FLOOD, DROUGHTS, AND EXTREMES IN UTAH SNOWPACKS

Randall Julander[1]

ABSTRACT

Utah has seen hydrometeorological extremes over the past decade. Last year saw snowpack records not just exceeded but shattered at some sites. In one case, snowpack was 50.8 centimeters higher than the previous record long term maximum snow water equivalent. This single year erased the total deficit of the six previous drought years at this site. Other sites had record snowpack in southern and northeastern Utah. Previously, six consecutive years of drought had decimated reservoir storage, caused huge forest and range mortality in even the hardy Atemesia species. Tree ring records indicate that this was one of the more significant droughts over the past 480 years in the Colorado River Basin (Woodhouse, 2003). The drought has caused significant agricultural damages as well as to other sectors of the economy such as power and tourism. The ever present concern over global warming and its impact on western snowpacks has been mentioned in numerous studies as well as through public discourse. Historical analysis has shown that at 15 carefully chosen, long term snow courses snowpacks have been on a gradual decline although none were statistically significant. This study quantifies the impacts of these extremes on snowpack averages at these 15 sites. Are these times really different than those of historical past and are they really more extreme?

METHODS AND ANALYSIS

Extreme events happen in every climatological parameter from temperature to snow. The question is are they happening more frequently now than in the past and to what degree, is Utah getting more record low snowpacks or record highs? In order to answer these questions, the period of record maximum and minimum April 1 SWE data from 15 long term snow courses in Utah that represent a complete spectrum of geography and elevation were plotted. Figure 1 shows the results of that analysis and one can clearly see that there seems to be a relative consistency across the historical period of record with respect to the minimums but with respect to the maximums, 1952 seems to have been the year with a few others in the late 30's and early 80's. Zero values, predominantly from three low elevation, southern latitude courses represent the lower bound on some snow courses and add value to the minimum SWE plots so these were added to the analysis. Figure 2 shows the results of that analysis and to some extent, the drought years of the late 1980's and 1999-2004 seem to have marginally more occurrences. Still, the distribution of minimums with zero values included is relatively constant through time. In fact, splitting the record into the early half, 1930-1967 and the later half, 1968-2005 we have 27 (46%) minimums in the early record and 32 (54%) in the later half.

Figure 1.

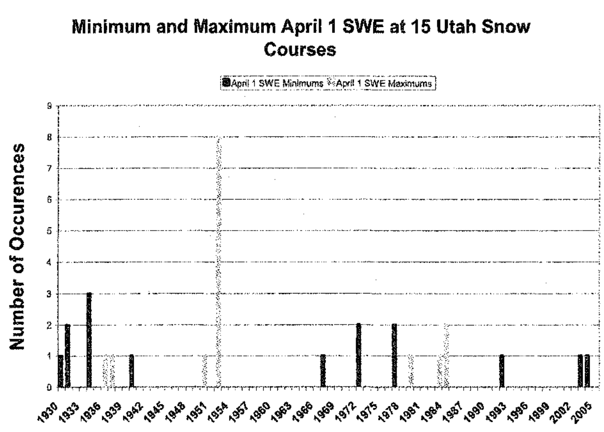
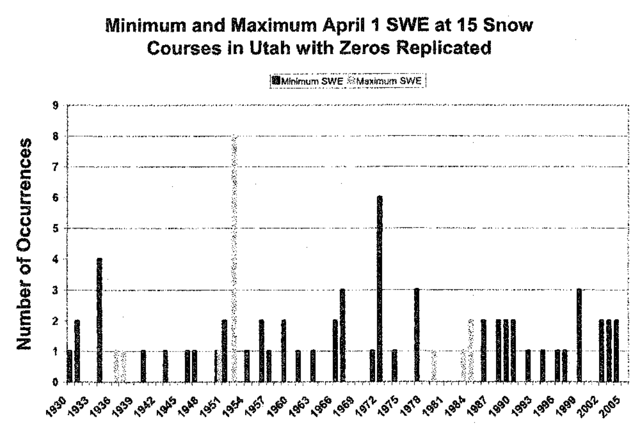


Figure 2.



