Frequency of Warning Level Snowfall in Northeastern Nevada

National Weather Service

Elko, Nevada Weather Forecast Office

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1. Introduction:

The Great Basin topography is extremely complex with hundreds of narrow mountain ranges predominantly oriented in a north-south direction, separated by flat narrow basins. Numerous mountain ranges have vertical relief of 5,000 feet or greater, leading to extreme variations in snowfall. This type of terrain is no more prevalent in the Western CONUS than in the National Weather Service-Elko, NV County Warning Area (CWA). The diverse terrain and large public forecast zones, due to expansive areas of unincorporated land in this part of the country, has led to numerous forecast challenges when forecasting warning level snowfall. The vast majority of the populace lives in the lower elevation basins, but numerous commercial byways pass through the region over higher terrain (**Figure 1.**).

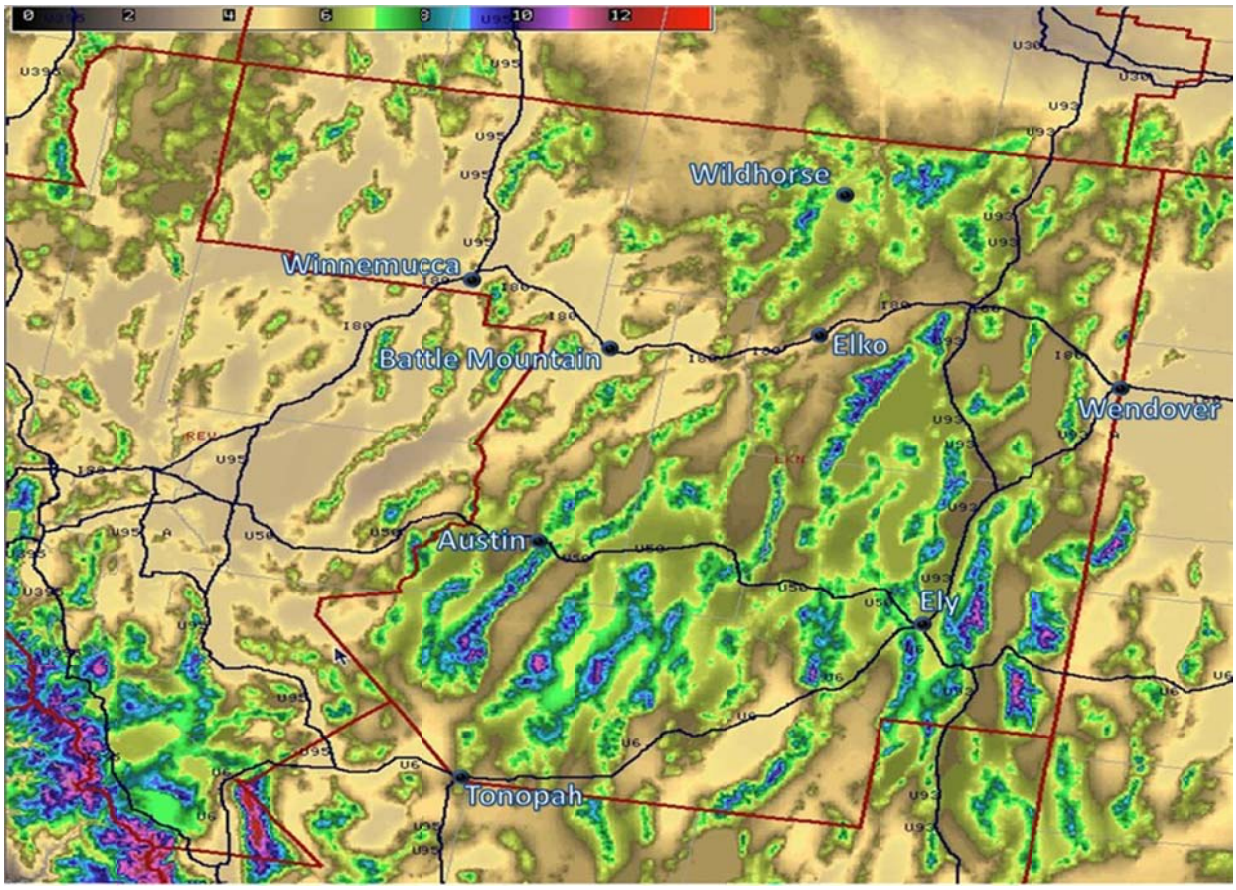

Figure 1. Elko CWA Topo Map and Study Locations

The motivation for this study was to find out how often warning level snowfall occurs in different geographical locations and elevations throughout the CWA. With the relatively new elevation-based hazard capability in the Graphical Forecast Editor (GFE), forecasters will be able to use this study as an aid in their decision making process based on climatological frequency of occurrence. The end goal is to improve office warning performance by decreasing false alarm rates for lower elevations, as well as decreasing the number of missed events for the higher elevations.

2. Data and Procedures:

Warning level snowfall for Elko's CWA is defined as 6" in a 12-hour period or 8" in 24-hours for valley locations (which is characterized as elevations below 6500 feet). It is interesting to note that some basins within the CWA are above 6500 feet and not considered mountainous terrain, such as the town of Austin.

Selection of sites for this study was based on three distinct factors. First, one site was selected per forecast zone; second, sites with different elevations within the forecast area; and third, the period of record for snowfall, with longer periods of record being favored. The sites selected for this study and their corresponding forecast zone number are listed below in (**Table 1)**. The only unrepresented zone in this study is number 034, which is a recreational mountain zone in the CWA that has no reliable snowfall data for historic analysis.

Location	Forecast Zone Number
Tonopah	013
Winnemucca	030
Wildhorse	031
Elko	032
Wendover Airport	033
Ely	035
Battle Mountain	036
Austin	037

Table 1. Sites selected for this study with their corresponding forecast zone

For the basis of this study, warning level snowfall amounts were defined as 6" of snow or greater reported on the daily summary of either form B-91 (COOP sites), or Weather Service Form 1009. Snowfall totals for 24-hours were used at all sites and no hourly data were used in this study. In addition to one-day snow totals greater or equal to 6", two-day snow totals greater than or equal to 6" were also calculated and defined as an event.

There were two assumptions made with the data that could lead to errors in the results. First, the two-day snow event could lead to a high bias of events, because it is assumed that the snow began on day one and was continuous through day two. Due to the 24-hour snow total records, it cannot be discerned if there were two periods of snow or one continuous snowfall that transcended two days.

Example two-day event:

Site A Day 1 Snow = 4”
Site A Day 2 Snow = 3”
Site A 2-Day Snow Total = 7”

Second, multi-day snow events that had daily warning level snow amounts were counted as one continuous event and not two separate events, which could lead to a low bias of events. Using the 24-hour snowfall data, it is not possible to conclude if there was a significant break in the snow to count these storms as two separate events.

Example multi-day warning event:

Site B Day 1 Snow = 6”
Site B Day 2 Snow = 8”
Site B 2-Day Snow Total = 14”

With these two assumptions offsetting each another, there are no significant biases expected in the results.

Reliable snowfall records are notoriously difficult to find and this study was no different, but fortunately there were enough sites with sufficient periods of record. Periods of record for the study ranged from 28 years up to 125 years. All sites, except Elko, had periods of missing data with Tonopah and Wendover snowfall records ending over a decade ago. Wendover is the most extreme example with snowfall records ending in 1976. The nature of this study focusing on frequency of events and not a trend analysis of the data, limits the impact of the missing data.

Metadata indicates that all observing locations changed at least once during the period of record, with the only exception being Wildhorse Reservoir. Looking at the distance and elevation differences of the station moves, Elko, Battle Mountain, Winnemucca, and Austin were all compatible moves and should not impact snow data. Tonopah’s location from downtown (1906-1948) to the airport (1948-2000) can be considered a significant move. The airport is located seven miles east of town in the center of a basin at an elevation of 5395 feet. The town is located in a group of hills at an elevation of 6100 feet. As a result, these locations are vastly different and the data indicates this; more of which will be covered in the results section. Another incompatible move could be Ely, where the snow observation point moved from the airport

(elevation 6262 feet), to an observer five miles away at a slightly higher elevation of 6500 feet. The close proximity of the observer to the foothills of a mountain range could lead to enhanced upslope effects that would not be seen at the lower elevation location. Fortunately, the observation point was moved in 2010, so it will not impact the study, but it could be an issue in future research.

