TRENDS IN SNOW-LINE ELEVATION ALONG THE WASATCH FRONT, UTAH FROM MODIS FRACTIONAL SNOW-COVERED AREA

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ABSTRACT

The main source of water for the over 2 million people that reside along the Wasatch Front is annual melt of the mountain snowpack. There has been vast infrastructure developed to capture and transport melt water as it flows out of the mountains in the spring and summer. This natural reservoir is at risk, as population continues to increase and the climate warms and becomes more variable, this water source will become less reliable, straining the current water delivery system. Therefore, it is important to quantitatively understand how the snowpack has been changing over time, in order to predict and forecast how it will change, spatially and temporally, in the future. This project assesses changes in the Wasatch Front's snowline elevation and snow-covered area, on April 1st, over the last 18 years from the MODIS Snow-covered Area and Grain Size (MODSCAG) fractional snow-covered area product (fSCA). Although the data set does not span a multi-decade time series, which is typically preferred for climate analysis, the analysis shows a positive trend in snow-line elevation (toward high elevations) and negative trend in snow-covered area (declining snow-covered area). (KEYWORDS: snow line, Wasatch, MODIS, fractional snow-covered area, MODSCAG, declining snow-covered area)

INTRODUCTION

Since settlement in Utah began in the mid 1800's, the bulk of the population has settled along the western side of the Wasatch Mountains, or the "Wasatch Front." This area is a desirable place to live due to its proximity to water resources; streams that flow out of snowmelt dominated mountain watersheds. Populations have come to rely this natural reservoir and consistency of snow melt timing and magnitude, but this natural resource will be strained as the populations of the Wasatch Front continue to grow and the climate warms and becomes more variable. A warmer climate impacts snow water storage in two ways, 1) it shifts precipitation phase from snow to rain, and 2) it enhances snow albedo feedbacks in the spring, contributing to advanced melt.

This study examines how the snowpack has been changing over the last two decades by comparing the average snowline elevation along the Wasatch Front, on or near April 1, between the years 2000 and 2017 by using the MODIS Snow-covered Area and Grain Size (MODSCAG) fractional snow-covered area (fSCA) (*Painter et al.*, 2009). This product is available in near real time and historically from the snow data server at NASA-JPL. The spatial resolution of MODIS is relatively coarse for application in mountainous terrain, which is why we have chosen a fractional snow-covered area product as opposed to a binary product. The detection limit of the algorithm is ~15% snow cover for any given pixel, which is the threshold at which we define the 'snow line'.

METHODS

Study Area

The study area in this project includes the entire length of the Wasatch Range in northcentral Utah, and covers approximately 16,500 square miles. Precipitation typically begins to fall as snow in the Wasatch between October and November and typically transitions back to rain between April and May. The mountain snowpack can persist until June or July, particularly at the highest elevations.

Snowline Elevation Analysis

Snowline elevation in the Wasatch Mountains was analyzed using the MODIS Snow-covered Area and Grain Size (MODSCAG) fractional snow-covered area product (fSCA; *Painter et al.*, 2009). MODSCAG data from April 1 of each year, between 2000 and 2017 were downloaded from the Snow Data Server (NASA-JPL). In the