There is an interesting observation in these charts that if one were to use a shorter period of record for analysis, say from the 1960's or 1970's on, that the frequency of zeros and minimums in the later period would

Paper presented Western Snow Conference 2006
[1] Natural Resources Conservation Service, USDA, Ogden, UT

seem to artificially be increasing due to the relatively higher snowpack years of the early 1980's. Certainly the drought years from 1999 to 2004 were severe. When looking at the 2001-2004 period, the total state wide average snowpack was just 67% of average. 2005 was a huge year in southern Utah (160%-235%) and ranged from near average to near record highs (100%-155%) in the north. This one year brought the statewide SWE average back from 67% to 82% of the 1971-2000 average condition. Still, not one of the 15 long-term snow courses had a record high during 2005 compared to 8 having records in 1952. There were many short-term stations that had record highs in 2005 including Midway Valley, the poster child for breaking previous record high SWE. Next, the frequency of maximums and minimums (zero events included) in 15-year increments was examined to ascertain if any of these had more events than others or if there is a discernable trend toward more extremes. The long-term average for each snow course was subtracted from a 15-year moving average expressed as a percentage and plotted these values to see the relative difference.

Figure 3.

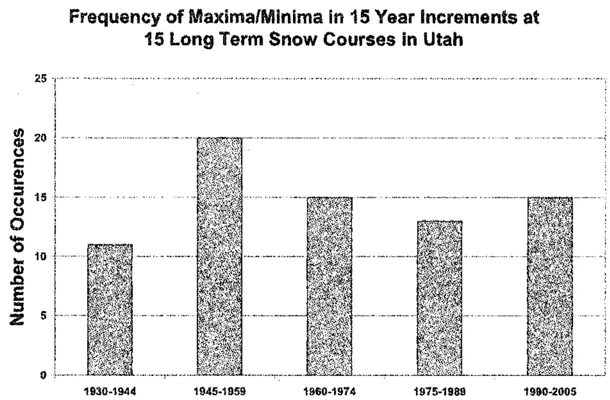
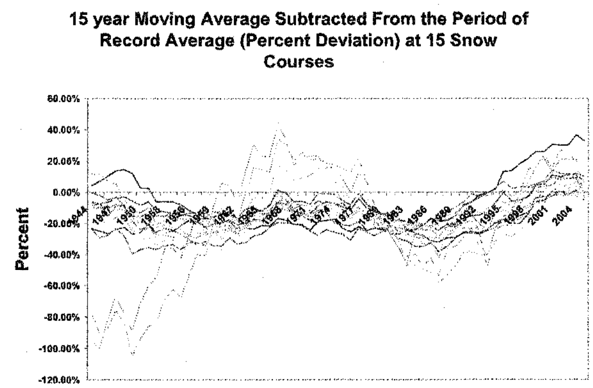


Figure 4.



The range of extreme events in Figure 3 is from 12 to 20 in any given 15 year increment of time with the lowest frequency, 12 being in the period of 1930 to 1944 and the highest frequency, 20 events in the immediately following period of 1945 to 1959. The remaining periods have 15, 13 and 15 events respectively. It certainly appears that there is no trend toward more extreme events happening in the more recent years. Depending on the start / stop years in this analysis, one could put one or two events or more in different time slots - i.e. moving the maximum year of 1952 forward or backward would influence the results and eliminating that year entirely would put it identical to the 1930-1944 period. In Figure 4, the percent difference between the long-term average and a 15 year moving average is shown. In the early years of Panguitch Lake and Bryce Canyon, there were a few large events at these relatively low catch sites which skewed the moving average to some degree and when expressed as a percentage, seem to be getting a lot of snow in those early years. This is simply a mathematical anomaly given a small long-term average. When examining the long term record, percent deviations range from -40% to +40% and as a rule, fall between the -20% and +20% range, where a negative number means greater than the long term average and a positive, less than the long term average. While the recent years have been dry, the deviations do not appear to be out of context with the historical record. Another factor that becomes apparent from Figure 4 is the fact that during both overall drought and wet periods, there tend to be are portions (some number of snow courses) of the State that are either near average or opposite of the general trend. When observing the general pattern of snowpack over the period of record in Figure 4, it becomes apparent that any meaningful comparison of current conditions is hampered by the short period of record, we have essentially a few dry and a few wet periods for analysis, far to few to determine an outcome of significance.

