SNOWPACK VARIABILITY ACROSS FOREST STAND BOUNDARIES IN A MODERATE SNOWPACK

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ABSTRACT

Snowpack in the southwestern United States is the largest source of water for irrigation and municipal use for much of the western states. The Colorado River alone provides water for some 40 million residents. As climate change continues to effect snowfall each year, the need for more accurate snow budget estimates will become increasingly important. The advancement of snow measurement methods and technologies has allowed for greater efficiency in data collection for calculating snow water equivalent (SWE) distribution. For these new technologies to be effectively utilized, a better understanding of the influences on snowpack variability is necessary. This study observes variability with regards to snow depth and density that could affect the accuracy of SWE estimates across forest stand boundaries. A forest stand boundary in the Sandia Mountains was studied to investigate variability between open and canopy transect locations. Snow pits and depth transects are utilized to study snowpack properties and changes thereof in the transect area. These results have the potential to increase the accuracy of water supply estimates from snowpack to increase the effectiveness of future water management budgets. (KEYWORDS: snow hydrology, snow variability, energy budget, moderate snowpack, forest stand boundary, water resource management)

INTRODUCTION

The American Southwest has seen recent patterns of extreme seasonal reversals, specifically related to winter precipitation variability (Goodrich and Ellis, 2008). These patterns make estimating water supply levels from annual snowfall more difficult. Research in the Valles Caldera, New Mexico has shown that forested areas such as in these mountainous regions play a role in reducing sublimation (Musselman, 2008; Harpold, 2014). Webb's research on snow water equivalent (SWE) variability across mixed canopy forests provides insight as to how mixed forested areas create complexities in estimating SWE from snow accumulation (Webb, 2017). More research must be done in these moderate snowpack, lower-latitude regions to better understand the effect of forest stand boundaries on snow accumulation and snowmelt patterns. This understanding could provide a better outlook as to how climate change will affect these regions as they continue to warm. Such information could also be useful for more informed decision making to address falling levels in local water tables and the prevention of wildfires in dry summer months. An improved understanding of snowpack distribution and annual variability in these regions will assist in the creation of more accurate large-scale snow model estimates and in the selection of weather station sites, both of which can be used make more effective water supply decisions.

A research site has been chosen in the Sandia Mountains of New Mexico to better understand how forest stand boundary effects play a role in snow accumulation and snowmelt patterns in a moderate snowpack. The purpose of this research was to survey the selected site, record measurements of snow depth and density, and begin to understand how snowpacks reacts to energy fluxes throughout the season in this region. MATLAB was used to determine the representativeness of transects when randomly chosen together. The same was done for the selection of depth measurements. The results of this study are inconclusive with regards to the effects of the forest stand boundary on snowpack variability; however, there is enough data to provide an excellent basis for further developing research projects to better test boundary effects and variability at the site.

SITE DESCRIPTION

The research site is located on the eastern side of the Sandia Mountains, about 20 kilometers (13 miles) northeast of the University of New Mexico in Albuquerque, New Mexico (See Figure 1). The transect plot is 250 meters north of the 10K trailhead parking lot, which as the name of the trailhead implies, is located along the 10,000-ft. (3,048 m.) elevation line. The area can be described as the Arizona/New Mexico Mountains Ecoregion, located at the beginning of the Canadian-Hudsonian Zone of the Sandia Mountains (Anderson, 1961; Bailey, 1913).

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The forested area in this region is dominated by spruce, fir and aspen trees. Bailey states that, similar to Harpold's findings mentioned above, these forested areas are the key to protecting the water supply for (Bailey, 1913).

The transect plot consists of an open area and a forested area running westward and up the mountain (See Figure 2). The entire transect plot area is 1,200 m^2, with the open area measured at 350 m^2 and the forested area at 850 m^2. The beginning of the forest stand was observed at 35 meters from the first transect, T0, in the open area. Thirteen 10-meter transects run in a north-south direction. Another 120-meter transect bisects the 10-meter transections perpendicularly. The plot also comprises of two snow pits, one located in the open area and the other well within the forested area.

