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Analysis of Historical Hail Size Distribution Across the West Central Texas Region

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ABSTRACT

Severe hail is a common occurrence in West Central Texas (which encompasses the County Warning Area (CWA) of the National Weather Service (NWS) San Angelo, TX Weather Forecast Office (WFO)). This is especially true during the months of April, May, and June, which is the peak period of severe thunderstorm development in that region. The NWS will soon be implementing Impact Based Warning (IBW) Severe Thunderstorm Warnings (SVR) that have the capability of activating Wireless Emergency Alerts (WEA), which will be, in part, dependent on how large the hail tag is that's associated with the warning. An analysis of the distribution of hail sizes across the NWS San Angelo, TX (SJT) CWA was performed in order to find out how often hail sizes have exceeded the threshold that would be needed for WEA to be activated with the new SVR IBW hail tags. Through this investigation, it was discovered that it is somewhat uncommon for hail to be large enough to trigger WEA in the SJT CWA. Therefore, it is important for warning forecasters to be cautious not to include hail sizes that reach or exceed this threshold unless there is sufficient confidence based on thorough radar analysis and meteorological expertise.

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1. Introduction

Severe hail is a weather hazard that causes substantial damage every year in the state of Texas. Hail loss claims across the nation between 1 January 2017 and 31 December 2019 was 2,769,362, with Texas having the most claims out of all 50 states (637,977 hail loss claims, which is 23% of the US hail loss claim total; National Insurance Crime Bureau, 2020). The West Central Texas region is no exception to the threat that large hail brings, as exemplified by a long-duration severe hail event that occurred over the city of San Angelo (population of 100,000+ people) on 21 May 2020. Baseball to grapefruit size hail occurred across the city on that day, causing extensive damage to homes and cars.

Forecasters at the NWS issue SVRs to warn the public and emergency manager partners about severe hail (which is defined as having a hail-stone diameter of 1 inch or greater) and/or wind gusts of 58 mph or greater (National Weather Service, 2020). WEAs, which are the emergency messages that are sent to people's smart phones that are within the warning polygon, are currently not triggered when a SVR is issued. However, the NWS is planning on implementing new IBW SVRs which would have different damage threats attached to them, along with the ability to trigger a WEA if the hail size chosen by the warning forecaster reaches a certain threshold. If the chosen hail-stone diameter is 1.75 inches or larger but less than 2.75 inches, then the damage threat tag would be "Considerable", while if the hail-stone diameter is 2.75 inches or larger, the damage threat tag would be "Destructive" and a WEA would be triggered.

This short study was performed to document the historical hail-size distribution across the SJT CWA and the sub-regions of this CWA, as well as how the time of year affects this distribution. This was done in order to see how common it is climatologically to get hail sizes that are large enough to trigger a WEA from these new IBW SVRs in the West Central Texas region. The hope is that this study will help aid warning forecasters when deciding what hail size to use in their SVRs.

2. Data and Methodology

Historical hail reports were retrieved from the National Centers for Environmental Information (NCEI) Storm Events Database (NOAA, 2020). The geographical area of study is the NWS SJT CWA (Fig. 1), which is a region known as "West Central Texas". When searching for hail reports, only the counties within the SJT CWA were searched: Haskell, Throckmorton, Fisher, Jones, Shackelford, Nolan, Taylor, Callahan, Sterling, Coke, Runnels, Coleman, Brown, Irion, Tom Green, Concho, McCulloch, San Saba, Crockett, Schleicher, Menard, Mason, Sutton and Kimble counties. Between 9 April 1955 and 1 July 2020, a total of 4909 hail events were documented across this region, with 3488 of them being at or larger than 1 inch in diameter (which we will define as being "severe hail"). It should be noted that 226 of the hail reports had no geographical coordinates (latitude/longitude) attached to them. As a result, these reports could not be included in the map shown later in Fig. 8.

The thresholds that are used for differentiating hail-size distributions in the analysis are based on the aforementioned new IBW SVR hail tag thresholds. To plot the hail reports that reached these thresholds, ArcGIS Online's NOAA Geo-platform was used (ESRI, 2020). In this paper, we will use the following definitions for the differing hail size ranges: "medium-sized hail" are hail-stones that range from 1 inch to less than 1.75 inches in diameter; "large hail" are hail-stones that reached a diameter of 1.75 inches to less than 2.75 inches; "very large hail" are hail-stones that reached a diameter of 2.75 inches to less than 3.75 inches; and "giant hail" are hail-stones that reached a