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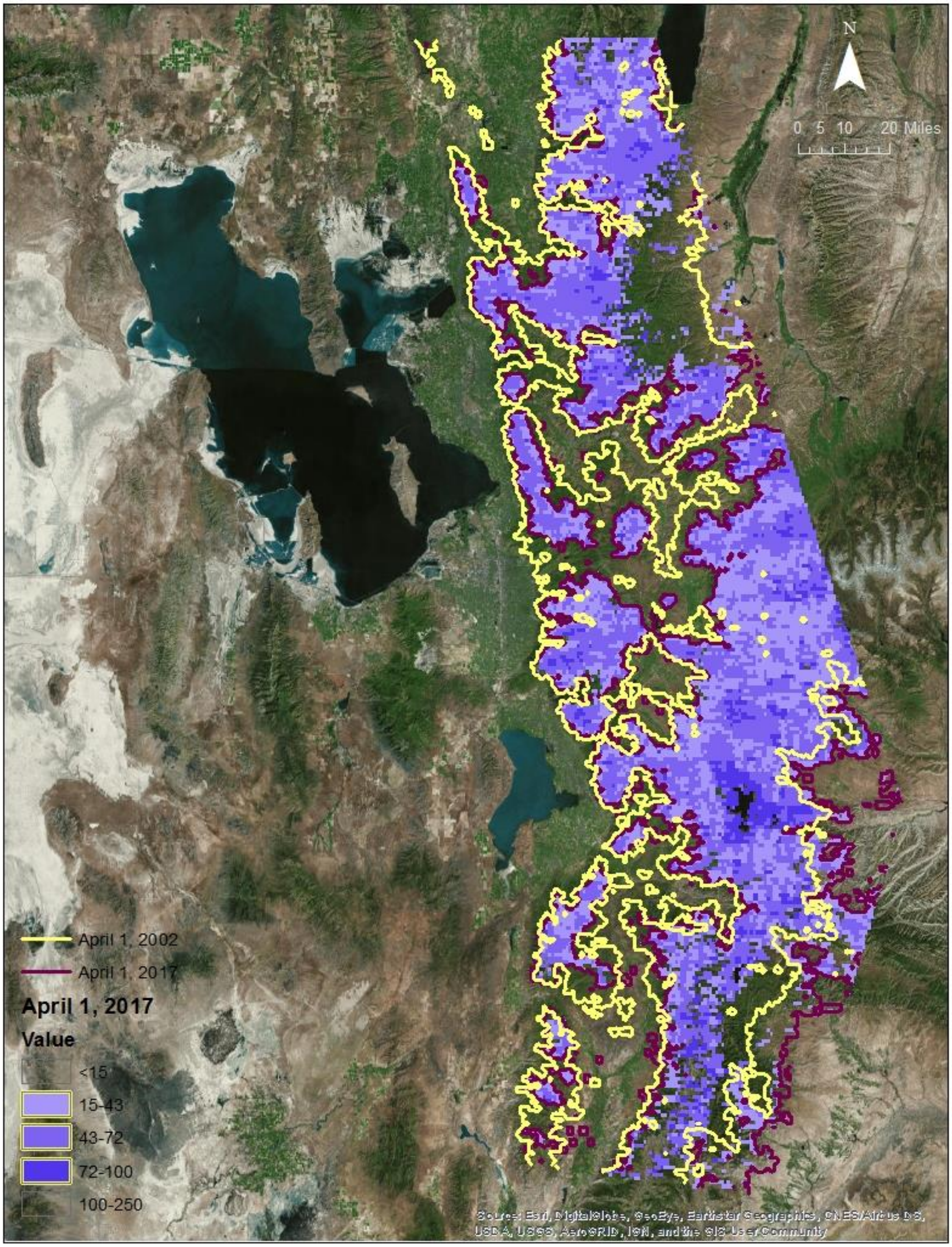

Figure 1. A comparison of snow-line elevation between April 1, 2002 (yellow) and April 1, 2017 (purple). Snow cover is shown in blue; lighter shades indicate a smaller fSCA, while darker shades indicate higher fSCA.

event that extensive cloud cover was present on April 1 the next closest cloud free day was selected for analysis. This was the case in 2006, 2010, and 2013, and then data for April 3, March 28, and April 3 were respectively analyzed instead.

After identifying reliable dates for analyses, MODSCAG data was clipped to the Wasatch Study area. Because the product has a detection capacity of 10 to 15% fractional snow-covered area, 15% snow cover and higher were selected to produce a snowline contour. Then, the average snowline elevation at 15% fractional snow-covered area was obtained by applying information to the contour line from a 30 meter DEM of the study area. Elevations were only analyzed along the Wasatch Front, and in years when the snowpack was discontinuous, the average elevations of each snow area were averaged together. Then, the percent of snow-covered area, as a fraction of the Wasatch Front study area, was found and compared to the average snow-line elevation for that year.

RESULTS AND DISCUSSION

Snowline elevations per year are shown in Figure 2, and snowline elevations and percent snow cover are shown in figure 3. Although it is ideal for studies about a change in the climate to be based on at least 30 years of data, only 18 years of data were analyzed here (from 2000 to 2017) due to MODIS being launched in 1999. Although a statistically significant conclusion about how the snowline elevation along the Wasatch Front cannot be made with reasonable certainty yet, the change in elevation is a good indicator of that year's climate. Figure 2 shows that when percent snow cover is low, elevations are high, and vice-versa. For example, the years 2004 and 2013 were low snow years, which is shown by their low percent snow cover and high snowline elevation. The drought in the western United States, which began in 2012, is reflected in the pattern of high snowline elevations and low percent snow cover between the years 2012 and 2016 (figure 2) which affects the steepness of the percent snow cover trendline.

