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Investigating the Relationships Between Canopy Characteristics and Snow Depth Distribution at Fine Scales: Preliminary Results from the SnowEX TLS Campaign

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BOISE STATE UNIVERSITY

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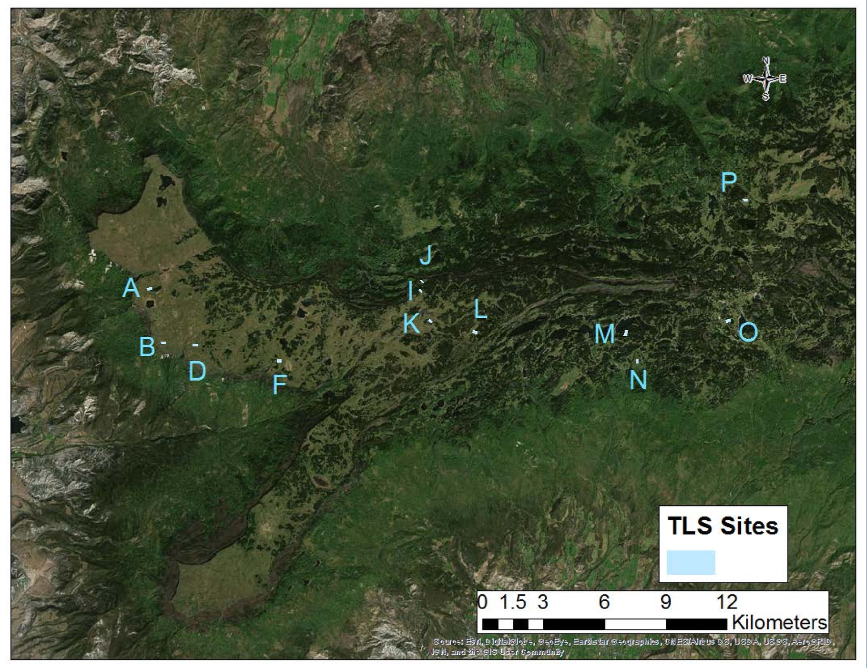
Objective

Using terrestrial laser scans (TLS) from multiple sites across Grand Mesa, CO I will describe the relationship between both forest cover and topography on snow depth distribution. Specifically, I focus on canopy patch configuration and possible predictors of wind redistribution from digital elevation models (DEMs). Additionally, topography is examined for its effect on snow depth.

Background: Snow distribution is controlled by many biophysical and geographical attributes of the landscape such as vegetation cover and topography. In forested environments, forest and vegetation has been observed to strongly control snow depth distribution (Deems et al., 2006, Trujillo et al., 2007) by the mechanisms of canopy interception and wind redistribution from open areas to forest edges. The effect of forest canopy on snow depth is dependent upon the stand density (Anderson, 2014), species and stand configuration, as well as climate (Dickerson-Lange et al., 2017).



TLS sites on Grand Mesa

Site K. Snow on and snow off images from Site K

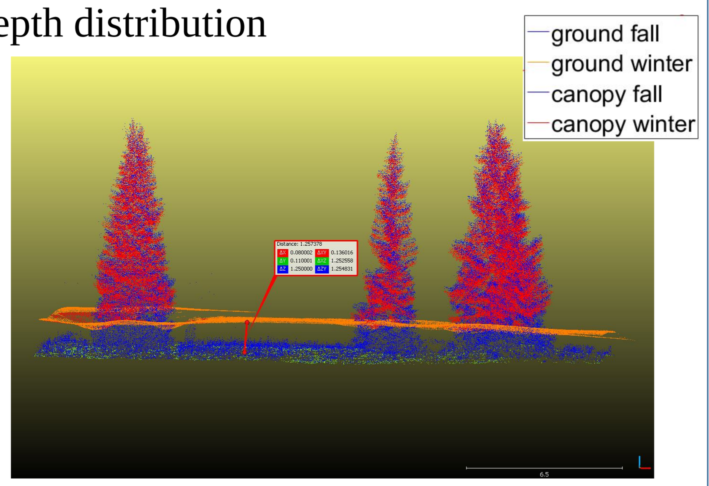
SnowEx -multiyear NASA campaign designed to:
1. Determine the effect of forest canopy on remote sensing retrievals and snow distribution

Data:
Point clouds from terrestrial lidar scanning ***(TLS)*** from the 2017 Colorado ***SnowEx Field Campaign*** in Grand Mesa, CO.