3. Results:

There are large differences in warning level snowfall frequency within the National Weather Service-Elko, CWA. The average number of events varies from an 18% chance per winter (once every five winters) for Wendover, with up to seven events per winter at Wildhorse Reservoir (**Table 2.**). In general, there is a strong correlation between lower elevations and fewer events, with an event once every two winters across the lower valleys of the Humboldt River. The likelihood increases to one event per season further upstream of the Humboldt River Valley in Elko County. Higher elevation basin floors of central Nevada around Ely experience two events per winter, with upwards of four events per winter at Austin, located in the foothills of the central mountain ranges. Farther south on the CWA border, Tonopah airport averages one event every 2 winters, but this data most likely does not represent the town of Tonopah itself, due to the previous issue of location noted in section 2. When the observation site was located in town there were 28 events in 28 years, but only 14 events in 46 years at the airport. Unfortunately there hasn't been any data from the town of Tonopah in over 60 years, but it is likely that the lower elevation and location of the airport compared to town causes the large difference in event frequency. Wildhorse Reservoir, which has the highest frequency of occurrence, is situated on a high plateau surrounded by mountain ranges. This area is prone to orographic enhancements from both southwest flow and northwest flow, sits at a much higher elevation, and is the northernmost site for this study.

Location	Elevation(ft)	Period of Record (yrs)	Snowfall Events >= 6"	Avg Events Per Winter	Max Events (season)	Min Events (season)
Wildhorse	6239	28	200	7.1	14	1
Austin	6780	79	300	3.8	10	0
Ely	6262	69	114	1.7	6	0
Elko	5030	82	86	1.05	5	0
Battle Mountain	4505	65	41	.6	4	0
Tonopah	5395	74	42	.57	4	0
Winnemucca	4313	125	70	.56	3	0
Wendover AP	4240	57	10	.18	2	0

Table 2. Historical Warning Level Snowfall Frequencies for Elko CWA

In addition to the variability of events based on location, there are also large spreads in events per season at a specific location. All locations, except Wildhorse Reservoir, experienced at least one winter without a warning level snow event. The highest occurrence of snow events was at Wildhorse Reservoir with 14 events in a season.

The research also looked at warning level snowfall events per month for each sites period of record. This data is depicted in graphical format (**Figures 2 through 9.**). The data indicates a dissimilar trend between the northern CWA sites and southern CWA sites. The northern CWA sites of Elko, Winnemucca, Battle Mountain, and Wildhorse Reservoir all show a mid-winter peak in the number of warning level events. Specifically, January is the highest frequency month with December a close second. Snowfall events rapidly decrease in the months of February and March. This is likely caused by higher solar insolation decreasing snow ratios at lower elevation sites, and the probability of the progressive westerly storm track shifting north. Further south at Austin and Tonopah, the maximum frequency of events occurs later in winter during March; with a secondary maxima occurring in April for Austin. The most likely cause of this could be contributed to the frequent number of cut-off lows that occur in March and April across central Nevada. Ely is an interesting site that seems to be impacted by both the northern and central Nevada weather patterns. There is a noticeable snowfall maximum in January, with a second maximum in March, but a slight lull for the month of February. The lull in February is not an artificial trend caused by missing data, because there was only one month missing out of 69 years.

The last approach of looking at the data was snowfall frequency on the decadal scale. Unfortunately, some sites with large periods of missing data make the results inconclusive. The number of warning level snowfall events by decade are depicted graphically in (**Figures 10 through 17.**). Elko is an interesting site that has had a large increase in events during the past two decades, compared to the 1930-80s. The metadata indicates the site has changed to 3 different locations, with all moves being compatible. When looking at season snowfall trends there is a slight trend towards higher yearly snowfall totals during the past two decades, but not significant enough to account for the large increase in warning level snowfall events. The reason for the increase in events is inconclusive, with undocumented changes in observation procedures being a possible cause. Winnemucca is another good site which has the longest period of record with only the 1880s and 1990s having missing data. The snowiest decade occurred during the 1880s, with a secondary peak during the 50s and 60s. Besides these two peaks, warning level snowstorms were mostly uniform for the remaining period of record with 4 to 6 events per decade. All other sites either have a short period of record or large gaps in the data, thus no clear decadal trends can be summarized from this data.

4. Conclusion:

The results for the frequency of warning level snowfall showed to be highly variable across National Weather Service-Elko's CWA. Elevation and geographical proximity to mountain ranges have a large impact on how often warning level snowfall criteria were met. It was also shown that frequency of warning level snowfall occurred during early to mid-winter across the northern CWA and during the late winter across the southern CWA. The progressive, westerly storm track is typically located across northern Nevada during mid-winter, which most likely causes the mid-winter peak across the northern CWA. Late winter and early spring cut-off lows are more common across central Nevada, which causes the later peak in events across this region.

With such a low return interval frequency for warning level snowfall across certain forecast zones, forecasters should differentiate the significance of a warning level snowfall event between zones. For example, zones 030 (Winnemucca) and 036 (Battle Mountain) have a two-year return interval frequency for 6" warning level snow and zone 033 (Wendover Airport) has a five-year return interval frequency. Compare these low return intervals to the seven events per season at Wildhorse Reservoir. Impacts will likely be much greater across the lower elevation towns and cities during warning level snow events, than across the higher elevation locations that routinely receive greater snowfall.

Acknowledgments:

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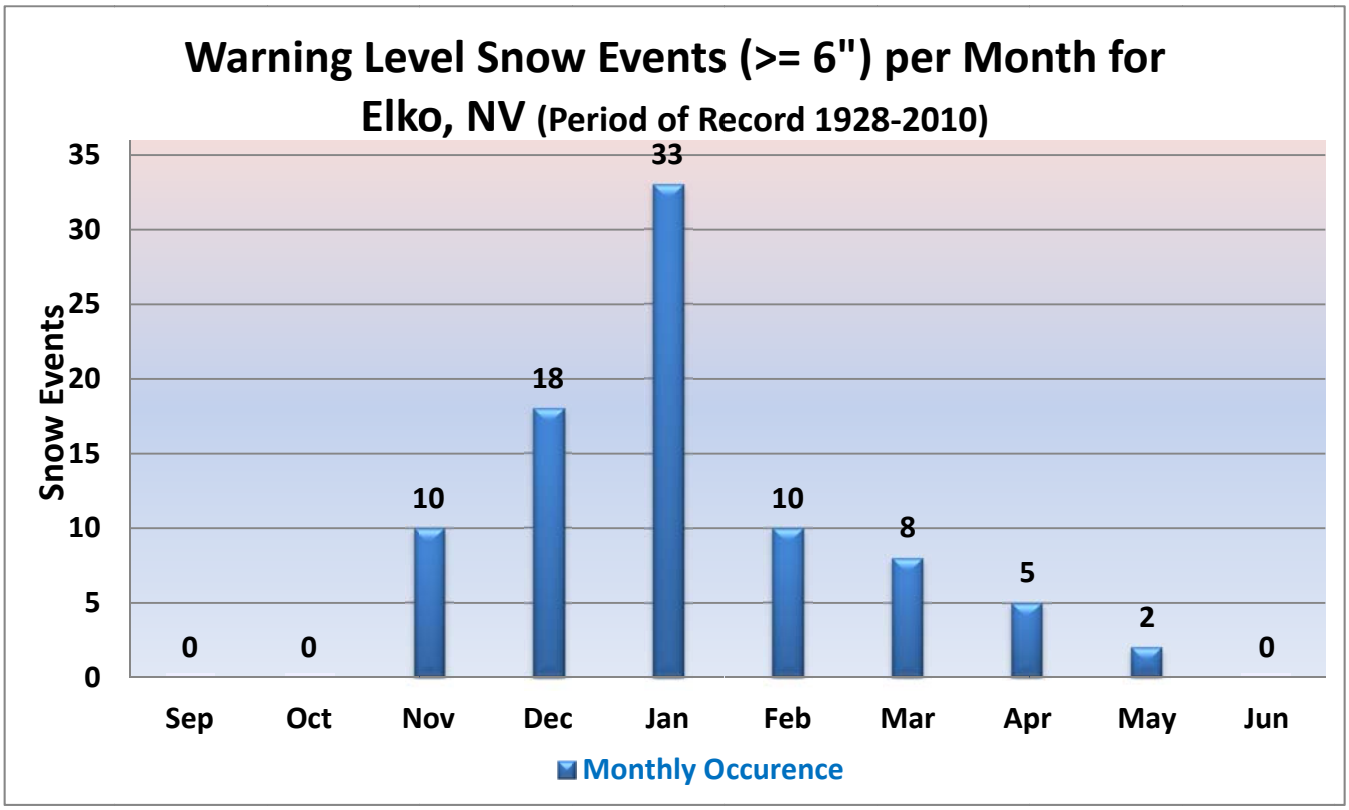

Figure 2. Elko, NV Warning Level Snow Event per Month (1928-2010)