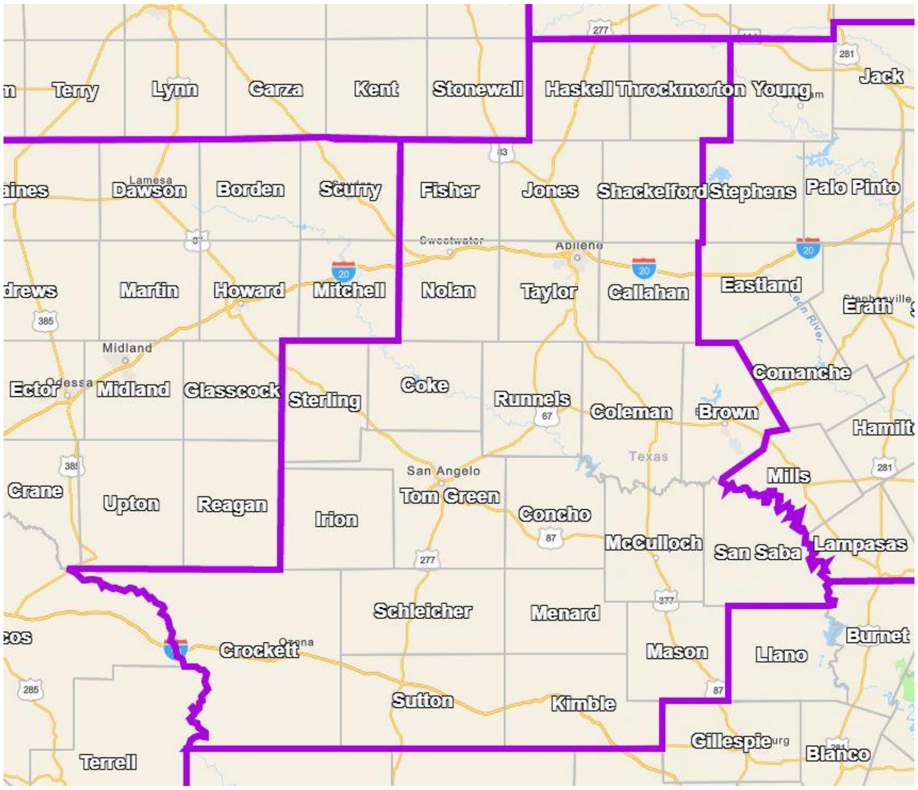

Figure 1: NWS San Angelo, TX County Warning Area

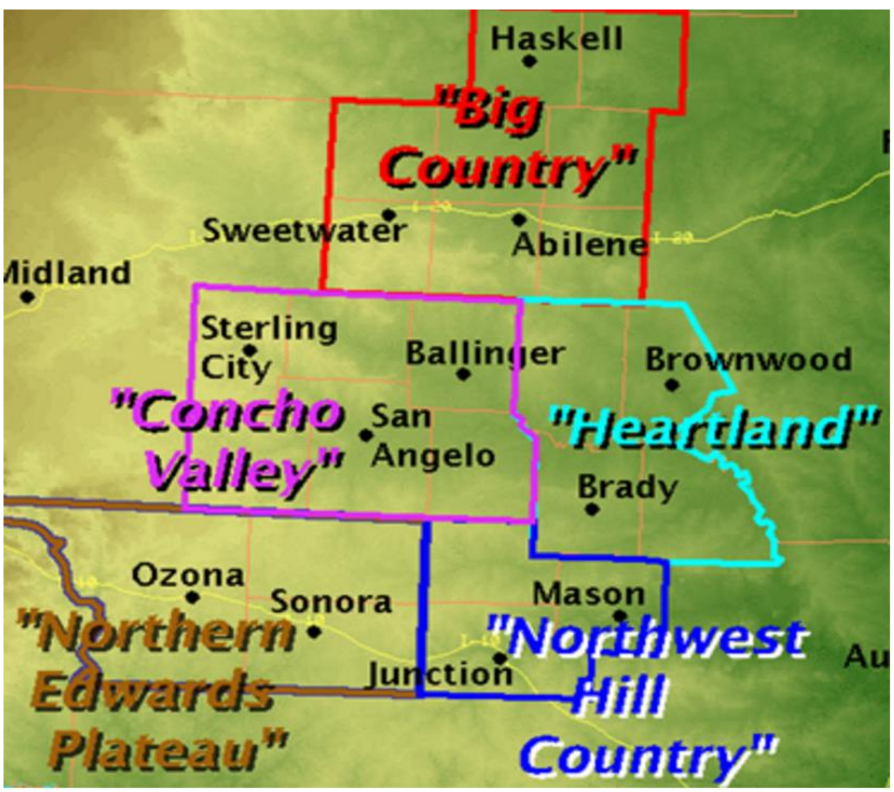

Figure 2: Sub-regions within the NWS San Angelo, TX County Warning Area

diameter of 3.75 inches or larger.

Within the SJT CWA, there are also 5 different sub-regions: the Big Country, Concho Valley, Heartland, Northern Edwards Plateau, and Northwest Hill Country (Fig. 2). A comparison was done between these regions to see if there were any noticeable differences in severe hail reports and hail-size distribution.

Finally, a comparison was conducted of severe and very large hail versus the time of year, to see the hail-size distribution patterns that showed for the different seasons.

3. Analysis

Analysis of the 3488 severe hail events that were recorded across the SJT CWA showed that medium-sized hail (41.3% of all severe hail cases) were actually less commonly reported than large to giant sized hail (58.7% of all severe hail cases, Fig. 3). However, once hail-stone sizes became very large (which is the threshold that would trigger a WEA), the number of occurrences became much less common (only 10.6% of severe hail reports, Fig. 4). Finally, as one would assume, giant hail-stones were even more infrequent (only 2.1% of severe hail reports, Fig. 5). There were only 3 reports out of the 3488 severe hail reports that had hail-stone diameters of 5 inches.

If we divide the hail-stone diameter thresholds up even further and display them in a bar graph, we can clearly see that once hail-stone diameters go above 2.5 inches, there is a substantial drop-off in hail reports (Fig. 6). While there were 1680 reports of large hail-stones, there were only 296 reports of very large hail-stones. There's another significant decrease in hail reports once hail-stones reach giant size. While there were 296 reports of very large hail-stones, there were only 72 reports of giant hail-stones.

Taking a look at the differences in the hail-size distributions in the 5 different sub-regions of the SJT CWA, all 5 sub-regions show a similarly significant drop-off in hail reports once the hail-stone diameter size increases above 2.5 inches (Fig. 7). One also sees the notable differences in the number of severe hail occurrences between the 5 sub-regions. These differences can be seen spatially as well (Fig. 8). One factor explaining this difference is the fact that supercell thunderstorms, which are responsible for producing 2 inch or larger hail-stones most often compared to other storm types (~96% of all 4653 cases of 2 inch or greater hail-stone diameter between 2003 and 2011, as shown in Smith, B. T. et al. 2012), have been shown to occur in the Spring-time most frequently across North Texas and Central Oklahoma, part of which is comprised of the Big Country sub-region and, to a lesser extent, the Concho Valley (Smith, B. T. et al. 2012). Another likely reason behind this are the population differences in each sub-region. The Big Country (estimated 2020 population of 204,730 people), and Concho Valley (estimated 2020 population of 139,309 people) have significantly more population than the other regions (estimated 2020 populations of 63,299, 11,894, and 11,229 people in the Heartland, Northern Edwards Plateau and Northwest Hill Country respectively), which correlates to more severe hail reports, as shown in Fig. 9 (ESRI, 2020). It stands to reason that the higher the population, the more likely that there will be someone who sees the severe hail and reports it.

