CLIMATE CHANGE IMPACTS ON UTAH'S CENTRAL WASATCH SNOWPACKS

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ABSTRACT: Climate change has resulted in winters that are much different than in previous decades. For the better part of 20 years, the central and southern Rocky Mountains of the western US have had less snow than normal and the distribution of snowpack is much different than the average. April 1st snowpack distributions are simulated for Utah's Central Wasatch Mountains for the previous 35 years. Comparing a given year to the 35 year average snowpack is interesting enough. More interesting is the difference between the average and any specific year's snowpack. Most of the last 20 years of drought have reduced snowpacks on all aspect and at all elevations compared to the average, but some years display an unanticipated result. In these cases most of the Central Wasatch Mountains, and especially south and west faces, and the alpine valley floors are in drought. However, the upper elevations have snowpacks that exceed the average snowpack by significant amounts. In these special instances most of the Central Wasatch Mountains have a typical drought signature, but there is snowpack in excess of the average at the upper elevations. In these cases, and unlike the drought years, the total amount of water in the Central Wasatch watersheds, stored as snowpack, is normal or more so, even though the actual distribution of the snowpack is anything but. Most of the Central Wasatch Mountains have a typical drought signature on south and west aspects, and the valley floors, but the upper elevations have enjoyed a snowpack that is well above the average.

KEYWORDS: snowpack distribution, climate change, snowmelt, drought

1. INTRODUCTION

No one argues that it isn't happening. Winter snowpacks in the central and southern Rocky Mountains are a fraction of what they used to be in decades past. It rains when it used to snow. Snowline is higher. South and west facing aspects no longer hold snow through-out the winter, and peak snowmelt runoff is smaller in volume and earlier in the spring than it used to be. All this is of grave concern to ski area operators, winter highway maintainers, and water supply hydrologists working in mountains and watersheds where winter snow is the primary precipitation mode.

Like water supply, flood control, coastline protection, and the emergency management of tornados, hurricanes and winter storms; there are few public works activities more inextricably linked to climate than highway winter maintenance. Within the cohort of activities noted above, each is challenged to plan, expend, build and maintain for a nature that is serving up something different than it used to. That's the Climate Change Challenge. How to plan for a future that will be something different than the average of the past?

What climate change has brought about is a 'new normal'. This can be seen, in Utah's Central Wasatch Mountains, by examining simulations of winter snowpack distribution for the previous 35 years.

2. THE SNOWPACK DISTRIBUTION MODEL

InterAlpine Associates, along with similar, parallel efforts by others, has developed and implemented its Snowpack Distribution Model (SDM) in support of the work of snow hydrologists and water supply entities trying to better understand the impacts of climate change on annual mountain snowpack distributions and the resulting snow water volumes available for water supply [1, 2].

The results are *simulations* of the snowpack, and they do a good job of depicting the distribution of snowpack with elevation, slope angle and aspect in a given mountain range. However, at this juncture, these simulations *may not* accurately reflect the correct cumulative or integral snow water volume within the entirety of any given watershed in these mountains. That modeling capability remains the focus of on-going SDM research and development.

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3. SNOWPACK SIMULATION RESULTS

As one example typical of pre-drought conditions, Figure 1. depicts the difference between the snowpack of April 1, 1980 and the 35 year average April 1st snowpack for Utah's Central Wasatch Mountains. Those portions of this model run that are in darker blue or green are places where the snowpack is in excess of the 35 year average. 1980 was typical of the 'big winters' of the early 1980's, and was a 'good' water year, as well. This can be seen as the predominance of blues and greens, indicative of snowpack above and well above average. Snow Water Equivalent (SWE), the net water accumulated as snowpack, in the Central Wasatch watersheds was well above 'normal'. 'Percent of normal' SWE data products are compiled by the National Oceanographic and Atmospheric Administration's (NOAA) Snotel system. On April 1, 1980, various Central Wasatch watersheds had stored snowpack SWE, that were 150 to 200% of normal. 3 consecutive years of these above normal winter snowpacks in the central and southern Rockies, from 1980 to 1983, lead to the unplanned overtopping of the Glenn Canyon Dam spillways on Lake Powell that latter spring.