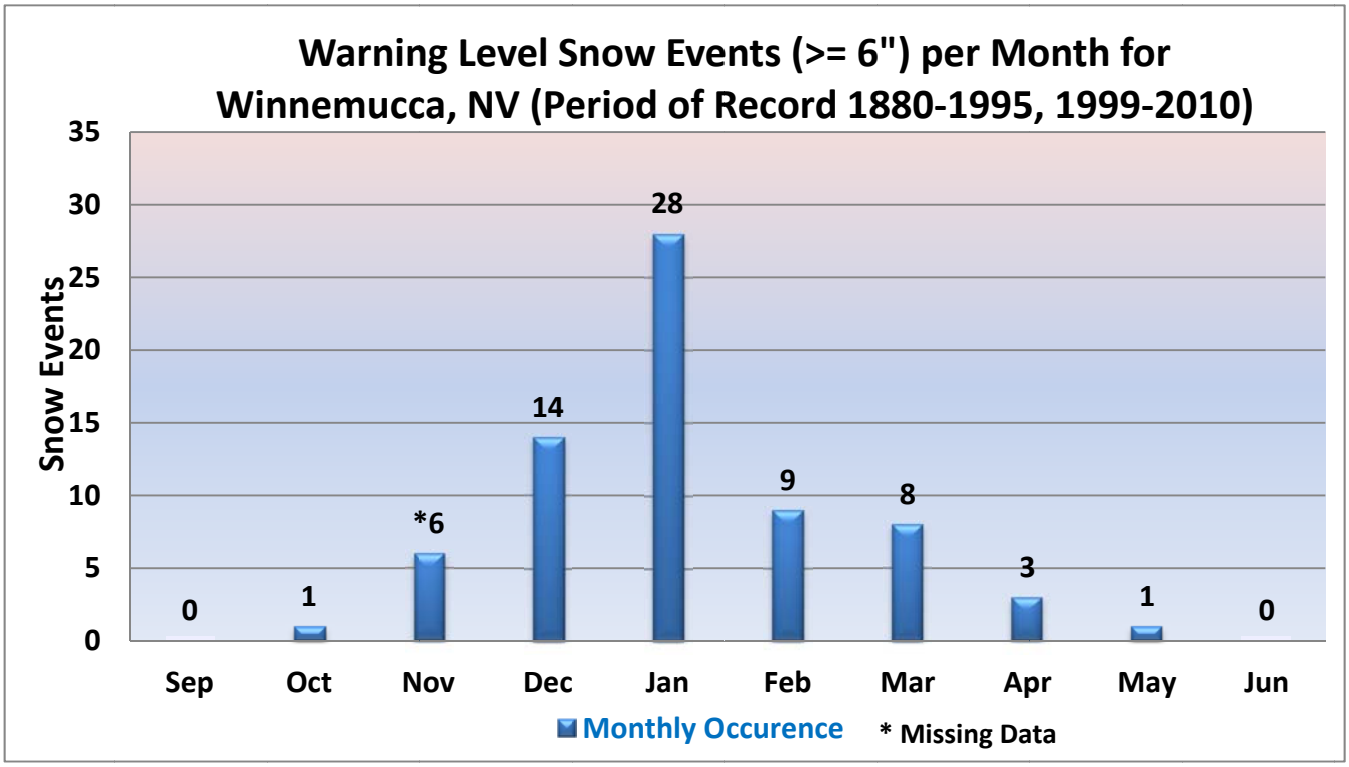

Figure 3. Winnemucca, NV Warning Level Snow Event per Month (1880-1995, 1999-2010)

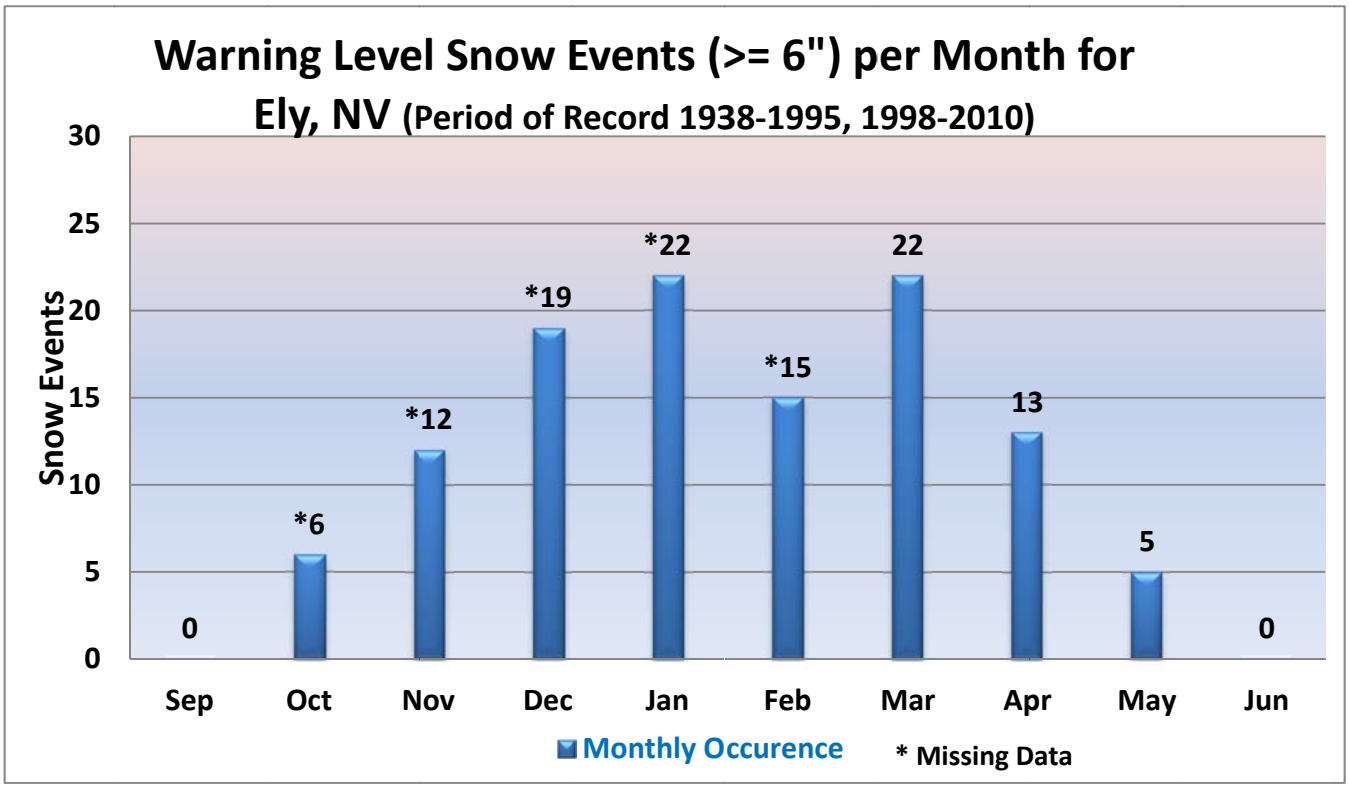

Figure 4. Ely, NV Warning Level Snow Event per Month (1938-1995, 1998-2010)

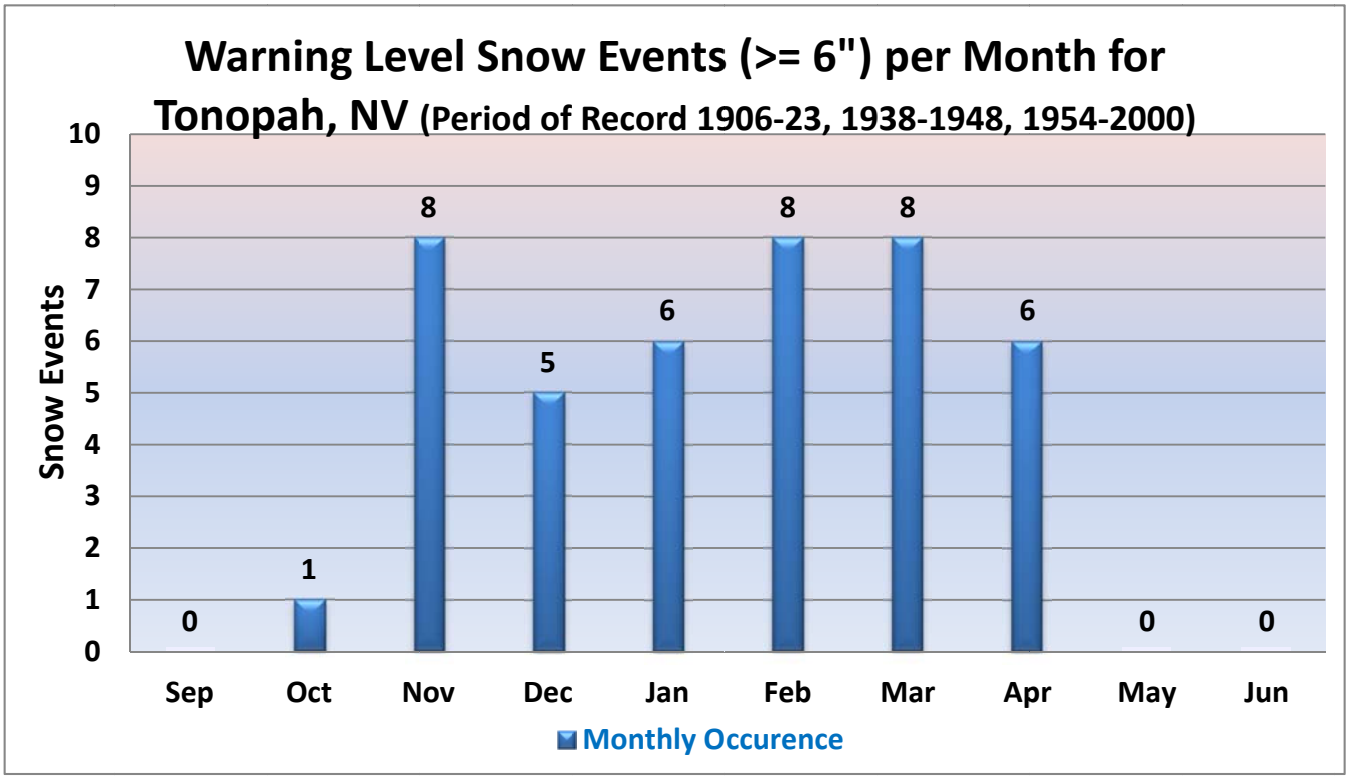

Figure 5. Tonopah, NV Warning Level Snow Event per Month (1906-23, 1938-48, 1954-2000)