Next, if we look at the number of reports of severe hail for all sizes, we see that reports of 1 inch hail (quarter size), 1.75 inch hail (golf ball size), and 2.75 inch hail (baseball size) were much more common than every other size (Fig. 10). This author believes that there is likely a social science cause to this distribution that is due to the fact that quarters, golf balls, and baseballs are more easily used by the public to compare hail sizes than less commonly used objects like ping pong balls (1.5 inch diameter), half dollar coins (1.25 inch diameter), tennis balls (2.5 inch diameter) and tea cups (3 inch diameter). The emphasis that the NWS puts on getting reports of quarter size hail or larger for verification of SVRs during its Skywarn training courses and public outreach is also likely a contributing factor for the amount of quarter size hail reports that are received.

Finally, there are no real big surprises when looking at the time of year that severe and very large hail occurs most often in the SJT CWA. It's common knowledge that the spring-time months are when severe thunderstorms (producing severe hail, winds, tornadoes and flash floods) are most common in the Southern Plains, which includes the SJT CWA. The analysis in this study confirms that severe hail, and specifically very large hail, occur most often during the Spring months. Figs 11 and 12 show that severe hail and very large hail occur much more often during the months of March through June than during any other times of the year. If we look specifically at very large hail, Fig. 13 shows that 94% of the time that very large hail has been reported, it occurred between March and June.

4. Conclusion

This study shows that large hail-stones are somewhat common in SJT's CWA, with Very Large and Giant hail-stones much more infrequent. In addition, this study shows that severe and very large hail reports are much less common outside of the Big Country and Concho Valley sub-regions of the SJT CWA. Also, the time of year can help the decision making for the warning forecaster, as this study shows that very large hail is fairly rare to find outside of the Spring-time months. Knowing all of this, forecasters should exercise caution when issuing SVRs that have hail-size tags that are large enough to trigger WEA (i.e. defined as "very large", or having hail-stone diameters of 2.75 inches or larger), unless there is high confidence. Having high confidence in a storm dropping very large hail would mostly depend on a thorough analysis of storm structure via traditional radar interpolation methods. However, based on the results in this study, additional factors that could nudge the forecaster confidence higher or lower would be: the overall frequency that very large hail has occurred in the past, the sub-region where the storm is occurring, and the time of year. If radar interpretation determines that the chance of very large hail occurring from a storm is border-line or perhaps a little better than border-line, and the climatological factors mentioned in this study decreases confidence in very large hail occurring, then the forecaster may want to lower the hail-size in the SVR. Otherwise, forecasters risk needlessly triggering WEA for hail-stone diameters that are unlikely to occur.

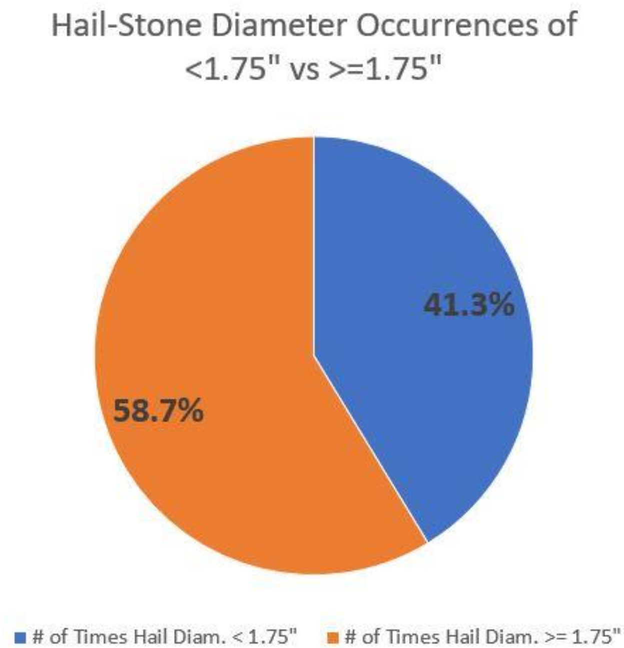

Figure 3: Pie Chart showing percentage of time that severe hail was less than 1.75 inches in diameter (blue) and the percentage of time that severe hail was equal to, or greater, than 1.75 inches in diameter (orange) within the NWS San Angelo, TX County Warning Area. Reports of hail-stone diameters that were 1.75 inches or larger were actually more common than hail-stone diameters of 1 to less than 1.75 inches.

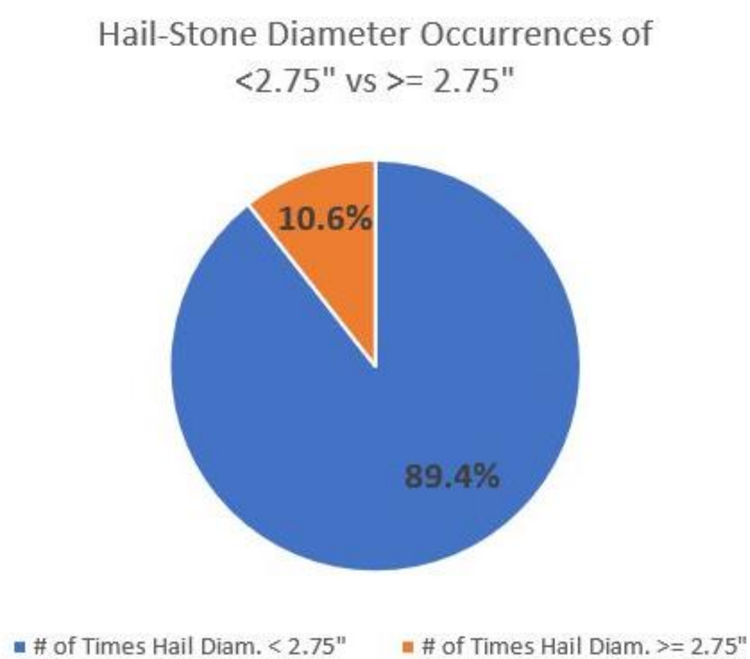

Figure 4: Pie Chart showing percentage of time that severe hail was less than 2.75 inches in diameter (blue) and the percentage of time that severe hail was equal to, or greater, than 2.75 inches in diameter (orange) within the NWS San Angelo, TX County Warning Area. Hail-stone diameters of 2.75 inches or larger were much less common than hail-stone diameters less than 2.75 inches.