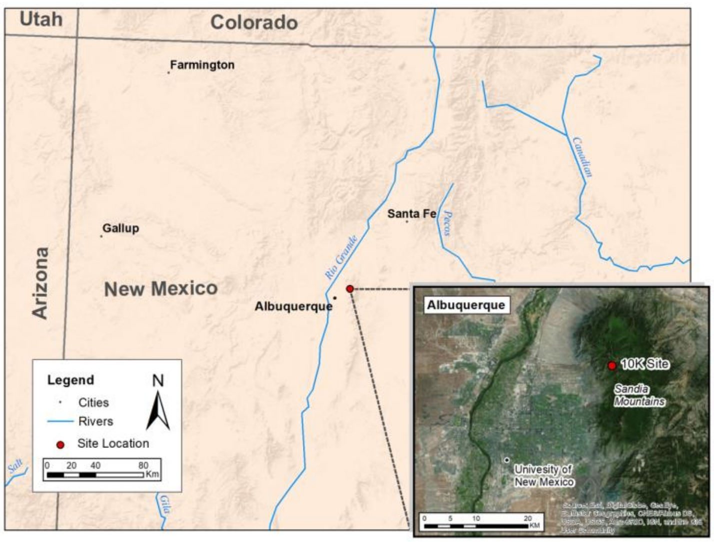

Figure 1. 10K Trailhead site location at 10,000 ft. above sea level in the eastern Sandia Mountains, approximately 13 miles northeast of the University of New Mexico in Albuquerque, New Mexico.

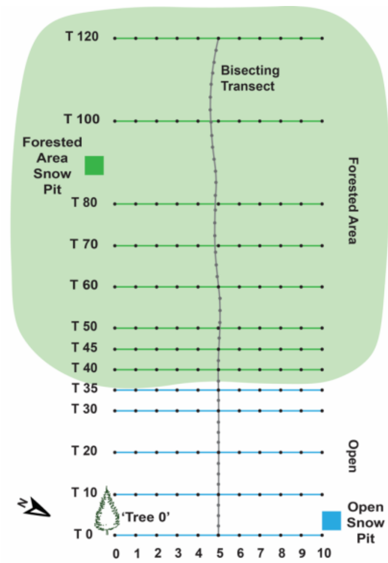

Figure 2. Research site transect plot diagram with numbered transects, the perpendicular bisecting transect, two snow pits and the observed forested area.

DATA COLLECTION AND ANALYSIS

Snowpack data was collected at the research site on a weekly basis during the 2019 snow season, starting on February 8 and ending on April 12. Snow depth was recorded manually using a 3-meter snow probe to collect measurements every meter on the 10-meter transects and every 3 meters on the 120-meter transect. This resulted in about 170 measurement points each visit. Observations at the two snow pits were also recorded, which included density, temperature and stratigraphy. Density was measured using a 1,000-cc wedge cutter and digital scale. Stratigraphy was observed using a crystal card and hand lens. Average depth and density numbers were calculated on a spreadsheet for each visit. The coefficient of variation was also calculated along each transect in order to analyze the variability in depth observed for each visit. Average depth measurements were matched with the corresponding snow pit densities for both the open and forested areas, and snow water equivalent (SWE) and total water volume were calculated for these areas.

Further analysis of the collected data included utilizing MATLAB to determine the number of randomly selected transects that were necessary to be representative of the average depth for the transect area. A similar MATLAB scrip was used to find the number of depth measurements needed as well. Methodology from Lopez-Moreno's paper on spatial variability of mean snow depth estimation was used to model these results (Lopez-Moreno, 2011). Trials were run 4 times for each week for transect selection and 20 times for depth selection. Snowpack energy fluxes were calculated with recorded snow pit temperatures and density measurements for the open and forested area. This included calculating the cold content as well as the ripening and output phase fluxes using Dr. Williams's lecture slides as a guide (Williams).

RESULTS AND DISCUSSION

Data collected from weekly visits indicated little variability between depth and density measurements early in the season. As the snowmelt period progressed, there were more apparent signs of variability between the open and forested areas. Depth measurements ranged from 0 cm to 143 cm in the open area, and 0 cm to 148 cm within the forested area for the time period studied. Density measurements ranged from 182 kg/m^3 to 447 kg/m^3 among both snow pits. The second row of graphs in Figure 3 show some variation appeared around the forest stand boundary, up to about 60 meters inward from the observed tree line. This data, however, did not provide a consistent enough pattern throughout the season to confirm a boundary effect was caused by the forest stand. Depth variability appears to increase across the entire site in April as the snowmelt period begins (Figure 3). Figure 4 contains snow pit density profiles plotted against snow pit depth, which shows a more consistent depth measurement in the forested area snow pit. This consistency is in agreement with both Bailey's and Harpold's research that the forested area in this region delays sublimation, protecting snowpack accumulation during the melt period.

