ULTRASONIC SNOW DEPTH SENSOR REFURBISHMENT AND TESTING AT THE NATURAL RESOURCES CONSERVATION SERVICE NATIONAL WATER AND CLIMATE CENTER ELECTRONICS MAINTENANCE FACILITY, PORTLAND, OR

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ABSTRACT

The Natural Resources Conservation Service (NRCS) National Water and Climate Center (NWCC) Electronics Maintenance Facility (EMF) in Portland, OR provides assistance and guidance to the NRCS Snow Survey and Water Supply Forecasting program regarding the use of electronic instrumentation to collect hydrologic and climatic data at SNOTEL (Snow Telemetry) and SCAN (Soil Climate Analysis Network) sites. Snow depth is an important component measured at SNOTEL sites. The most common sensor used to measure snow depth within the SNOTEL program is the ultrasonic snow depth sensor. Ultrasonic snow depth sensors are to be refurbished and tested at EMF or replaced every six years. When a snow depth sensor is returned to EMF, all the major electronic components, along with any degenerate sensor body components, are replaced by technicians, and the refurbished sensor is run through a ten-point test to ensure that it meets manufacturer and programmatic specifications. Sensors that meet specifications are redeployed at SNOTEL sites and field-checked annually. (KEYWORDS: SNOTEL, snow depth, direct snow measurement, instrumentation)

INTRODUCTION

The Snow Telemetry (SNOTEL) network is a network of automated data-collection sites maintained by the Natural Resources Conservation Service (NRCS) Snow Survey and Water Supply Forecasting program that collect and transmit hydrologic and climatic data to a centralized database. Every SNOTEL site collects values for snow-water equivalent (SWE) within the snowpack, snow depth, ambient air temperature and precipitation amount. The most common sensor used to measure snow depth within the SNOTEL program is the ultrasonic snow depth sensor. According to the Snow Survey and Water Supply Forecasting Handbook (USDA, 2018), ultrasonic snow depth sensors are to be refurbished and tested or replaced every six years. Sensors are removed from the site and sent to the Natural Resources Conservation Service (NRCS) National Water and Climate Center (NWCC) Electronics Maintenance Facility (EMF) in Portland, OR. EMF provides assistance and guidance to the NRCS Snow Survey and Water Supply Forecasting program regarding the use of electronic instrumentation to collect hydrologic and climatic data.

METHODS

The sensors that come to EMF for refurbishment and testing are catalogued, then dismantled to the point that they are only a sensor body and a wire lead. The plastic drip ring is removed, and any epoxy is cleaned from the sensor body. The transducer element is persuaded out of its hole using the appropriate method. The old PVC coupling is removed and replace with a new, stronger, Schedule 80 PVC coupling. The old snow hat is removed, along with the silicon affixing it to the sensor body, and a new snow hat is attached. A silica gel desiccant pack is placed in the bottom of the sensor body, and the control board is installed over the desiccant pack. The ranging board is installed over the control board. The ribbon wire is folded and seated into place on the ranging board, so as not to interfere with the transducer mounted on the other half of the sensor body. The new temperature sensor is threaded through the hole in the PVC fitting and held in place with silicon caulk, leaving a gap so that air can be displaced when the transducer element pulses. A five-wire plug is attached to the end of the temperature sensor wires. A PVC "T" is screwed in over the temperature sensor and oriented so it will not interfere with the ultrasonic beam. The new metal drip ring is epoxied into place and allowed to dry overnight. The transducer element is affixed to the sensor body using silicon caulk. The temperature sensor is plugged into the ranging board. The two halves of the sensor body are screwed together. Please see the poster with the same title for images of the steps described.

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After the sensor is refurbished, it is put through a 10-point range test at EMF. The sensor is attached to a ladder with the transducer element pointing horizontally, and read through a data logger. The transducer pulse is transmitted at a large white board on wheels. The white board is moved at three-foot increments from three feet to 30 feet, making sure that the board is located as close as possible to the incremental marks on the floor. Sensor range values must fall within 0.4% of the distance to the target. For example, if the unit under test is reading a target that is 30 feet away, the recorded value must be within 0.12 feet of the actual value.

RESULTS

Sensors that meet specifications are redeployed at SNOTEL sites and field-checked annually. Figure 1 shows an example of the data collected by in-situ ultrasonic snow depth sensors at SNOTEL sites.