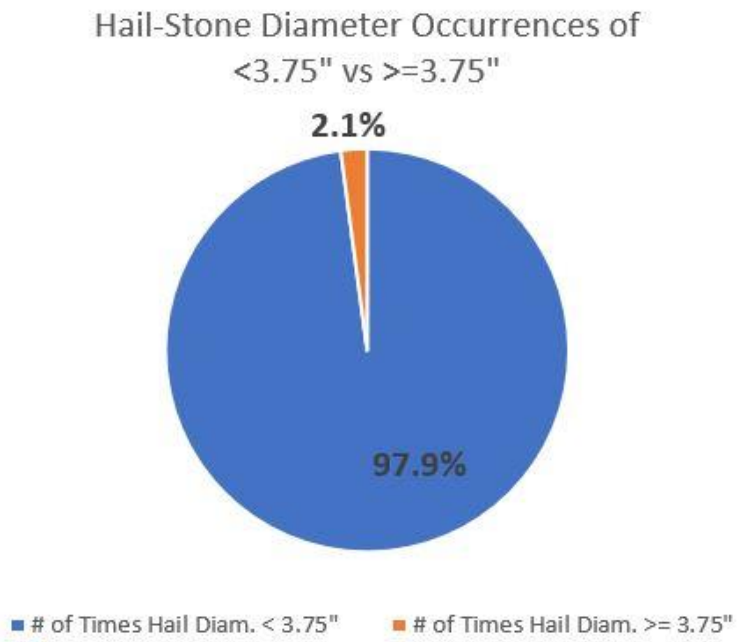

Figure 5: Pie Chart showing percentage of time that severe hail was less than 3.75 inches in diameter (blue) and the percentage of time that severe hail was equal to, or greater, than 3.75 inches in diameter (orange) within the NWS San Angelo, TX County Warning Area. Hail-stone diameters that were 3.75 inches or larger were a fairly rare occurrence.

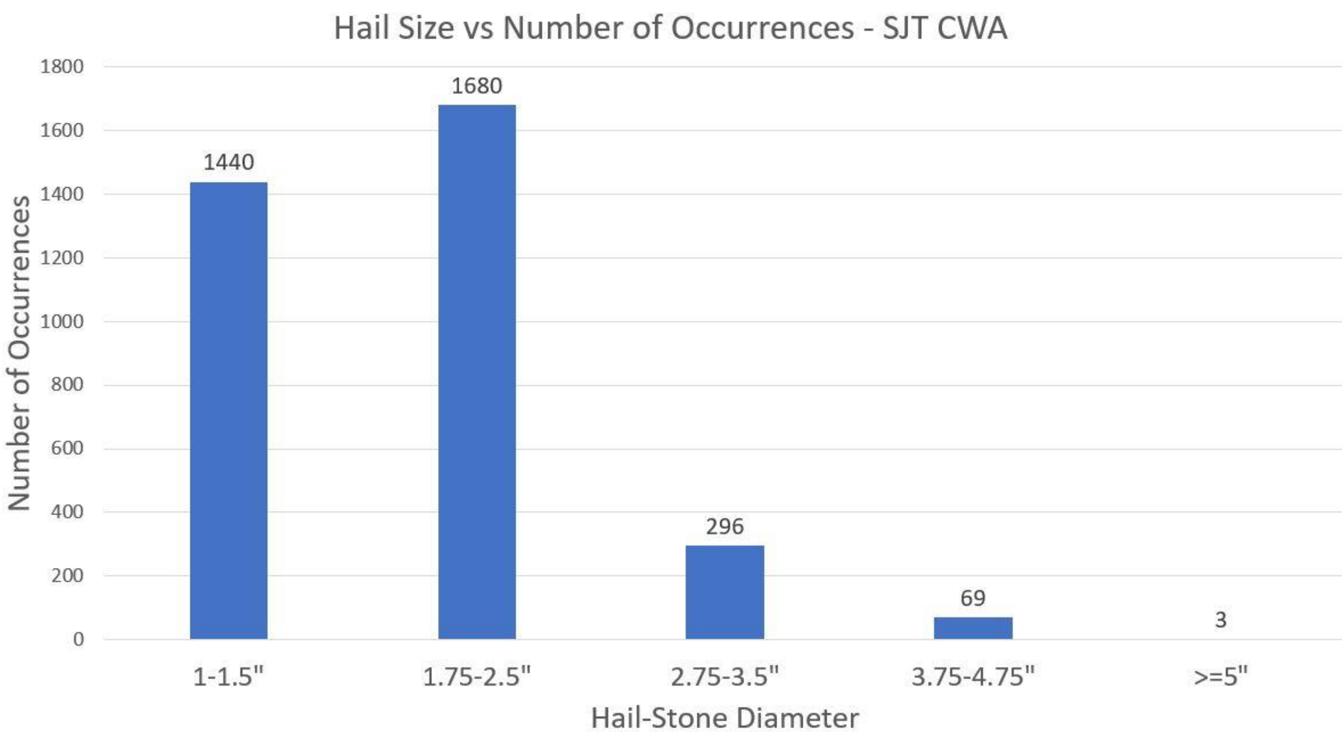

Figure 6: Bar Graph showing hail-size distribution across the NWS San Angelo, TX County Warning Area. Hail-Stone diameter range is on the X axis, while Number of Occurrences is on the Y axis. Notice the significant drop-off in severe hail reports once the hail-stone exceeds 2.5 inches in diameter.