Figure 5.

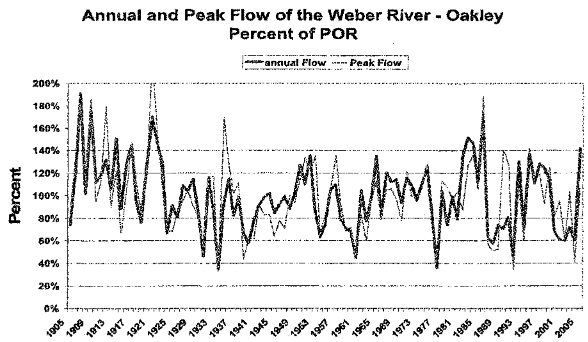
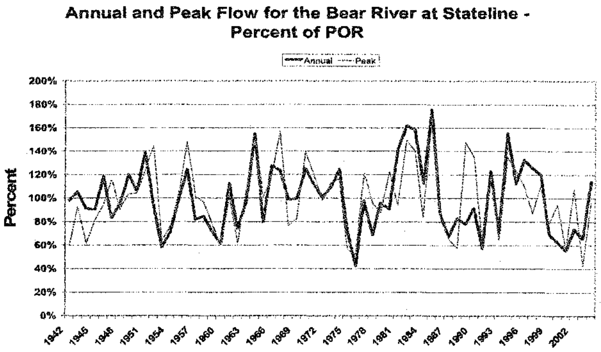


Figure 6.



Figures 5 and 6 show the annual and peak flow expressed as a percent of the period of record average. The Weber record begins in 1905 and the Bear in 1943. As one examines the Weber flows, the early century exceptional wet period stands out in contrast to the record from 1925 to the present condition. Absent this period, the Weber and the Bear flows are very similar as they are geographically, geologically and physically very similar in all watershed characteristics. This early period wet cycle shows up in many long term streamflow records the most infamous of which is the Colorado River and upon which the Colorado River Compact was based allocating flow between the Upper Basin and the Lower Basin states on a figure that turned out to be substantially higher than any in the subsequent record. When using an "F" test for variability comparing the first 15 years of data to the last for both the Weber and the Bear, the Weber showed no significant difference in variability whereas the Bear did. This could be a process of determining where in the record to test as other periods of comparison such as 1971-1985 were not significant and the length of the period of comparison could determine the outcome as well. If one trips through various periods and lengths of comparison of the historical record in both snow and flow, some are significantly more variable and some are not making an objective comparison difficult. The question is " are current conditions statistically more variable or are we currently getting statistically more or less of a given parameter than in previous periods". The answer is difficult to ascertain because it is both yes and no dependent on both the periods examined as well as the length of the given period. Figures 7 and 8 show a moving 15 year sequence of T-Tests for differences in average snowpack as well as the same for F-Tests for variance beginning with the 1930-1944 period, then 1931-1945 and so forth. All are compared to the 1991-2005 period. There are approximately 46 T and F Tests displayed.

Figure 7.