Approach:
1. Create rasters of snow depth (DEM's of differencing): snow on – snow off
2. Create canopy metrics (max ht, range, std deviation, etc.) from canopy classified points.
3. Create metrics which reflect the spatial relationships between snow and canopy edges.
4. Identify correlation between metrics and snow depth distribution

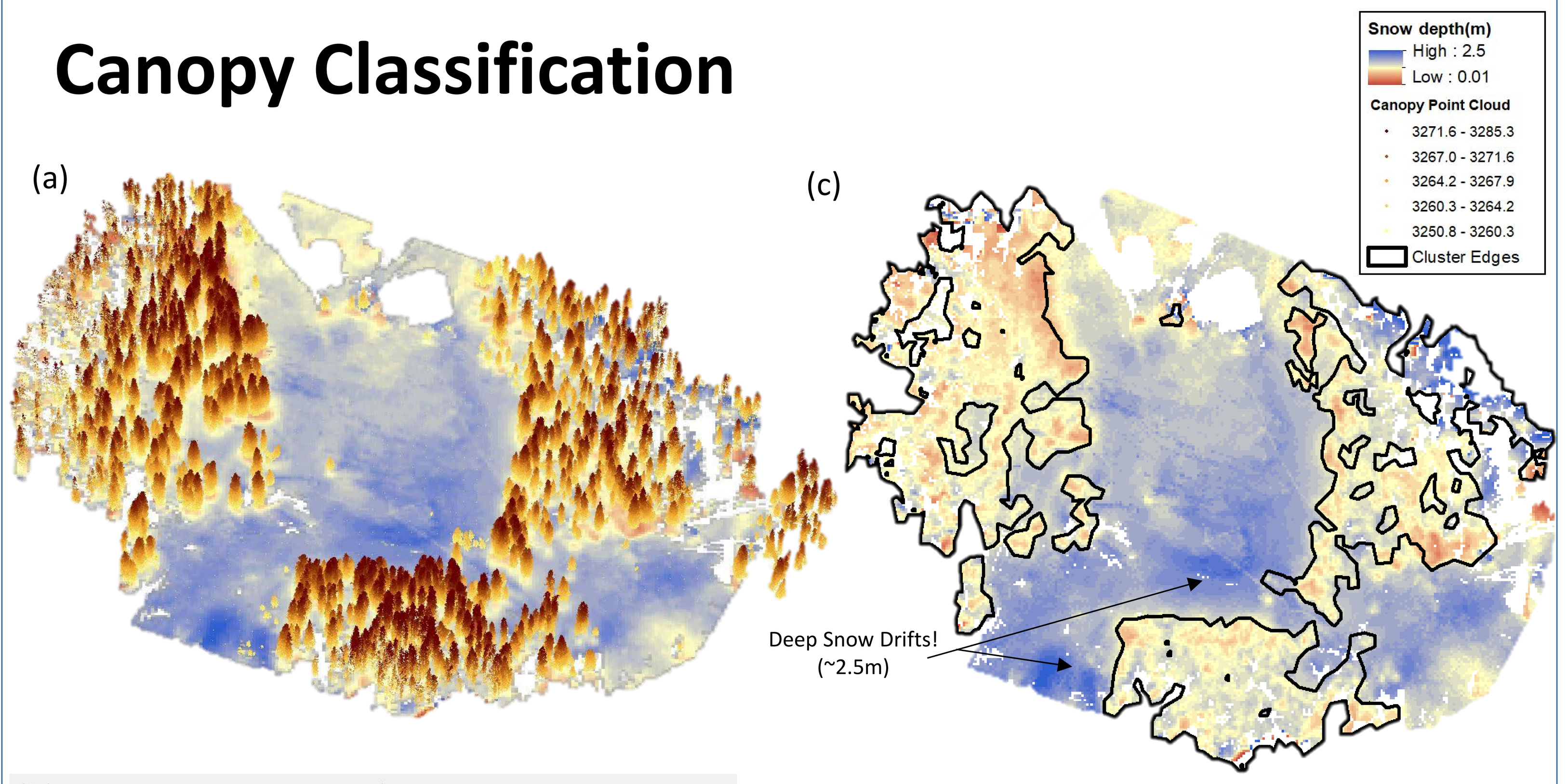
Calculating Snow Depth:
1. Georegister point clouds from fall and winter (snow off and snow on)
2. Create digital elevation model (DEM) of ground
3. Difference the two dates