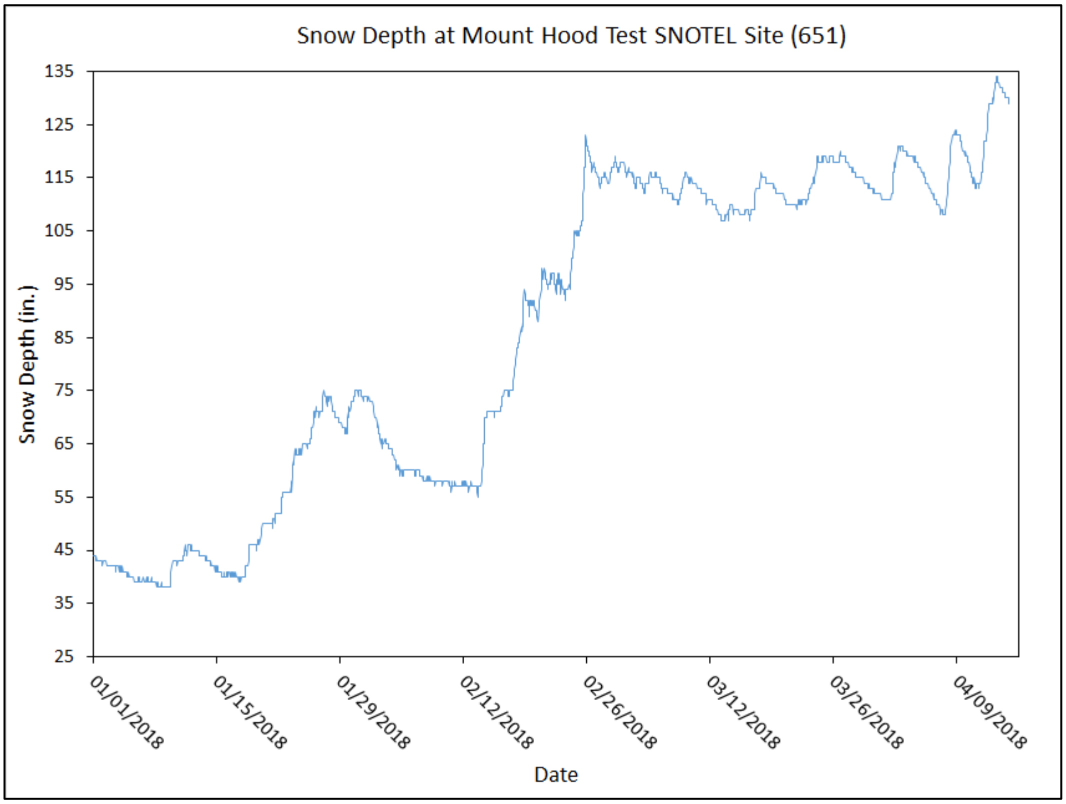

Figure 1. Example of the data collected by an in-situ ultrasonic snow depth sensor.

CONCLUSIONS

The EMF in Portland, OR provides assistance and guidance to the NRCS Snow Survey and Water Supply Forecasting program regarding the use of electronic instrumentation to collect hydrologic and climatic data at SNOTEL and SCAN sites. Snow depth sensors are refurbished or replaced every six years to ensure that the data collected at SNOTEL sites are as good as possible.

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THE EFFECT OF FOREST STRUCTURE ON SNOWPACK ALONG ARIZONA'S MOGOLLON RIM

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EXTENDED ABSTRACT

Across the Western US, snowmelt, particularly from mountain forests can contribute more than 75% of surface water resources. This is true even in the semiarid southwestern US, where 80-90% of annual runoff can occur during the late winter and spring. Snowpacks in this region, which are already shallower and temporally more variable than snowpacks of wetter and cooler climates further north, are particularly vulnerable to climatic changes such as regional warming and drought.

Changes in forest structure have the potential to exacerbate or mitigate snowpack changes brought about by these climatic changes. Forest structure exerts a strong control on snowpack because of the interplay of various factors such as interception and shading from the trees. For example, interception reduces the amount of snow reaching the ground, while shading by terrain and/or forest vegetation protects the snowpack on the ground from sublimation loss (e.g. Musselman et al., 2008; Rinehart et al., 2008, Veatch et al., 2009; Figure 1). For example, this tradeoff means that despite causing a decrease in interception, forest removal may result in equal or reduced SWE (Harpold et al., 2014; Biederman et al., 2014). Furthermore, the relative importance of these factors depends on climate and topography. For example, steep north facing slopes, which are already shaded may be more sensitive to changes in interception than to forest shading, while on sunny south facing slopes, shading from nearby trees can be important for retaining snowpack.

Figure 1. Image at one of our study sites depicting deep snow in areas shaded by trees and shallow / absent snow in sunnier areas, particularly on the warm sides of canopy stands.