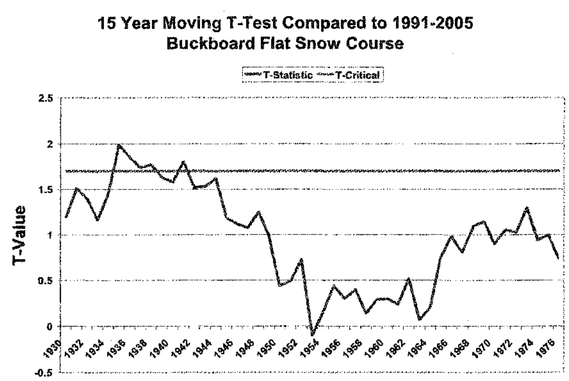
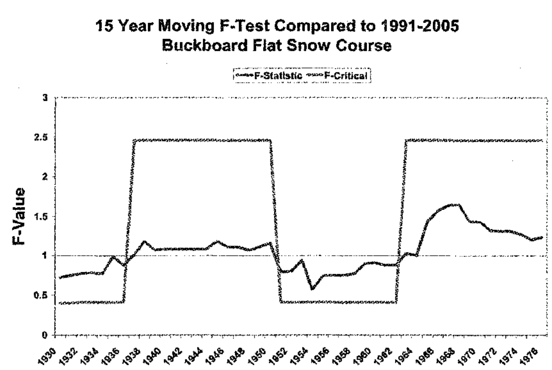


Figure 8.



In Figure 7 we see that only in the early period of record are there statistical differences between 15 year moving averages and the 1991-2005 period. When testing the same data for variance, the early and mid portion of the record has greater variability than the 1991-2005 data.

The period of 1999 to 2004 saw a prolonged drought over much of Utah. The 2005 water year saw many record snowpacks and annual/seasonal streamflows in southern Utah as well as the Uintah Basin in northeast Utah. One site in southern Utah, Midway valley experienced a peak SWE that was 275% of average, this amounts to 50.8 centimeters more than the previous SWE peak. Normally climatic records such as SWE and annual precipitation are broken by several centimeters, not shattered by an order of magnitude. In Figures 9 and 10 one can see the impact that this event had on SWE average at this site.

Figure 9. Midway Valley SWE 2005

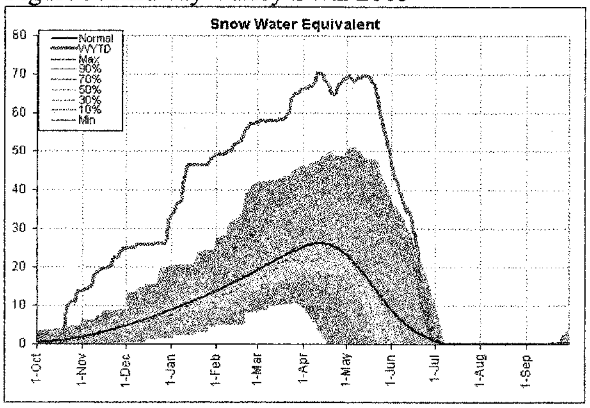
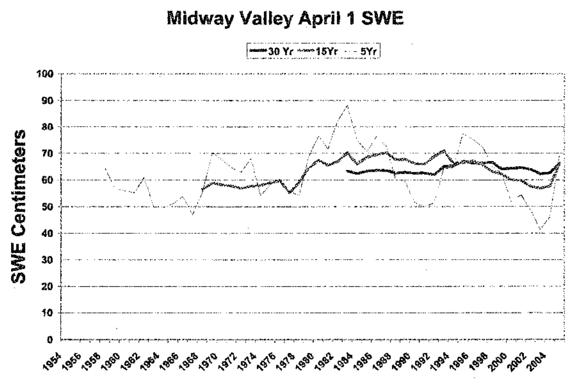
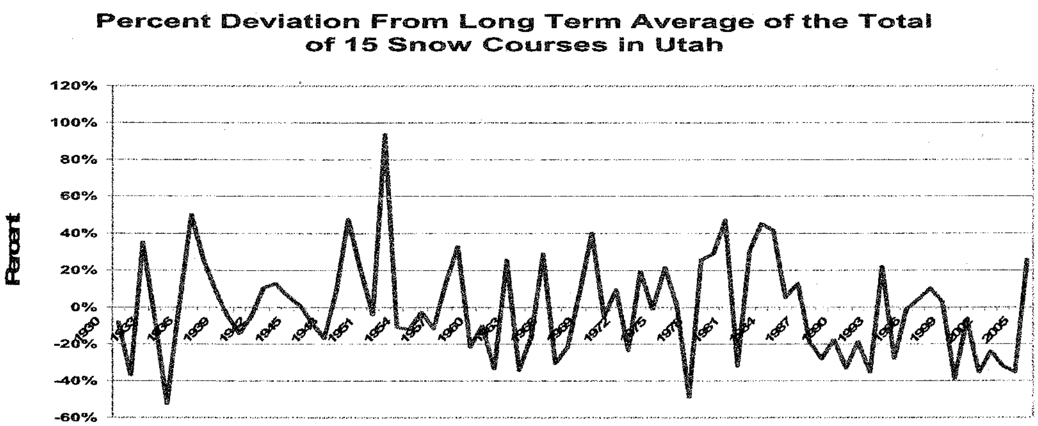