Net energy flux calculations, which are plotted in Figure 6, confirm that more energy was absorbed in the open area during the melt period. This is synonymous with the results in Figure 3 and Figure 4, which show the snowpack and snow pit depths in the open area decreasing faster during the melt season. This can also be seen in Figure 5, where the snow water equivalent (SWE) line for the open area appears to be decreasing at a faster rate than the forested area. These results again illustrate the important role that the forested area plays in reducing sublimation as the snowmelt period begins.

MATLAB analysis of depth data showed that the percentage error dropped below 5% after more than one transect was randomly chosen. This was interesting when compared to the result for selected depth measurements, which had a maximum error of about 1.5% when only ten depth points were randomly chosen across the site plot. Perhaps these results indicate minimal depth variability existed at this site during the snow season, or that the resolution of transect data was not fine enough to capture enough variability across the transition into forest stand. More research will be needed to better determine if this range of variability is representative for each season.

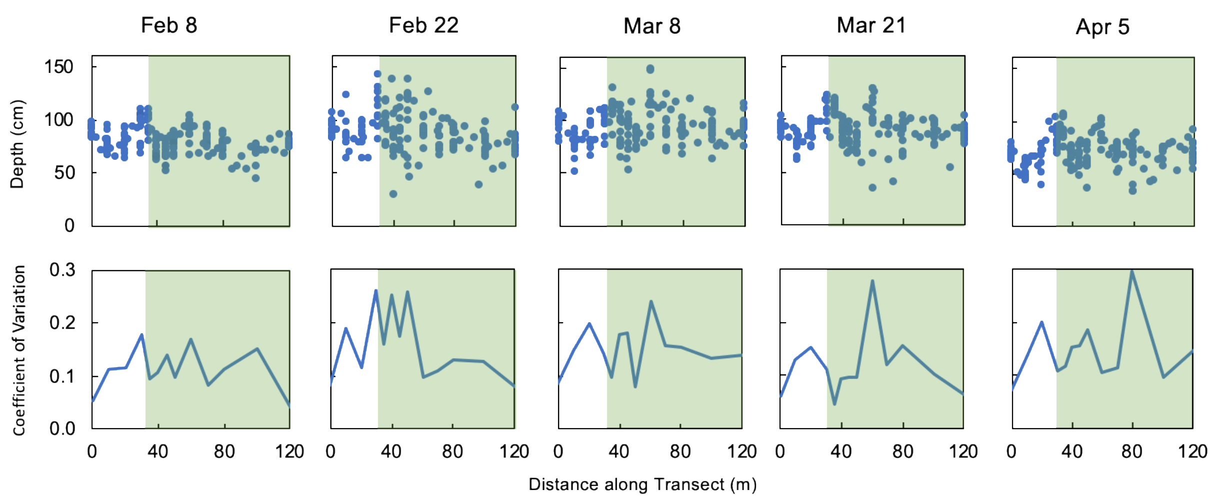

Figure 3. Snow depth measurements (above) and corresponding coefficient of variation calculations (below) across the observed forest stand boundary marked in green; displayed in two-week intervals.

FUTURE WORK

The data in this study will be valuable for preparing future research projects at the 10K trailhead site. Collecting data for multiple years will encompass the seasonal variability that is expected as extreme reversals continue. This will provide a more accurate picture of the normal snow distribution patterns in this region. In order to further the study of variability across the forest stand boundary, future projects will include new methods to gather more data points across the site. One consideration is to use photogrammetry to gather a much finer resolution of depth measurements across the entire transect plot. Another concept being considered is the creation of temperature profiles across the forest stand boundary with wireless temperature buttons to capture continuous data. This would provide more data to better understand the energy flux changes that occur in this moderate snowpack