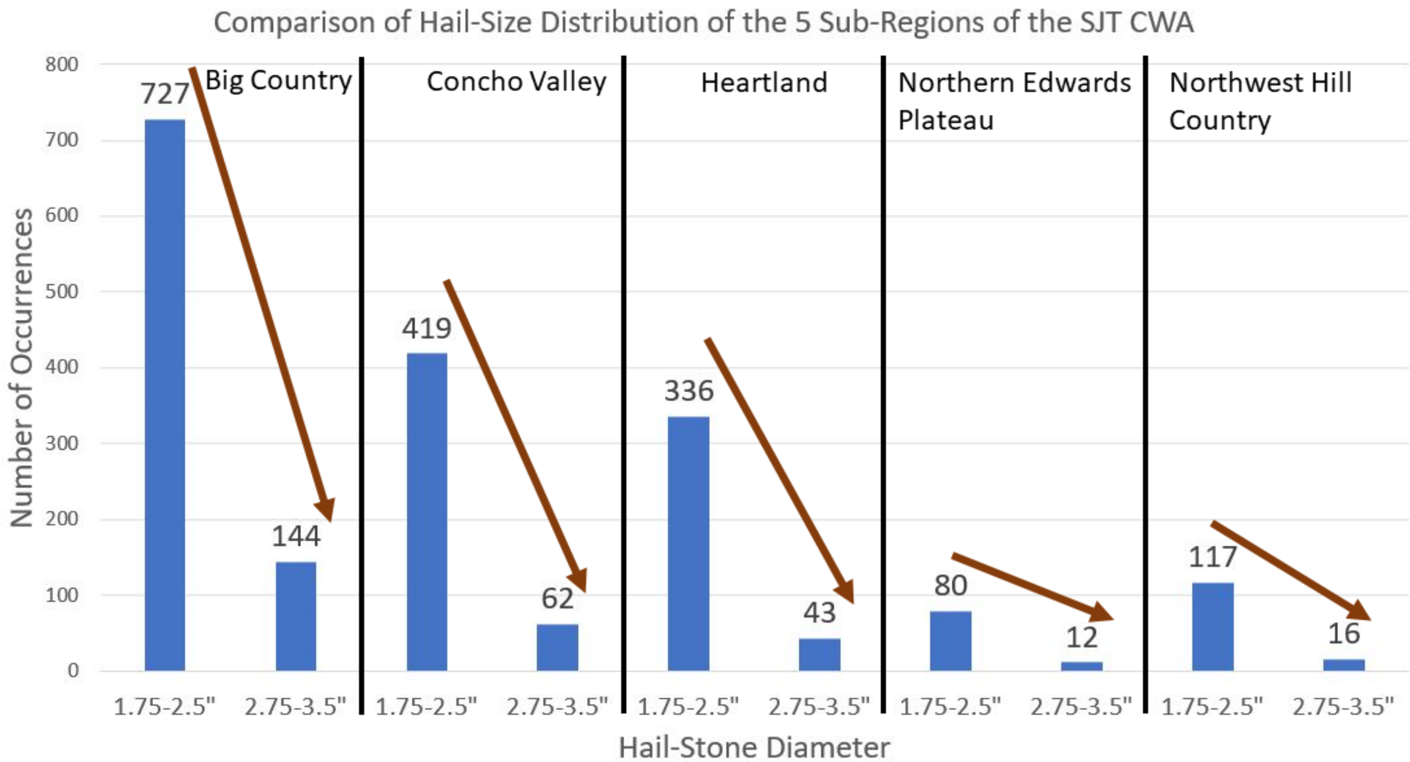

Figure 7: Bar Graph showing a comparison between hail-stone diameters of 1.75-2.5 inches and 2.75-3.5 inches in the 5 different sub-regions of the NWS San Angelo, TX County Warning Area. The Brown arrow emphasizes the significant drop in reports as the hail-stone diameter increases above 2.5 inches across all 5 sub-regions.