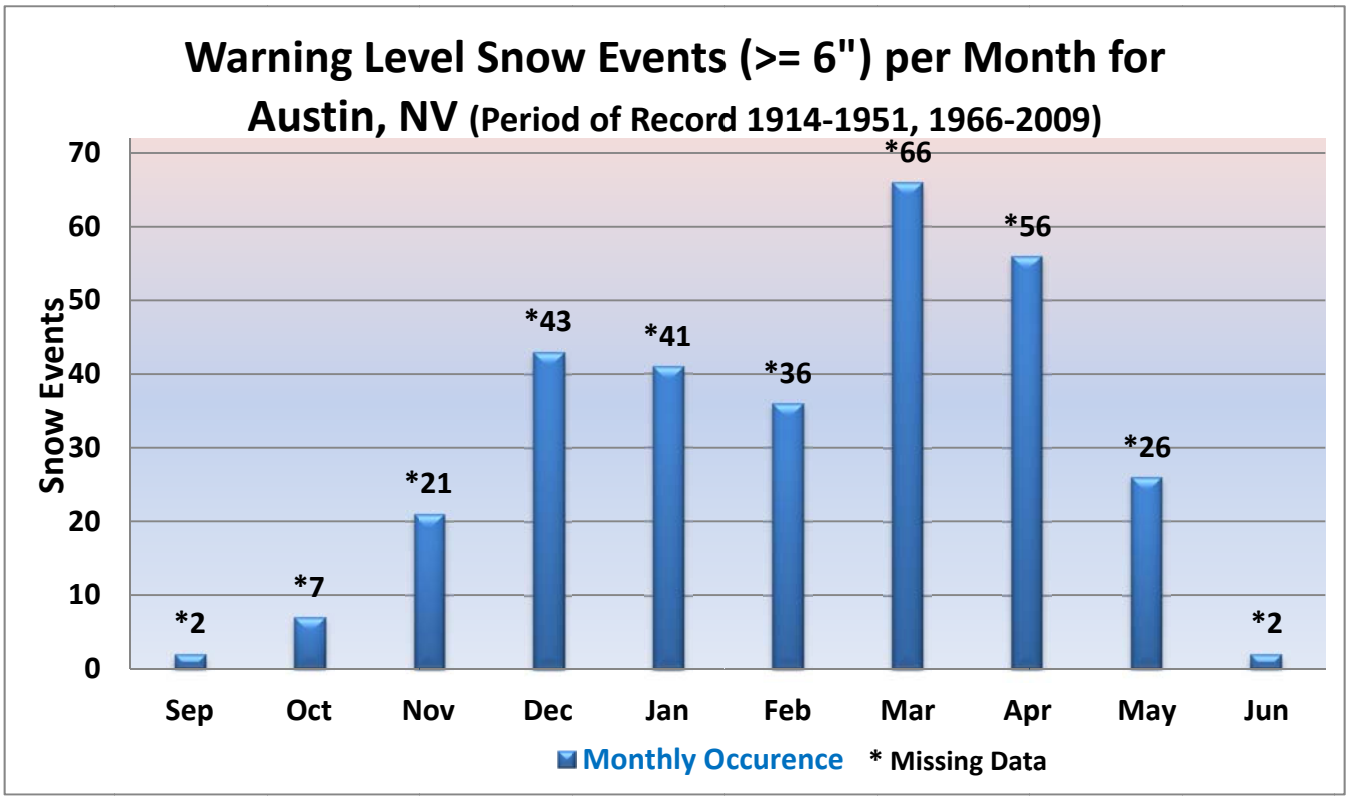

Figure 6. Austin, NV Warning Level Snow Event per Month (1914-1951, 1966-2009)

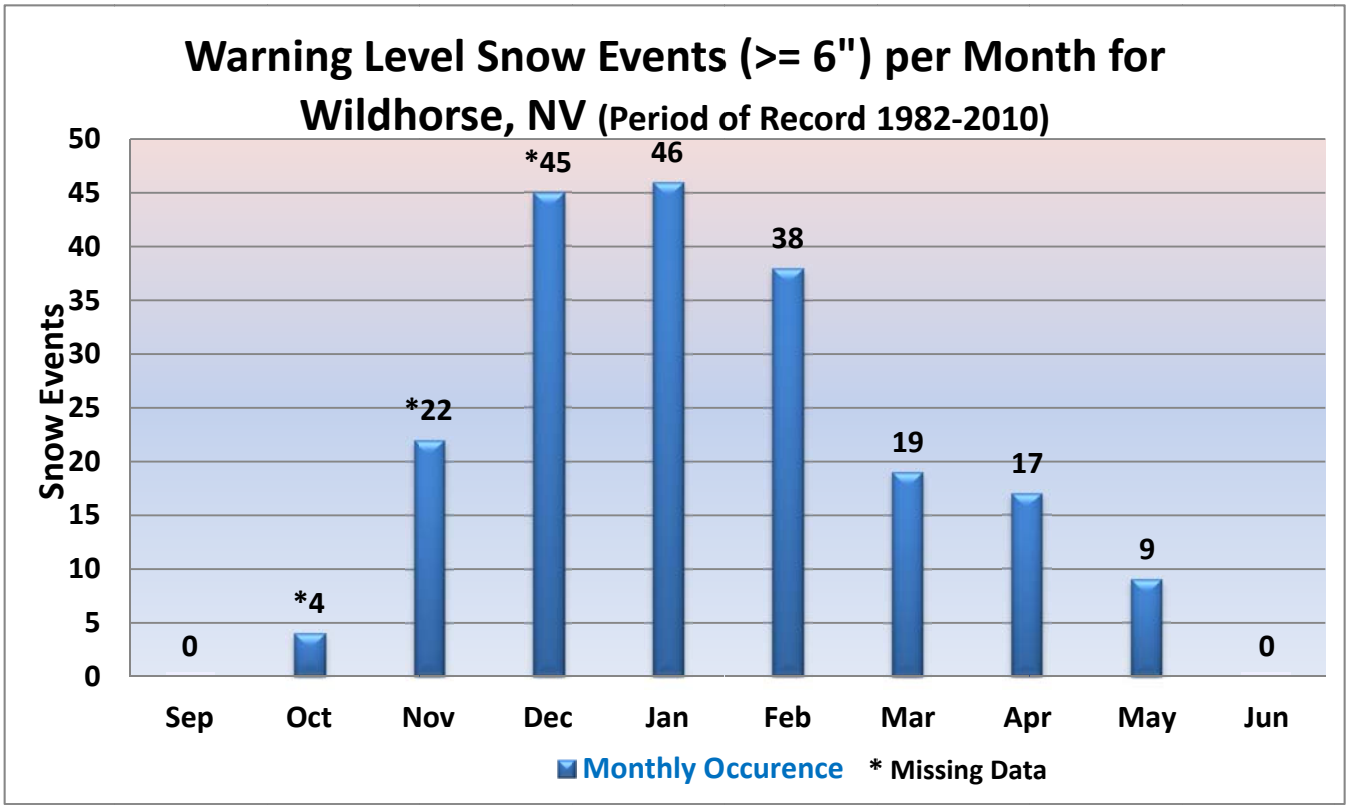

Figure 7. Wildhorse, NV Warning Level Snow Event per Month (1982-2010)