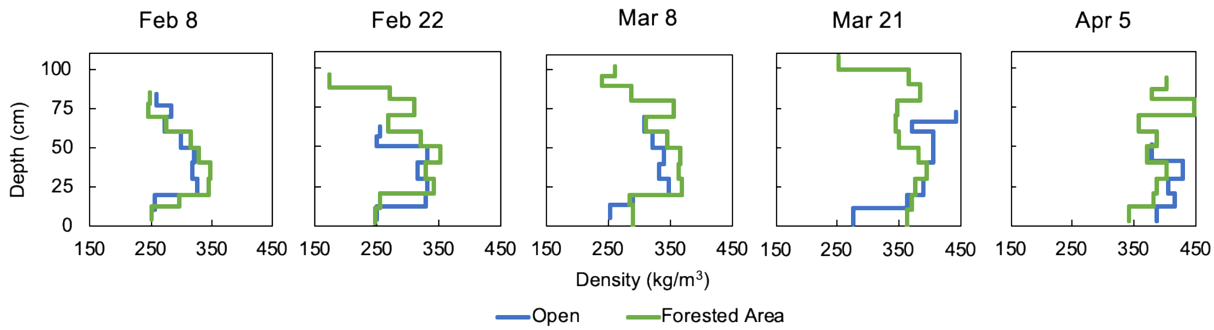

Figure 4. Snow density profiles and corresponding depths for both the open and forested area snow pits; displayed in two-week intervals.

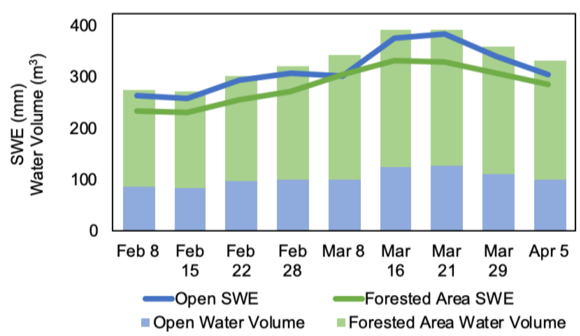

Figure 5. Snow Water Equivalent (SWE) and water volume calculations for both the open and forested areas; displayed in two-week intervals.

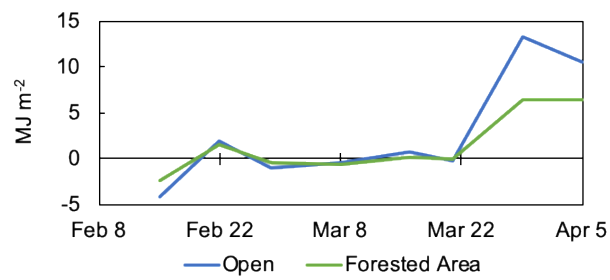

Figure 6. Net energy fluxes calculated for both the open and forested area snow pits; displayed in two-week intervals.

region. The goal is to utilize snowpack variability data to more accurately determine the effects that a tree stand boundary has on snowpack accumulation and snowmelt, and ultimately, to improve snowpack and water supply estimates for effective water management decisions.

REFERENCES

Anderson, R.Y. 1961. Physiography, climate and vegetation of the Albuquerque region. *New Mexico Geological Society 12th Annual Fall Field Conference Guidebook,* 63-71.

Bailey, V. 1913. Life zones and crop zones of New Mexico. *North America Faun No. 35,* 46-49. U.S. Department of Agriculture.

Goodrich, G.B. and Ellis, A.W. 2008. Climatic controls and hydrologic impacts of a recent extreme seasonal precipitation reversal in Arizon. *Journal of Applied Meteorology and Climatology, 47*, 498-508.

López-Moreno, J.I., et al. 2011. Variability of snow depth at the plot scale: implications for mean depth estimation and sampling strategies. *The Cryosphere*, *5*, 617-629.

Musselman, K.N., et al. 2017. Slower snowmelt in a warmer world. *Nature Climate Change, 7*, 214-219.

Musselman, K.N., et al. 2008. Effects of vegetation on snow accumulation and ablation in a mid-latitude sub-alpine forest. *Hydrological Processes, 22*, 2767-2776.

Webb, R. 2017. Using ground penetrating radar to assess the variability of snow water equivalent and melt in a mixed canopy forest, Northern Colorado. *Frontiers in Earth Science, 11*(3), 482-495.

Williams, M.W. Snow II: Snowmelt and Energy Balance [PowerPoint Slides]. *Introduction to Hydrology*. Department of Geography, University of Colorado, Boulder.