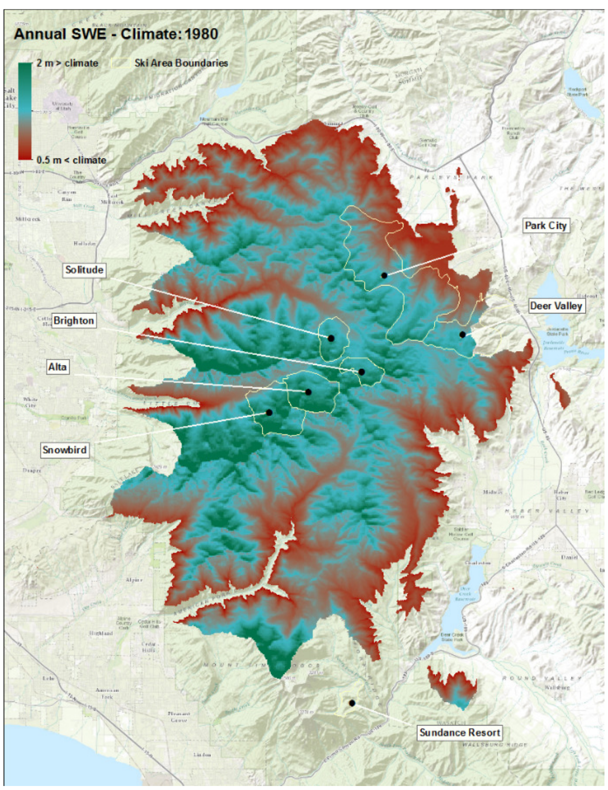

Figure 1. The difference between the April 1, 1980 snowpack and the 35 year average snowpack for the Central Wasatch Mountains, Utah.

On the other hand, Figure 2. depicts this same difference between the 35 year average snowpack and, in this case, the April 1, 2015 snowpack. Unlike 1980's and similar to many of the more recent 20 years, 2015 was in a serious climate change driven drought. In 2015, anywhere you went in the Central Wasatch Mountains the snowpack was below the average. This can be seen by the predominance of orange and burnt orange, indicative of snowpacks below and well below average. The April 1, 2015 SWE was 67% of normal.

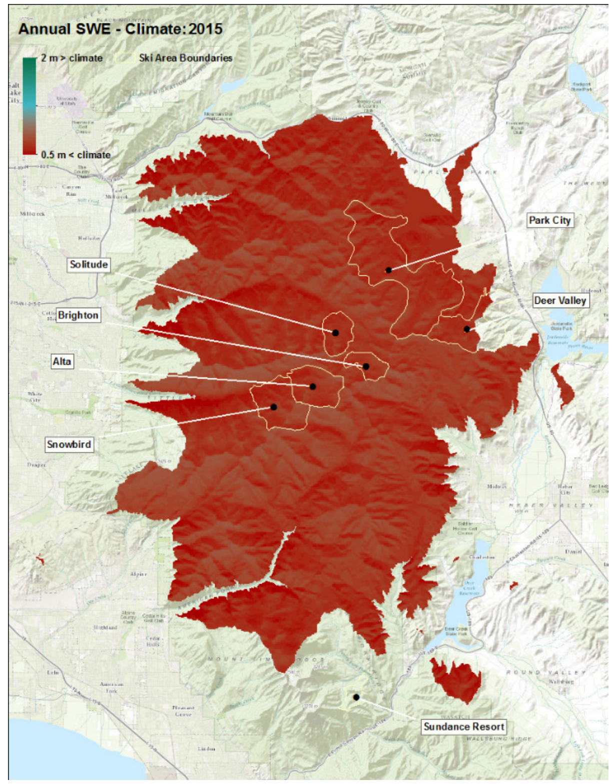

Figure 2. The difference between the April 1, 2015 snowpack and the 35 year average snowpack for the Central Wasatch Mountains, Utah.

In Figure 3., below, we see the difference between the April 1, 2005 snowpack and the 35 year average. This is the unanticipated result. Note that almost all of the Central Wasatch Mountains are in drought conditions, similar to 2015. However, at the upper elevations, there is significant snowpack that is well above average. This can be seen by the proliferation of blue hues in the upper elevations, indicative of snowpack that is above the average. Though counter intuitive, based in the drought snowpack distribution signature, the April 1, 2005 SWE was 140% of normal.