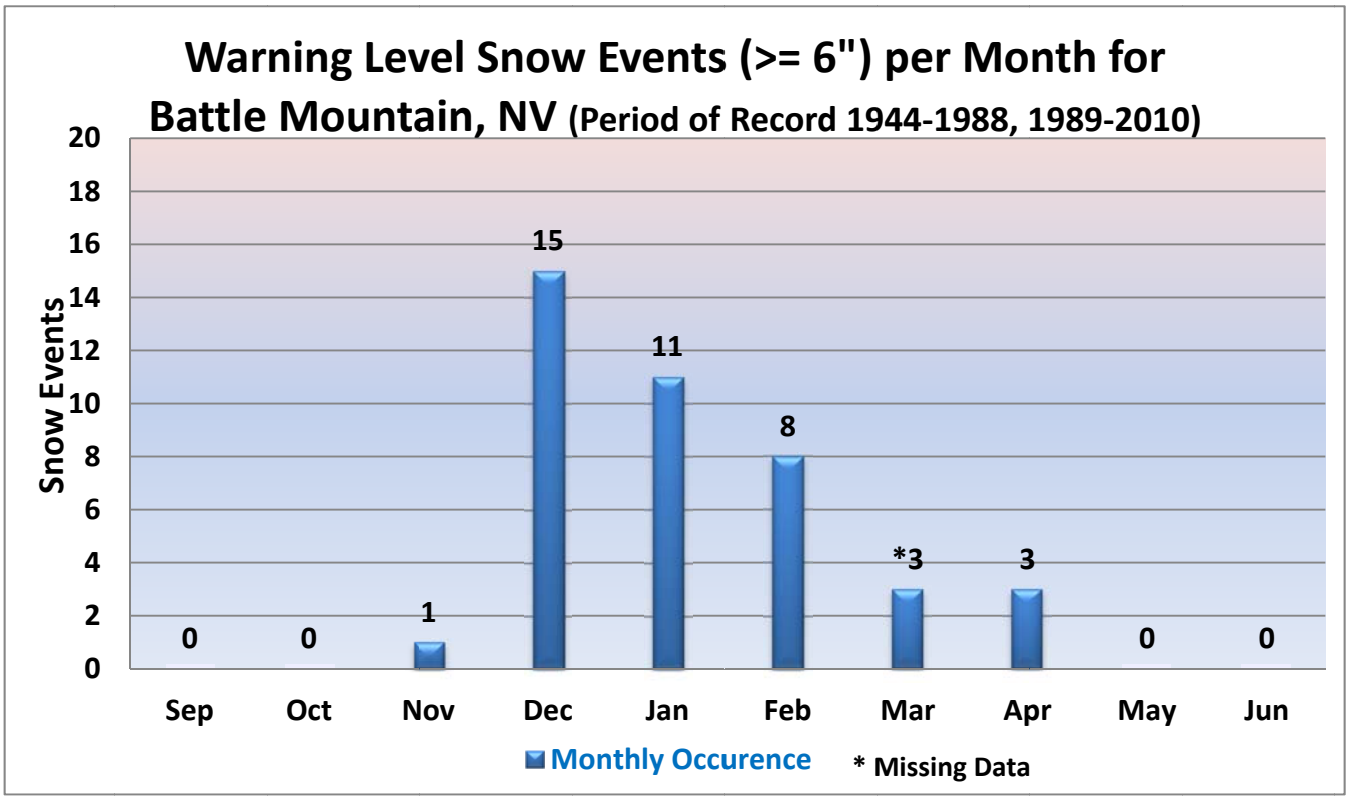

Figure 8. Battle Mountain, NV Warning Level Snow Event per Month (1944-1988, 1989-2010)

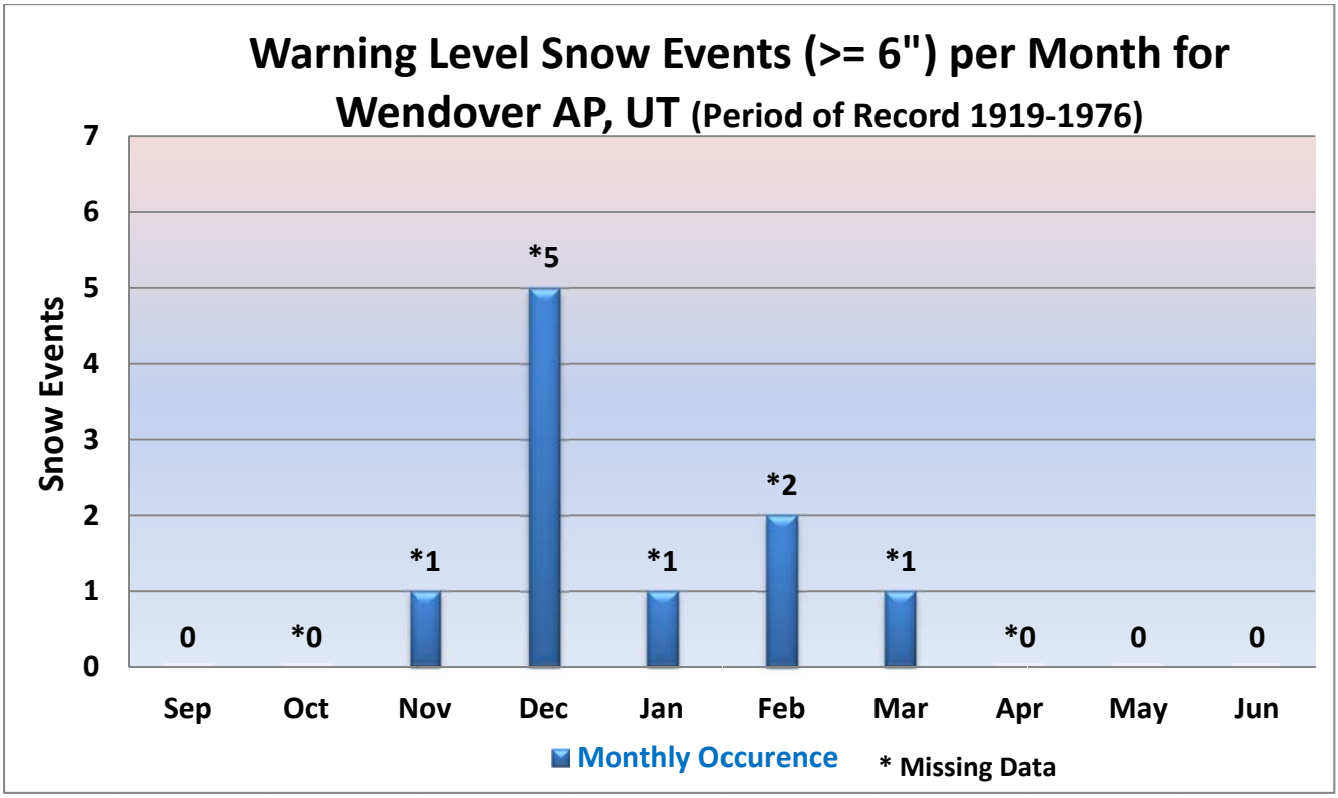

Figure 9. Wendover AP, UT Warning Level Snow Event per Month (1919-1976)