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While there has been extensive work to understand the role of forest structure at high elevations with persistent seasonal snowpacks, the goal of this study is to understand how forest structure interacts with climate and topography to regulate the thin, variable, and often ephemeral snowpacks of the Southwest. Specifically, we 1) examine the spatial variability of snow, as it relates to variable canopy structure using LiDAR-based snow data from Arizona, and 2) determine through comparison of LiDAR data with model snow simulations assuming no vegetation whether forest cover increases or decreases snowpack in different topographies and climates in the area.

In this study, we use LiDAR maps of snow, forest structure and terrain, synchronous ground observations, and process based and machine learning models to understand the impact of forest structure on snowpack within the economically important Salt and Verde watersheds in Arizona. Two LiDAR boxes (each having an area of ~100 km^2), capture snowpack for a mid-elevation ponderosa pine forest, and a high-elevation mixed conifer forest with montane meadows. In this study, we focus on airborne LiDAR surveys for each box in February, 2017 representing mid-winter snow conditions. These surveys are accompanied by ground surveys of snow depth (n~4000) and snow density (n~300) at seven intensively studied sites within the LiDAR domains, capturing a wide range of variables expected to control snowpack: elevation, slope, aspect, forest density, and forest geometry. Ground measurements of snow depth are used to correct small errors in the LiDAR snow depths, and artificial neural network (ANN) machine learning of the snow density measurements is used to create maps of snow density, which are combined with the LiDAR snow depth maps to produce maps of SWE.

To understand the impact of forest structure on snowpack across the LiDAR domains, we use a 1 meter energy balance model called SnowPALM (Broxton et al., 2015), along with machine learning of the LiDAR and ANN-based SWE maps to predict how radiation and snowpack are affected by forest canopy. Through this modeling, we produce sub-canopy radiation maps for the LiDAR domains, as well as maps of what SWE would look like in the absence of any tree cover across the LiDAR domains. Differences between the observed snow amounts and modeled snow amounts assuming no trees indicate SWE differences caused by trees. These differences are examined in relation to tree cover percent and under canopy shading factor (which is calculated as one minus the under canopy solar forcing index computed by SnowPALM).

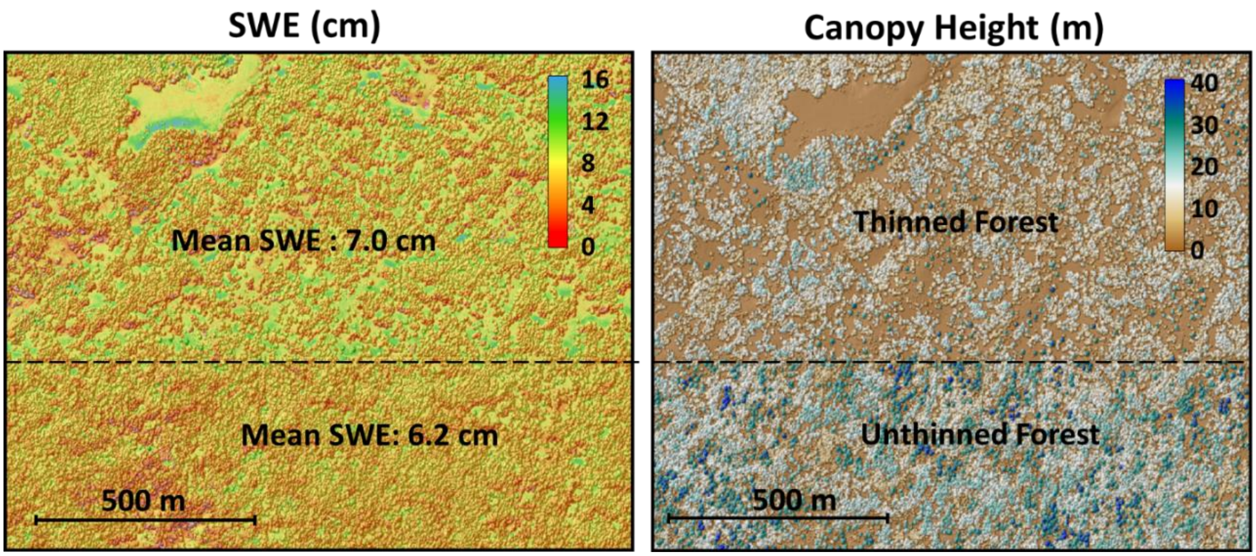

Figure 2. **Left:** SWE distribution across a managed forest boundary at a site with flat topography in the mid-elevation LiDAR box showing the average SWE in the thinned and unthinned parts of the image. **Right:** Canopy height for the area. Note the canopy hillshade effect on both maps to emphasize the locations of trees.

