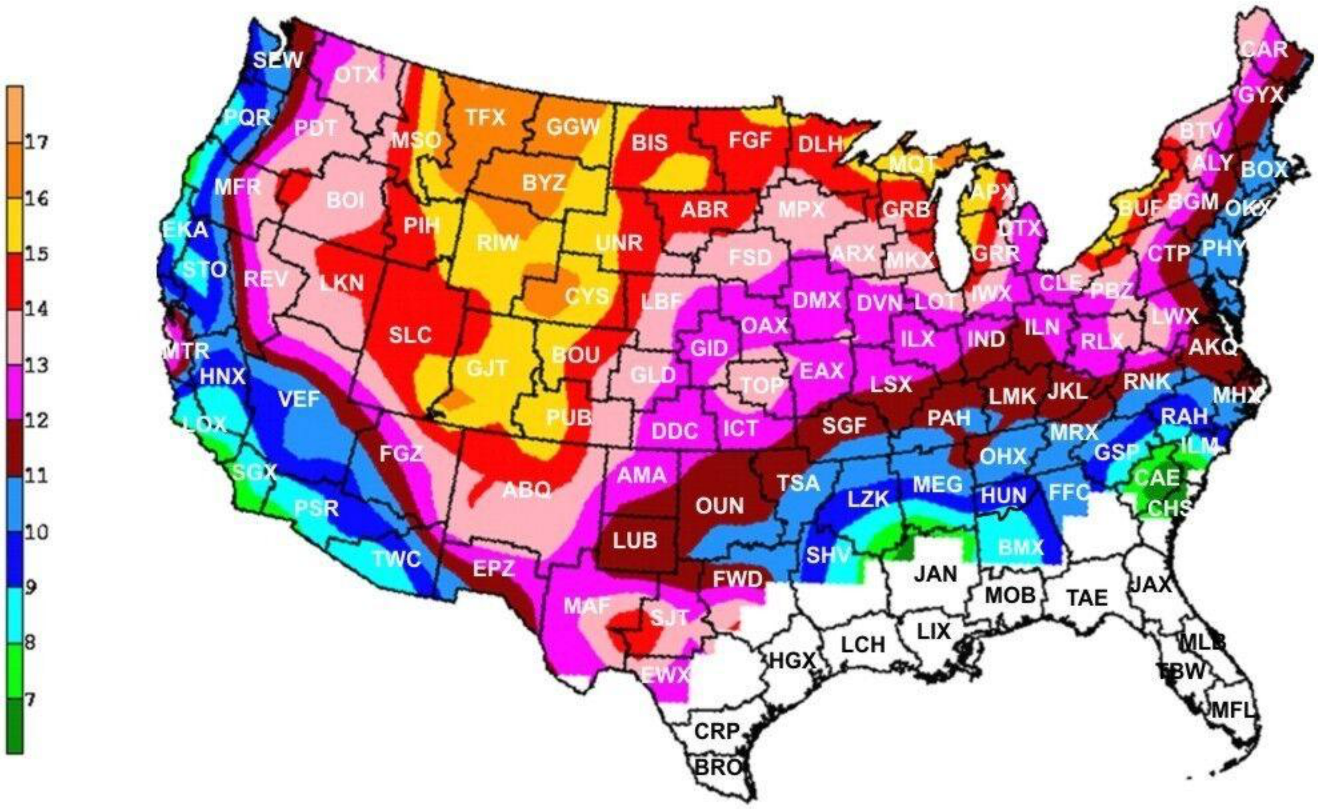
Next, we'll use a correlation of surface temperature to a general ratio thanks to a fantastic graphic created from [FOX 43](). We see that from the sounding above, that surface temperature being the destination the flake traveled to, would fit somewhere around 12:1 to 15:1 verbatim the graphic below. We finally take the precipitation liquid output from the area we're forecasting and multiply by the ratio. So, if we had a value of let's say 1.2'' of forecasted precipitation: 1.2 multiplied by 15:1 gets us a snowfall total of around 18" of snow. This ratio is higher than 10:1, so you can expect this to be a lighter, "dry" snow!



SNOW RATIOS AND TEMP

RATIO	TEMPERATURE (°F)
5:1	>32°
10:1	30°
15:1	25°
20:1	18°
25:1	12°

From a sample size of decades worth of winters, an average snow ratio was calculated thanks to Mark Schnackenberg. Here, we see that the higher ratios are seen across the northern tier of the U.S. while it decreases gradually as you get further toward the oceans. This makes complete sense, since "landlocked" states are away from the higher moisture sources and happen to coincide closer to Canada, which happens to be much colder during the winter with higher snowpack and it being closer to the Arctic. Again, this is just an average, so we see extremes at times, but a great visualization nonetheless of what specific regions see certain ratios!



There's a lot that goes into forecasting snow and see why it can be difficult. It's way more than just trying to ascertain a surface temperature and how much liquid snow falls. You must consider what happens from the surface to the time a flake leaves the cloud, any possible missed warmer layers aloft that may of not have been captured well by models, unforeseen gusts mixed down to the ground, competing areas of rising vs sinking motion, etc., The point certainly was made, but despite the challenges, we've come a very long way to nail certain forecasts and give us a general idea of how much may fall for an area. Hopefully you've learned a lot and see what's like inside a meteorologist's mind when it comes to forecasting snowfall!