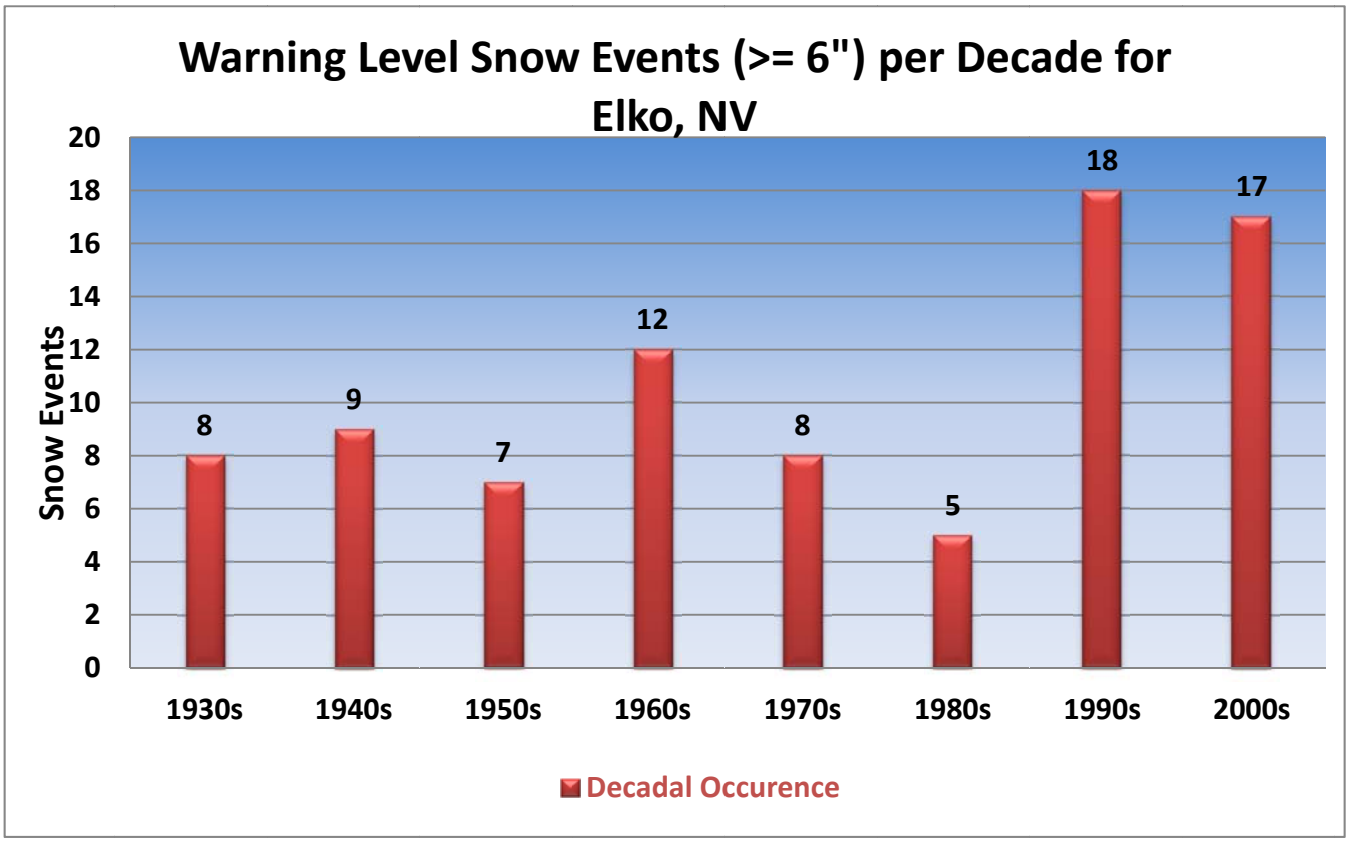

Figure 10. Elko, NV Warning Level Snow Evenst per Decade (1928-2010)

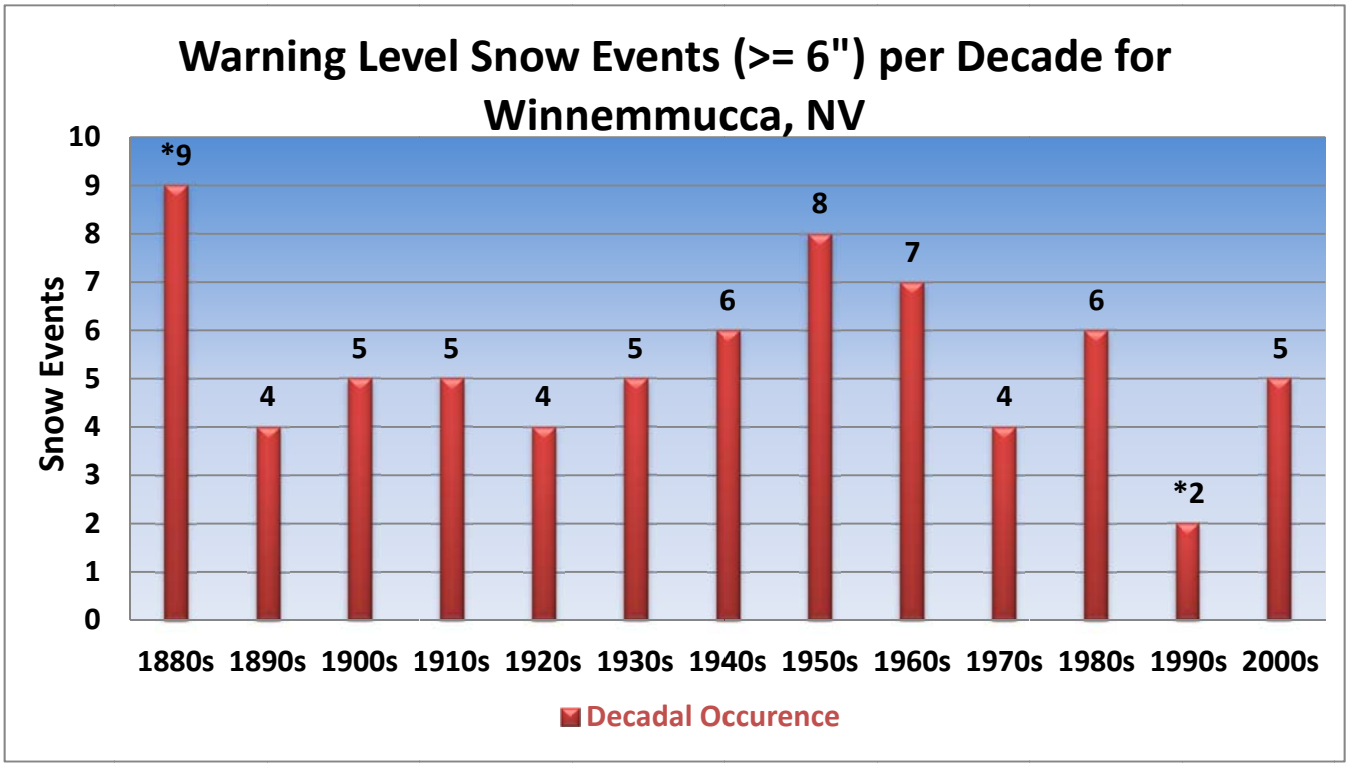

Figure 11. Winnemmucca, NV Warning Level Snow Events per Decade (1880-1995, 1999-2010)

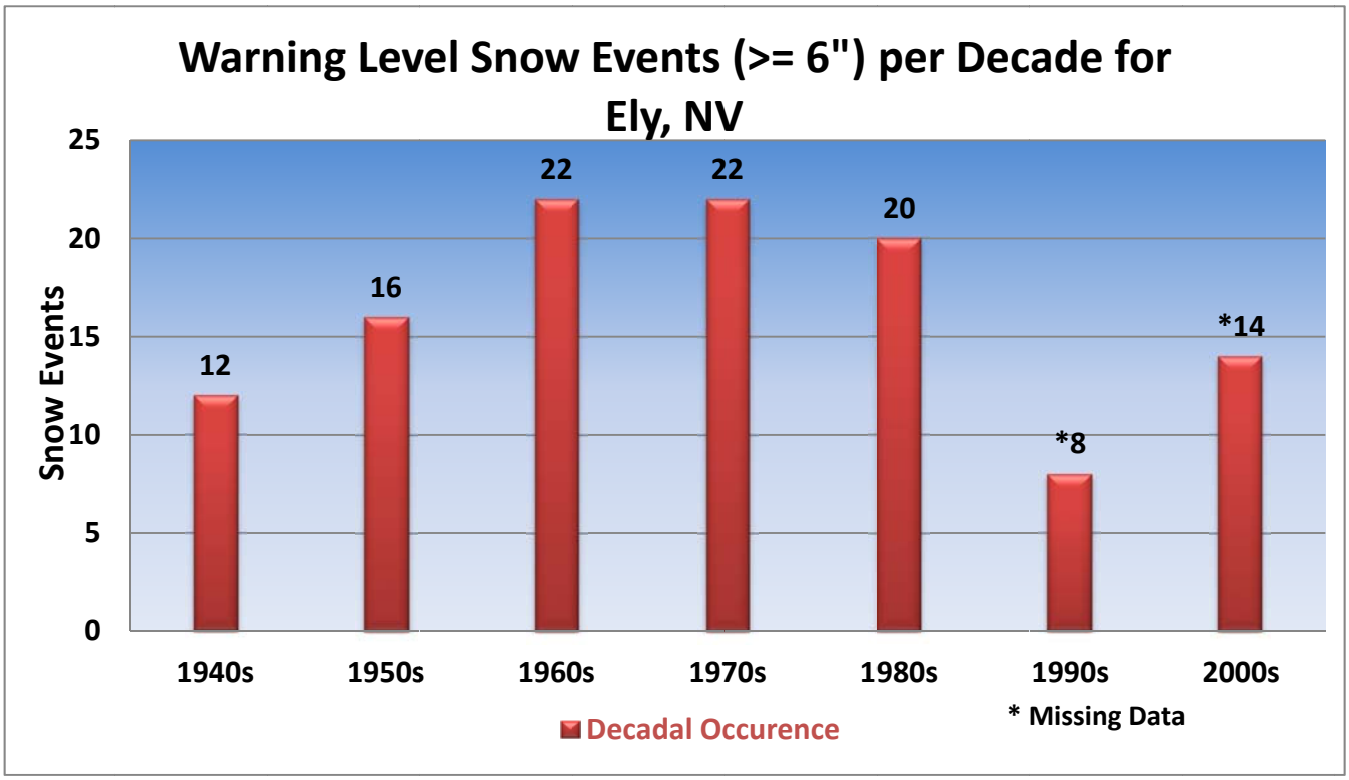

Figure 12. Ely, NV Warning Level Snow Events per Decade (1938-1995, 1998-2010)