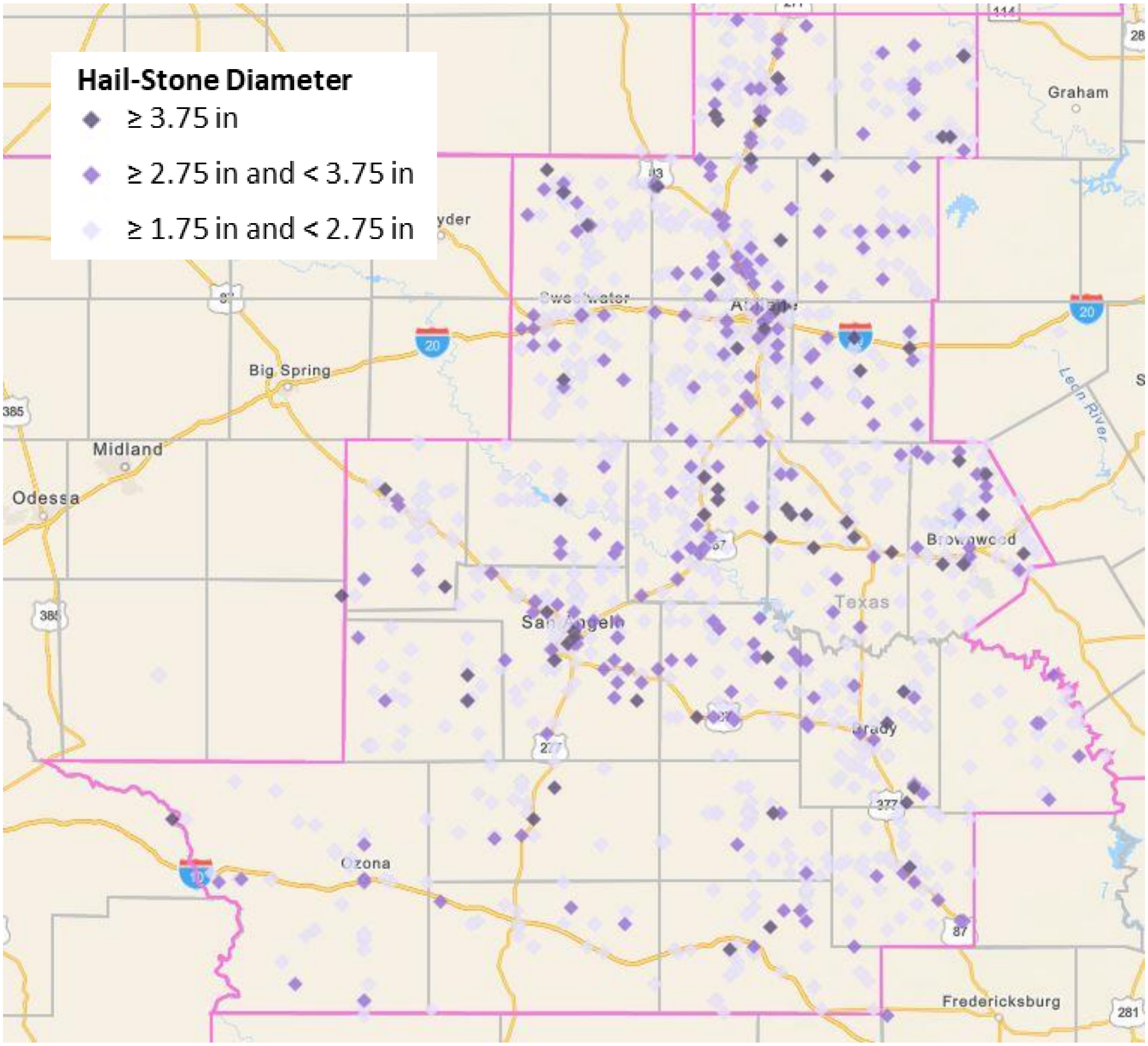

Figure 8: Map showing all of the hail reports (diamond shapes) across the NWS San Angelo, TX County Warning Area between 9 April 1955 and 1 July 2020 where the hail-stone diameter was 1.75 inches or larger. Light purple shading indicates hail-stone diameter size of 1.75-2.5 inches, regular purple shading indicates hail-stone diameter size of 2.75-3.5 inches, and dark purple shading indicates hail-stone diameter size of 3.75 inches or larger. Notice the higher concentration of severe hail reports across the Concho Valley and Big Country, where population is higher.

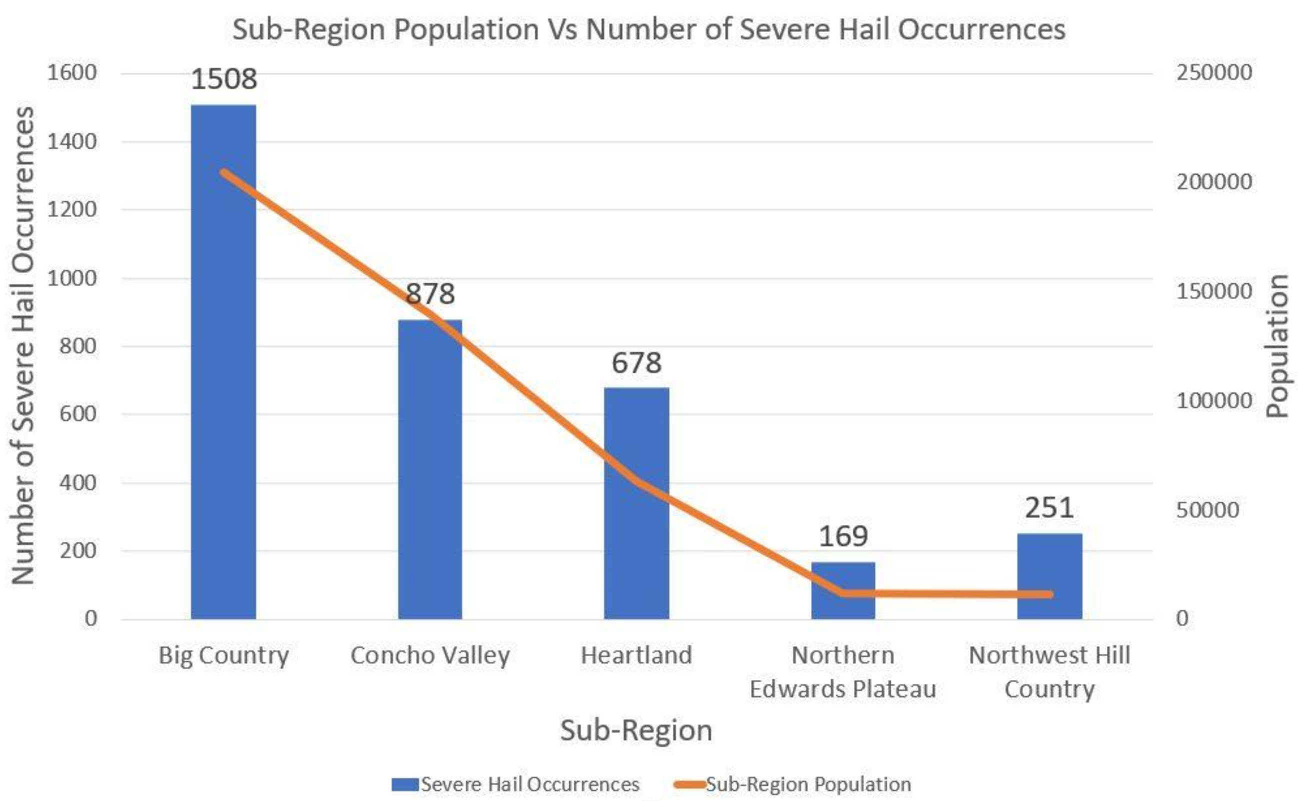

Figure 9: Combination Bar Graph/Line Plot showing the number of Severe Hail Occurrences vs Population in the specified Sub-Region in the NWS San Angelo, TX County Warning Area. Notice the drop-off in the number of severe hail reports as population in the sub-region decreases.