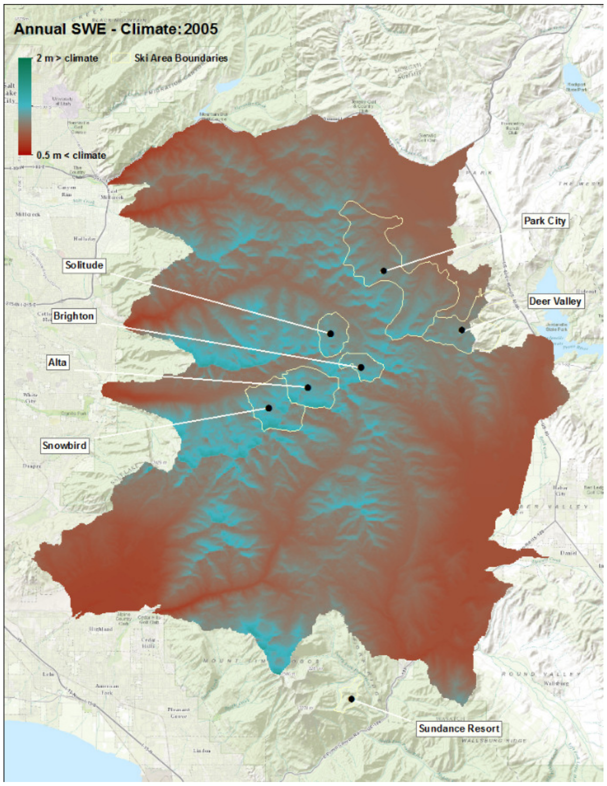

Figure 3. The difference between the April 1, 2005 snowpack and the 35 year average snowpack for the Central Wasatch Mountains, Utah.

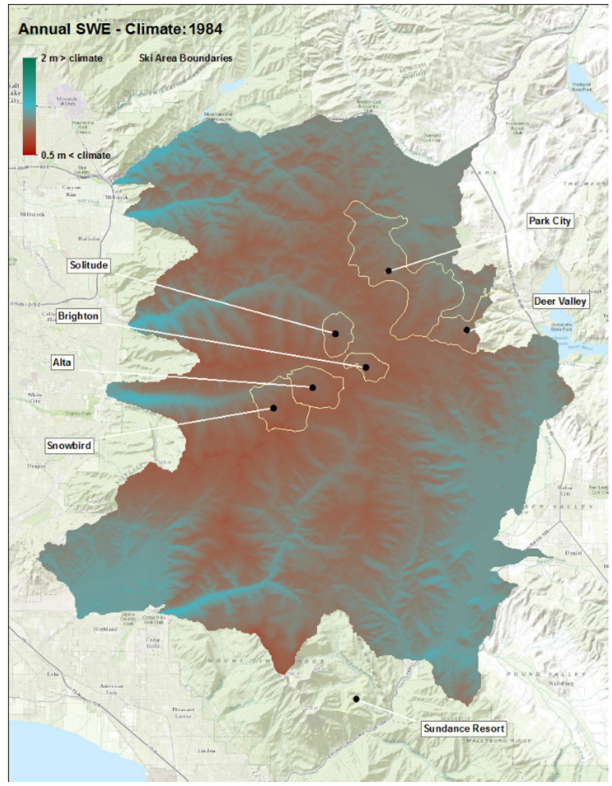

Figure 4. The difference between the April 1, 1984 snowpack and the 35 year average snowpack for the Central Wasatch Mountains, Utah.

Lastly, because of its hydrologic interest, note the relationship between the 35 year average snowpack and that of April 1, 1984 found in Figure 4. Figure 4. shows that there is a significant amount of lower elevation snow that has accumulated in excess of the average. These are depicted by the blue hues found in the lower elevations of the Central Wasatch Mountains, indicative of snowpacks that are above average in these places.

Spring snowmelt occurs at lower, warmer elevations earliest and fastest. As a consequence of the availability of significant lower elevation snowpacks, 1984 saw disasterous spring runoff flooding from the tributaries emanating from the Central Wasatch Mountains onto the Salt Lake valley floor.

4. CONCLUSIONS

Snowpack distribution simulations such as these and others allows one to examine, at scales much smaller than a watershed, the fine detail in the distribution of a snowpack at any given point in the mountains. There are scenarios, such as drought at all elevations and aspects, which are indicative of many of the last 20 years of drought in the Central Wasatch Mountains. One can also identify snowpack distributions most likely to have caused spring snowmelt flooding at regional and local scales. There are snowpacks that are typical of drought on south and west aspects, and at lower elevations, but which have significant upper elevation snowpacks, well in excess of the average. These snowpack distribution results in near and above 'normal' snowpack SWE, but their distributions are not the average. These simulations, and others like it, will provide and allow for additional insight into the 'new normal' that climate change is causing in mountain snowpacks, their distribution, and the resulting SWE water volumes in storage.

REFERENCES

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