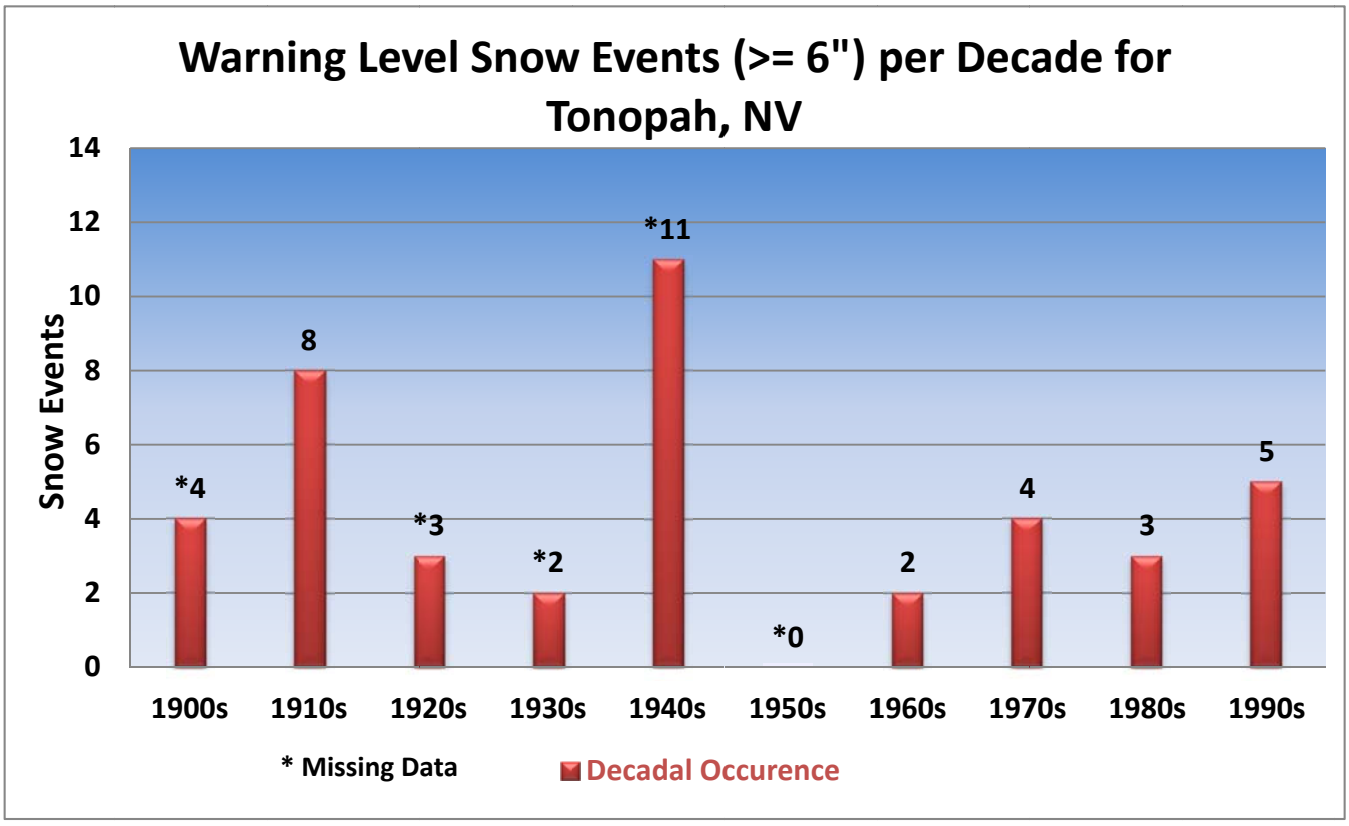

Figure 13. Tonopah, NV Warning Level Snow Events per Decade (1906-23, 1938-48, 1954-00)

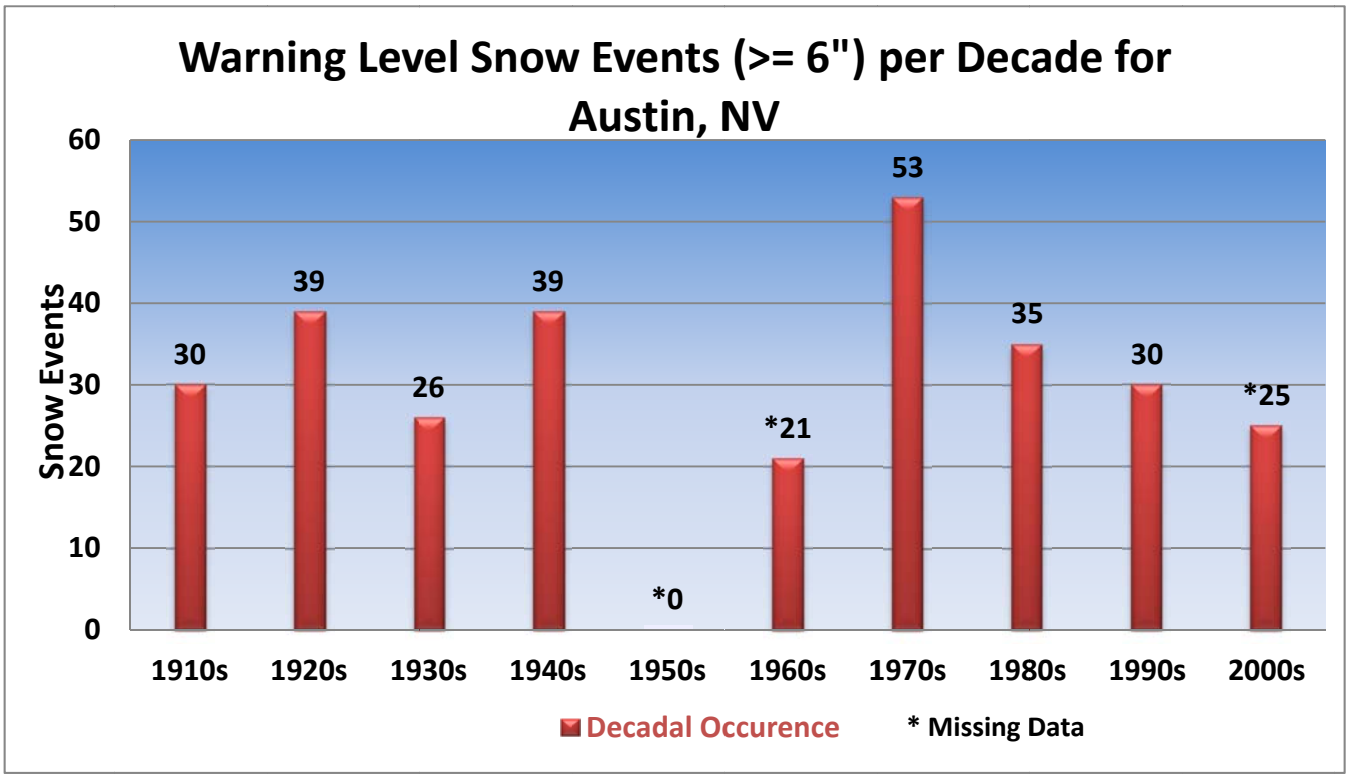

Figure 14. Austin, NV Warning Level Snow Events per Decade (1914-1951, 1966-2009)