Figure 10. Midway Valley 5, 15 and 30 Yr Avg



Displayed in Figure 9 is the bottom and top 10% of recorded SWE at Midway Valley along with the observed SWE from 2005. This site has nearly 25 years of daily data as well as 50 plus years of manual data, all summarily eclipsed by the 2005 event. In Figure 10 we see the overall impact in the 5, 15 and 30 year moving averages. This illustrates the importance of the time scale in the determination of both variability and magnitude of a sequence of historical occurrences. Each time series has amplitude and magnitude and the shorter the period, the greater each becomes. Short term trends in the 5 year moving average do not necessarily show up as any significant deviation in the longer term time series. A notable exception if the 2005 event which could significantly influence the 5, 15 and 30 year averages for some time in the future. It brought the 5 year moving average from 40 centimeters to 70, the 15 year average from 58 to 66 centimeters and the 30 year average from 63 to 66 centimeters.

Figure 11.



In Figure 11 the percent deviation from the long term average of the total of the 15 snow courses is presented such that a general statewide perspective on both magnitude and duration of maxima and minima can be obtained. The period of the early 1950's was extremely wet and the period of the 1990 - 2004 was extremely dry. It would be extremely useful to have snowpack data to correlate the wet period of the 1900-1920 period to see if it were as wet as the last part of the century was dry. Although the magnitude of the 1990-2004 period was not as severe as some events of the 1930's and 1977, the duration below average was longer. From 1987 -2005, there were a total of 14 years below normal and only four above.

CONCLUSIONS

One must ask the question - exactly what does it all mean? To say that this period is more or less variable or that this site is getting more or less of a given parameter at some point in time relative to another time conveys what meaningful information especially if the site has multiple episodes of variability or averages. Can one determine a trend and an outcome from these analyses? Given what is observed in these various analyses, the general conclusions tend to be vague in nature. One cannot objectively and definitively say that this is more than cyclic climatic variability. When comparing data records, it appears that various segments should be tested and not just one period for all stations. It is also apparent that 50 to 100 years of data record provides but a very a small glimpse into the nature of climatic variability especially with regard to the frequency of extremes. That said, the frequency of extremes does not appear to be increasing or decreasing in the parameters examined. It is also safe to say that we will continue to experience extremes in the future and that current maxima and minima will be exceeded except where bounded by zero and there will certainly be many of these as well. It is not safe to say that what we currently see is any more or less variable in magnitude or frequency than what has previously happened in the short historical record documenting these parameters. When comparing records of relatively short length, the comparative periods are critical. To say that at some sites in Utah, we are getting less snow currently than we have during previous historical periods is accurate but may only reflect overall climatic variability and may not be attributed to some specific cause. For example, comparing data from the extreme maxima events of the early 1950's to the extreme minima of the 1999-2004 will likely show statistical differences but it would not be reasonable to say that based on this trend, Utah will have little or no snow at some future date.

REFERENCES

Woodhouse, Connie A. 2003. "A 431-year Reconstruction of Western Colorado Snowpack from Tree Rings". Journal of Climate, May, 2003. Volume 16. p. 1551-1561.