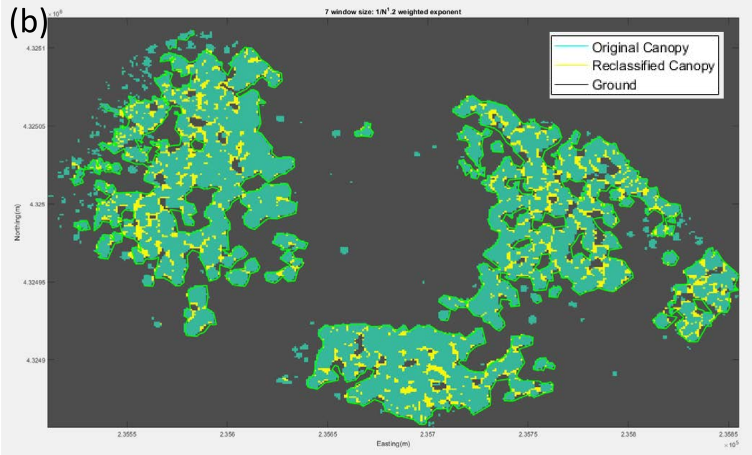
Snow depth = Snow on (elevation) - Snow off(elevation)



Georegistered Fall and Winter Scans. Snow depth is ~ 1.3m.

Canopy Classification





Figures 1a, 1b, 1c. Site K (a) Snow depth map overlain with canopy point cloud. (b) Interpolation method used to aggregate forest clusters: *7x7 pixel moving window with* $\frac{1}{distance^{1.2}}$ *weighting*. (c) Resulting forest edges traced overlain on snow depth.

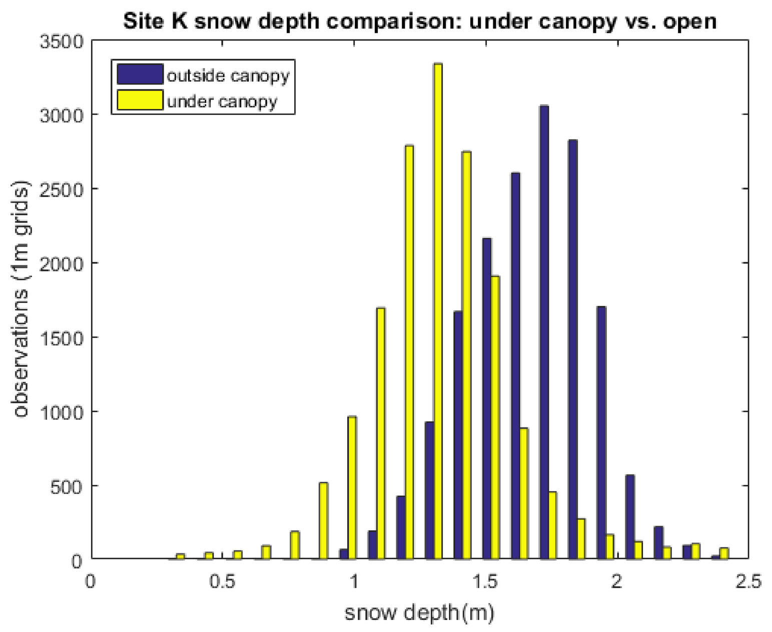
Canopy classification from point cloud performed using Boise Center for Aerospace Laboratory (BCAL) Lidar Tools extension in Excelis' Environment for Visualizing Images (ENVI).