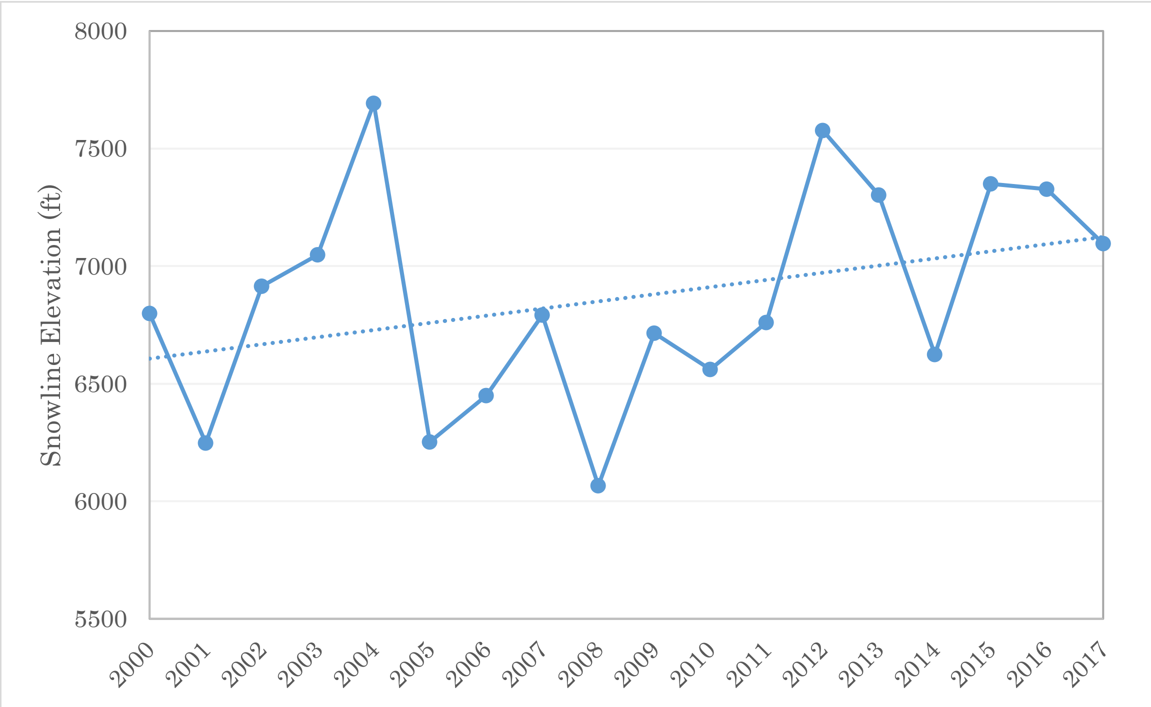

Figure 2. Snowline elevations on, or near, April 1 of each year with trend line.

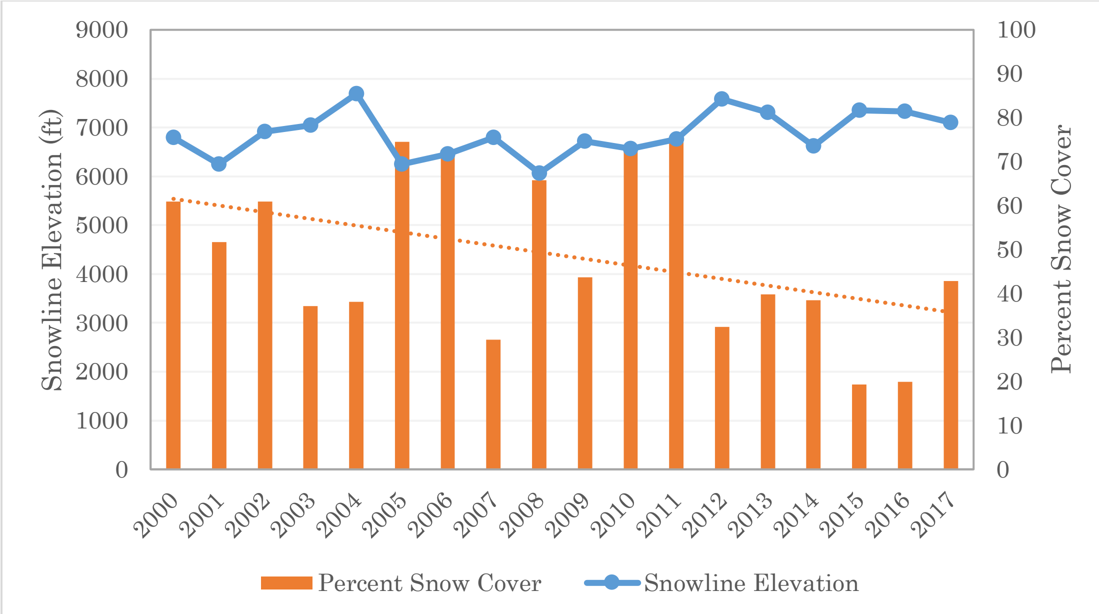

Figure 3. A comparison of the percent snow cover, with trend line, and snowline elevation on or near April 1 of each year.

Future work will be completed by using 8-day composites of the MODSCAG data as a better representation of the snowline elevation throughout spring, and to avoid days with unusable data due to cloud cover. Additional work could include examining areas with higher snowmelt by studying the area's geometry as well as determining SWE from snowpack observation networks.

CONCLUSIONS

The time series presented here, while only a snapshot in time, indicates that snow cover may be declining, and snow elevation rising, in the Wasatch Range over the last 18 years. As expected, years of high snowline elevation corresponded with low percent snow cover and vice versa. Additionally, the drought in the Western United States between 2012 and 2017 affect the steepness of the negative slope of the trendline showing percent snow cover. Understanding trends in snowline elevation and snow-covered area along on the Wasatch Front is critical to understand how the mountain snowpack is changing, critical for water resource availability for growing populations. Although this is not directly indicative of the amount of water held in the mountain snowpack, which is a product of snow depth and snow density (two snow properties that are difficult to retrieve with remote sensing), an analysis like this could be combined with ground observations in the future to indicate the total snow water equivalent of the snowpack.

REFERENCES

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