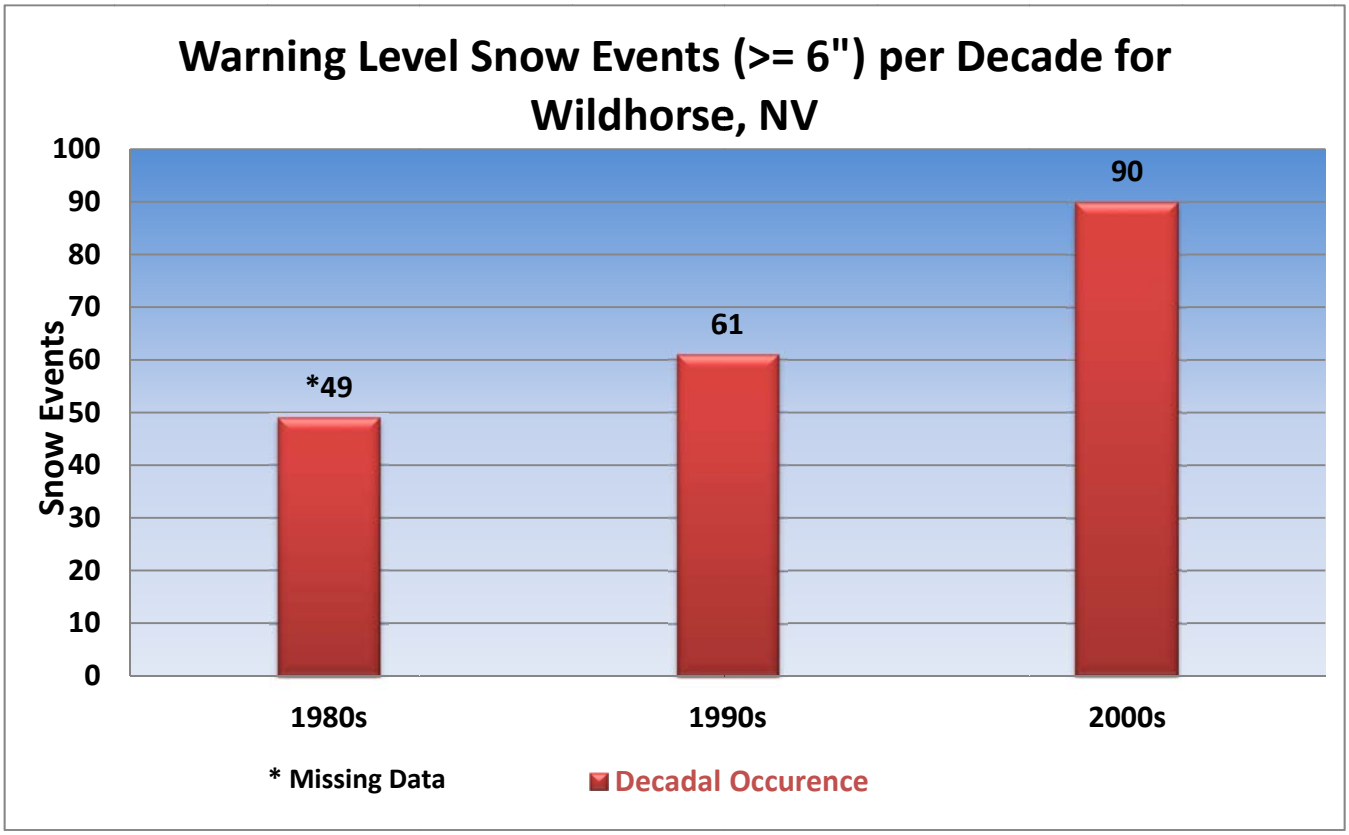

Figure 15. Wildhorse, NV Warning Level Snow Events per Decade (1982-2010)

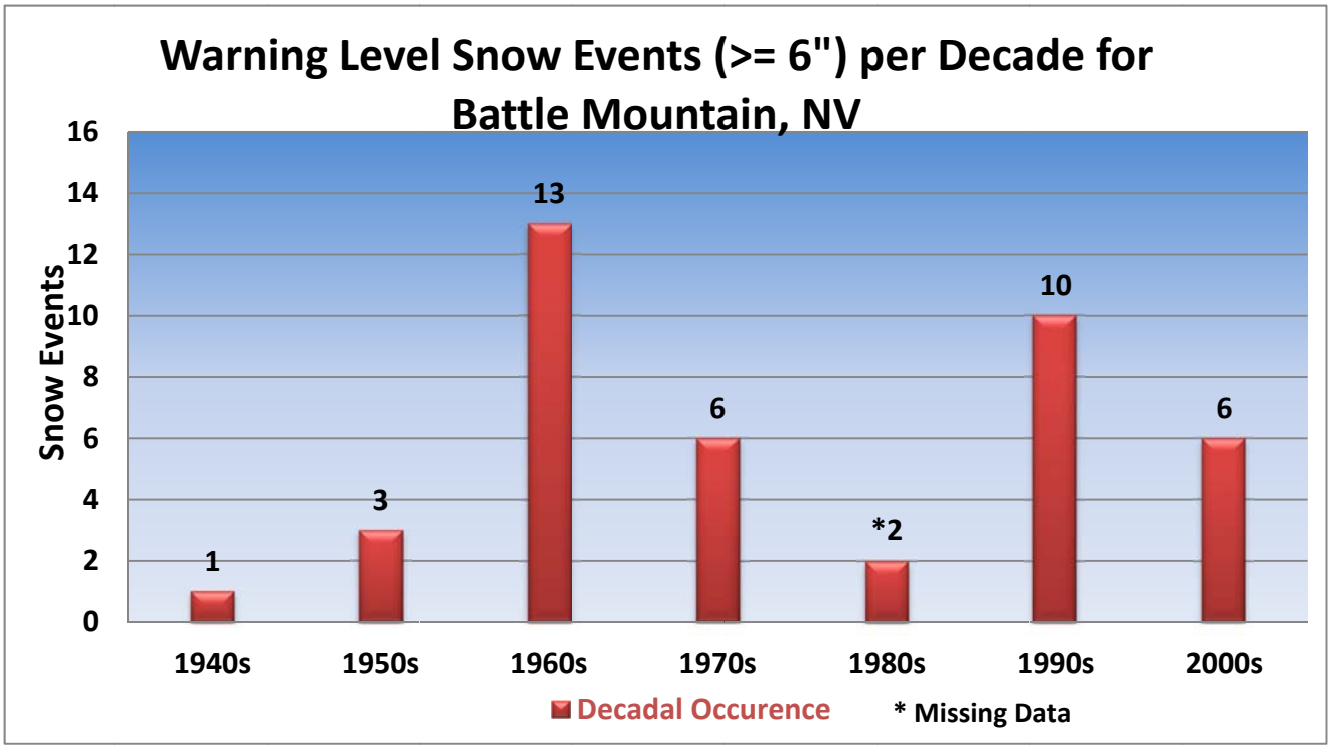

Figure 16. Battle Mountain, NV Warning Level Snow Events per Decade (1944-88, 1989-2010)

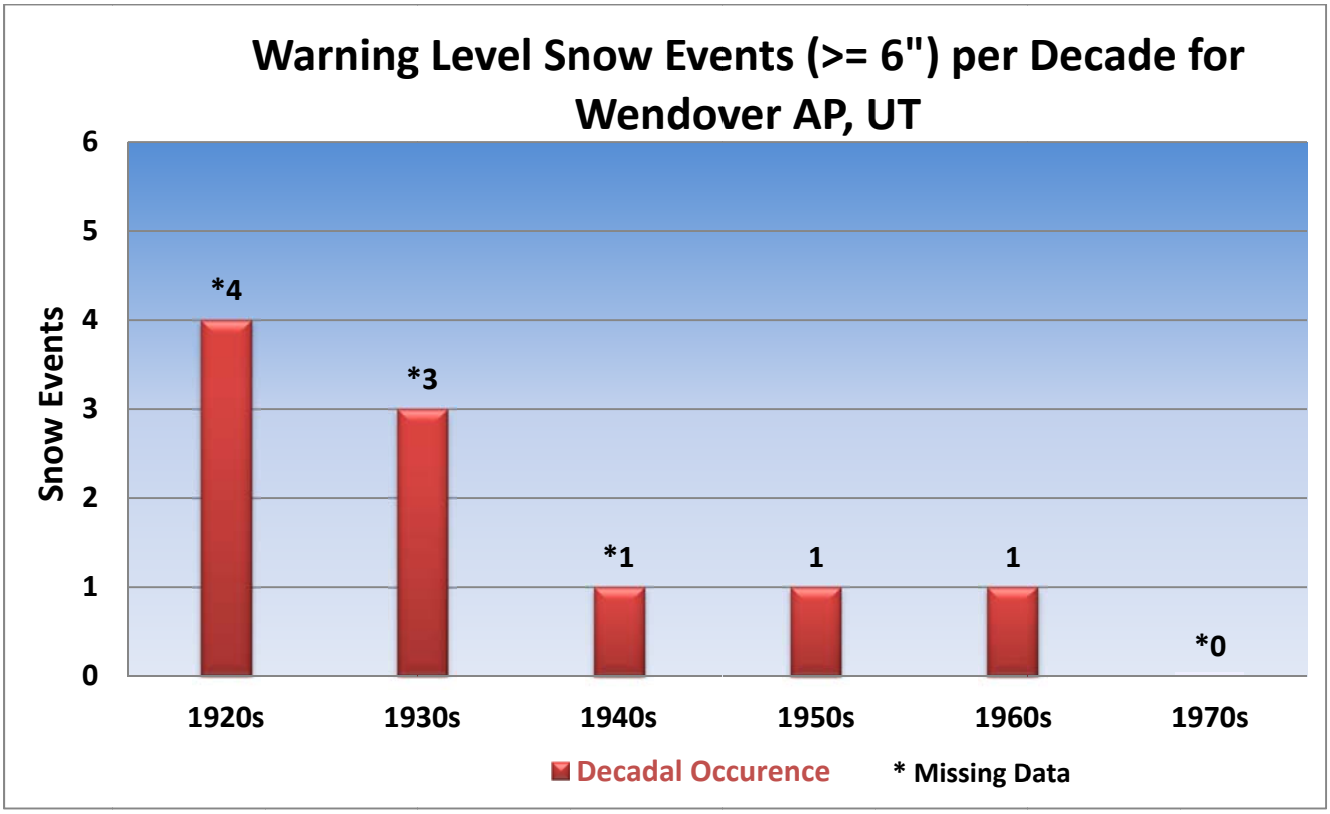

Figure 17. Wendover AP, UT Warning Level Snow Events per Decade (1919-1976)