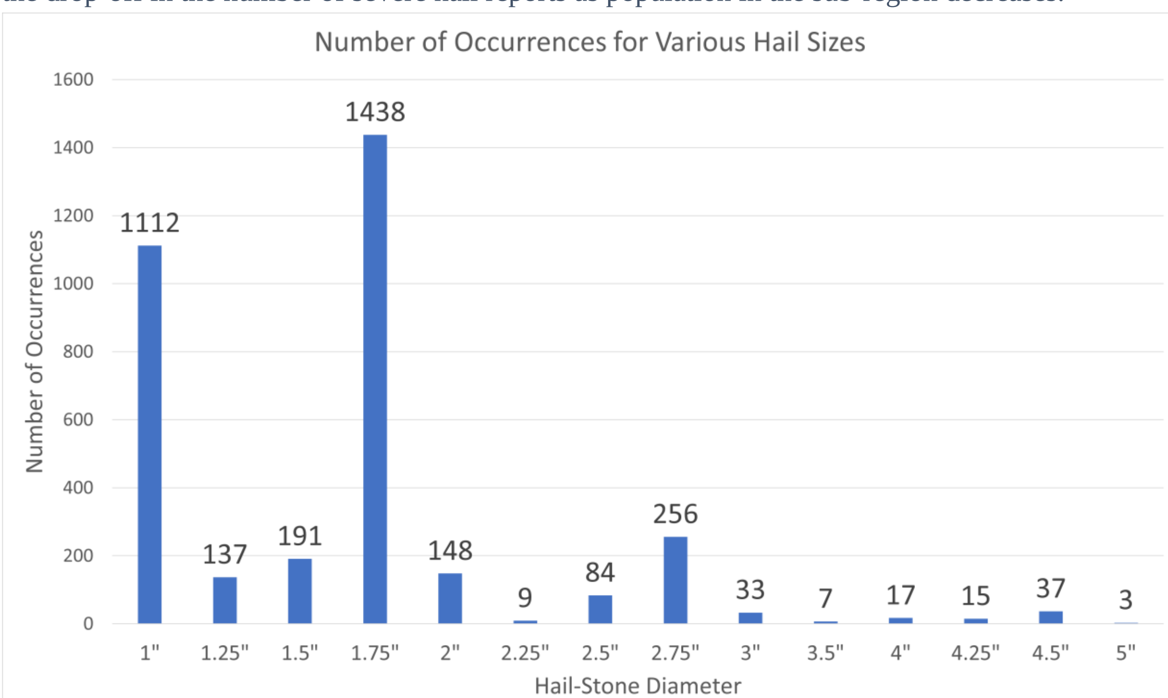

Figure 10. Bar Graph comparing number of occurrences between severe hail of all sizes. Interestingly, the most common reported sizes were 1 inch, 1.75 inches, and 2.75 inches, with much smaller number of reports for all sizes in between.

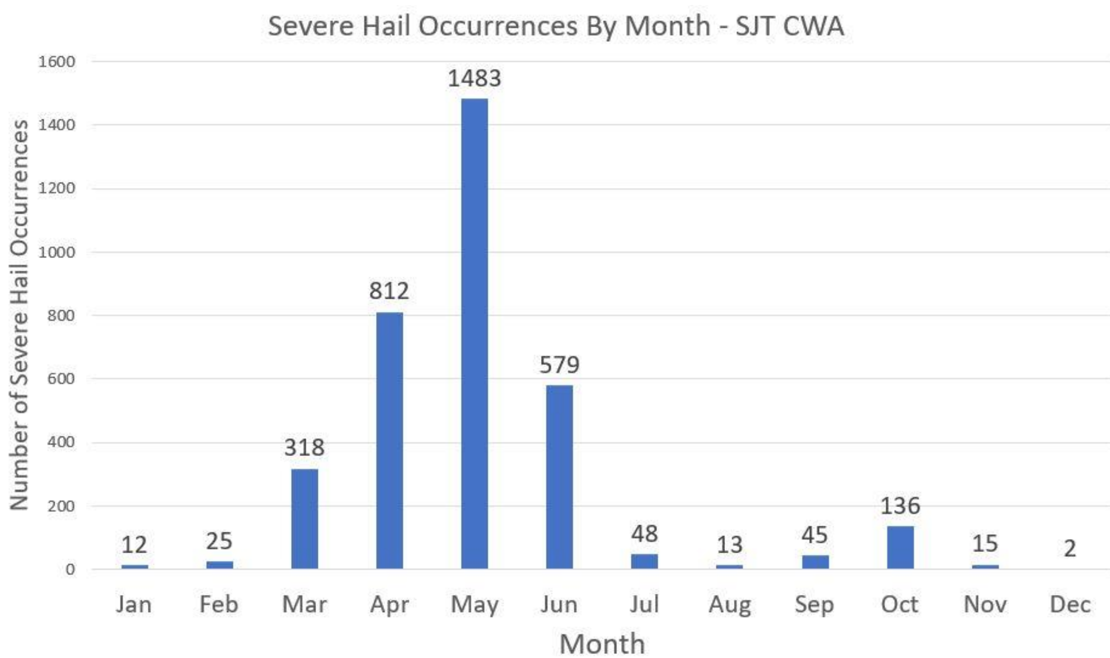

Figure 11: Bar Graph showing the number of severe hail occurrences across the NWS San Angelo, TX County Warning Area by month. The peak time of year for severe hail is the Spring-time, with May being the most active month.