Snow distributions and amounts vary in forests with different canopy structure. As an example, Figure 2 shows maps of SWE for an area of the mid-elevation box where there is a pronounced boundary between a thinned and an unthinned ponderosa pine forest. The thinned forest has more gaps between the tree stands than the unthinned forest. In general, there is more snow in the thinned forest, in particular in the mid-sized forest gaps and on the shaded southern edges of large clearings. Less snow is found under tree canopy, on the exposed sunny sides of tree stands, and in the middle of large clearings. These differences in snow amounts reflect differences in interception, and variable energy inputs in shaded vs non-shaded areas next to trees. Overall, SWE amounts in the thinned forest in this area are ~13% more than in the unthinned forest.

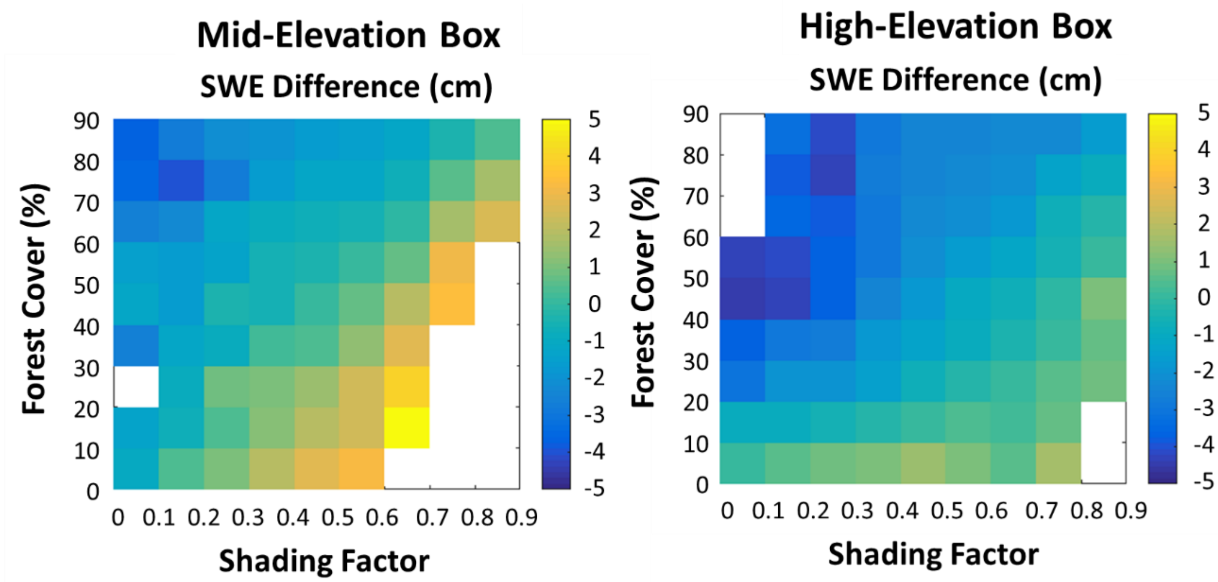

Figure 3. Observed minus bare earth SWE in different categories of forest cover and shading factor for the **(left)** mid-elevation and **(right)** high-elevation LiDAR boxes. Shading factor is calculated as one minus the sub-canopy solar forcing index.

The above example offers clues about the impact of forest structure on snowpack, but when looking across the entire LiDAR domains, we find that the interaction of treecover and shading leads to a net-positive or a net-negative SWE response to forest cover. Figure 3 shows that SWE is less, relative to unforested areas when the tree cover is high but the shading factor is relatively low. Conversely, areas with high amounts of shading tend to have more SWE than unforested areas, particularly at low-medium canopy cover. This effect is more pronounced in the mid-elevation LiDAR box. As a result of this interaction, the impact of forest structure on snowpack is not simple. Rather, it is different for different topographies and climates. For example, we find that forest cover doesn’t seem to affect snowpack on south-facing aspects as much as it does for north-facing aspects. Furthermore, there were significant differences between its effects for the mid-elevation vs high-elevation LiDAR box. For example, on north facing slopes in the high-elevation box, SWE tends to decrease monotonically as canopy cover increases, while in the mid-elevation box, SWE increases for low-medium canopy cover and decreases for high canopy cover, suggesting the increased importance of forest shading, perhaps for retaining snowpack which is more easily lost in the warmer environment of the mid-elevation box.

(KEYWORDS: Airborne LiDAR, Modelling, Forest Structure, SWE, Arizona)

ACKNOWLEGMENTS

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