Preliminary Results

1. Comparison of means (under canopy vs. outside canopy)

<u>T-test results:</u>
-*statistically different means* - snow depth under canopy vs open.
-p-value = 0

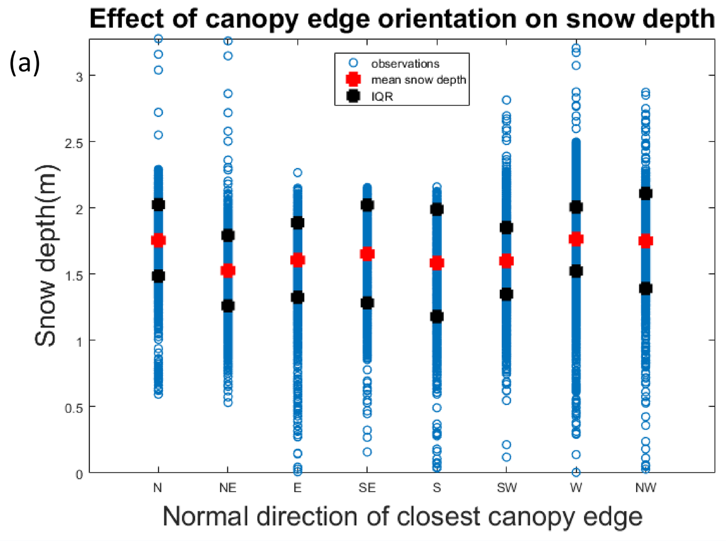
Mean snow depth:
<u>outside canopy</u>: 168cm
<u>Inside canopy</u>: 132cm

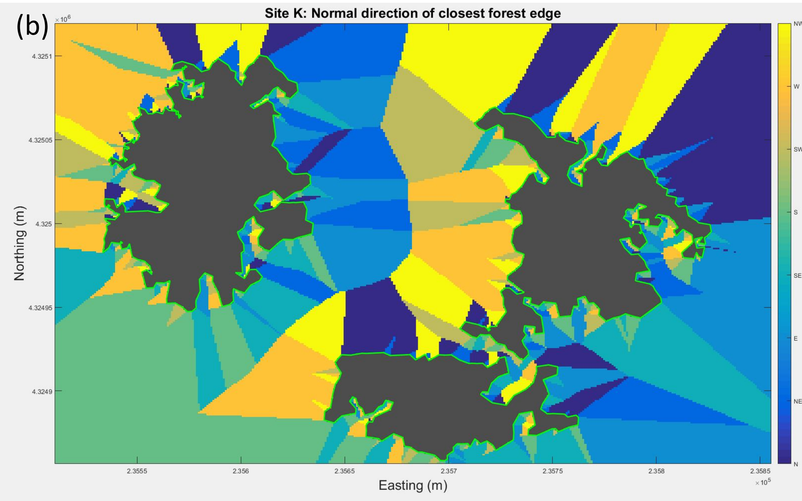


Figures 2a, 2b. Snow depth deeper in the open. Snow depth values under canopy vs. outside of canopy. Histogram portrays values from ~16,000 1m^2 grid cells over entirety of Site K.