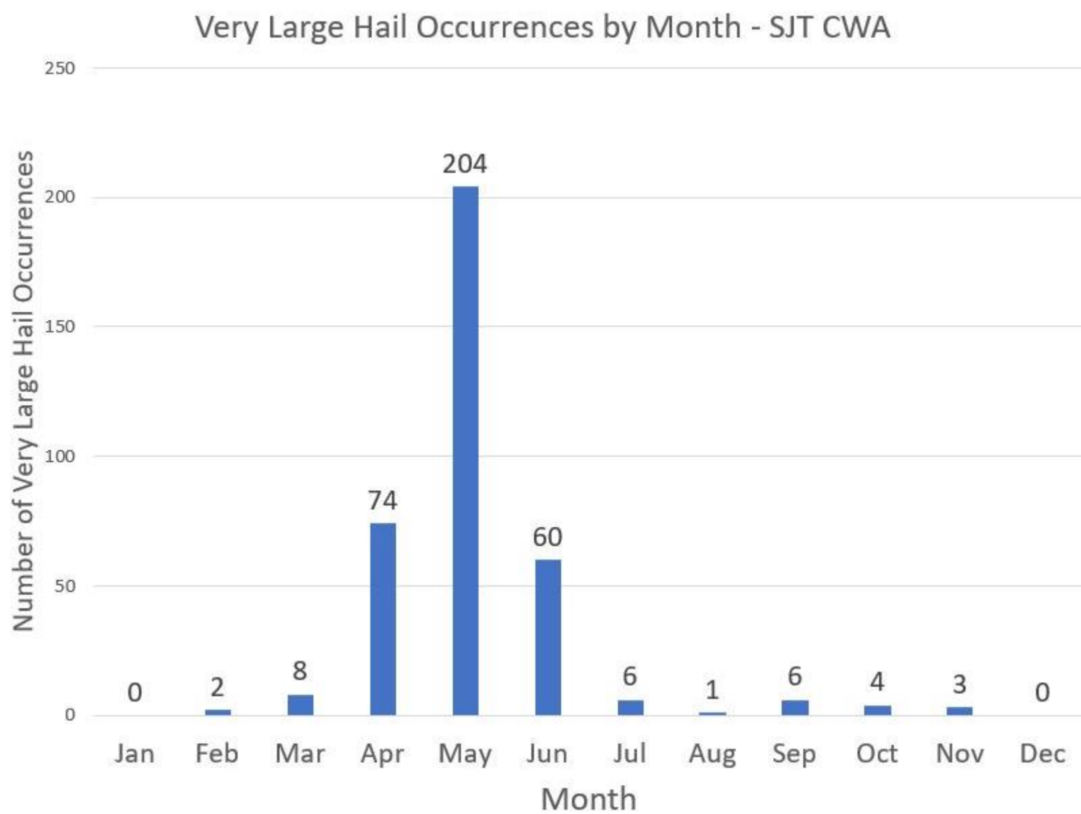

Figure 12: Bar Graph showing the number of very large hail occurrences across the NWS San Angelo, TX County Warning Area by month. The peak months of very large hail are April through June, with May, once again, being the most active month.

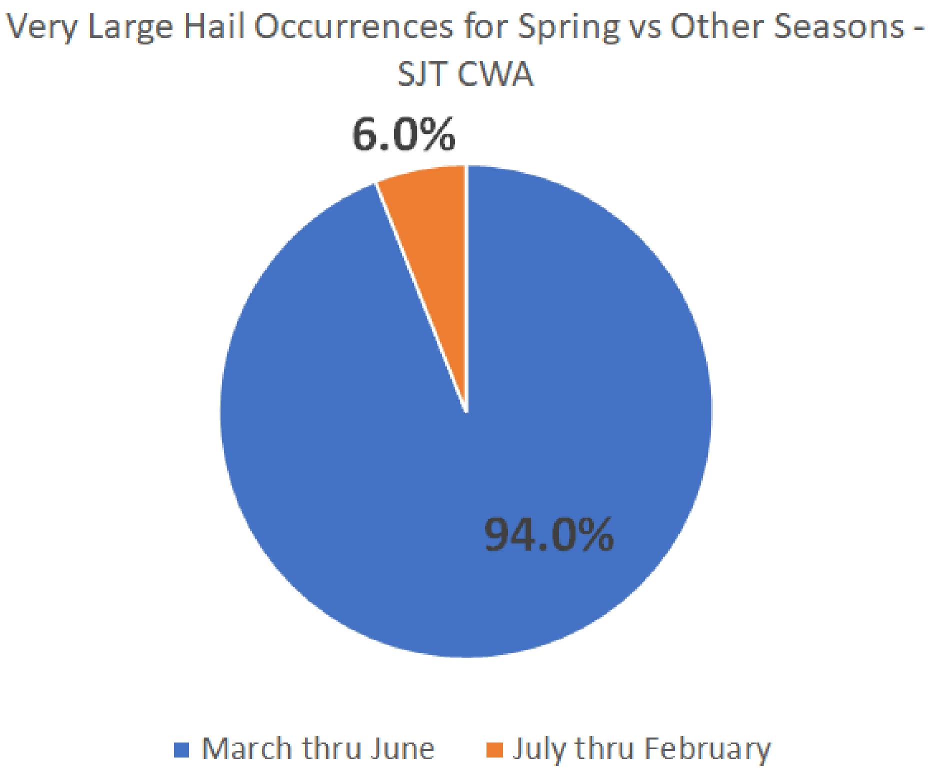

Figure 13: Pie Chart showing the percentage of time very large hail occurred during the Spring months vs all other months for the NWS San Angelo, TX County Warning Area. 94% of the time very large hail was reported, it occurred during the Spring months.

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