2. Effect of Forest Edge

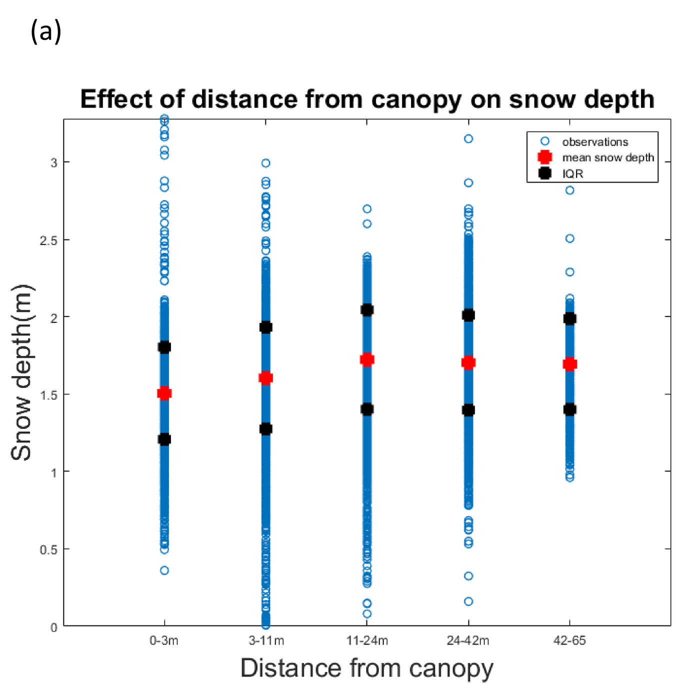
- For each line segment of forest cluster edge (Figure 3a; green border), calculated the direction normal to line.
- Each snow depth cell located outside of cluster, was assigned direction of closest line segment.
- Snow Depth Vs. Orientation Evaluated.

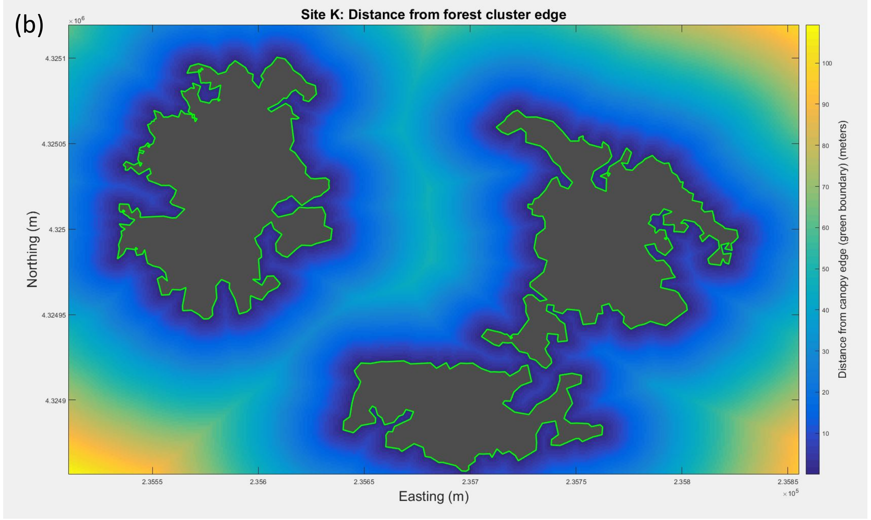




Figures 3a, 3b. Bearing from forest edge. (a) Mean and interquartile range (IQR) vary based on orientation of nearest forest edge. Deepest snow in N and W which is visible in Figure 1c, annotated with "Deep snow drifts!..." (b) Representation of direction of closest forest edge to cell location

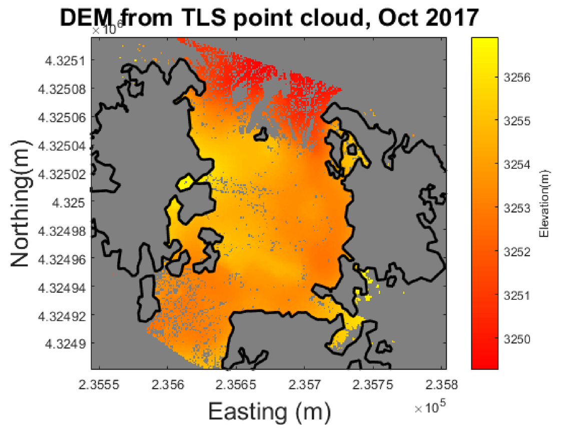
3. Distance from canopy edge.



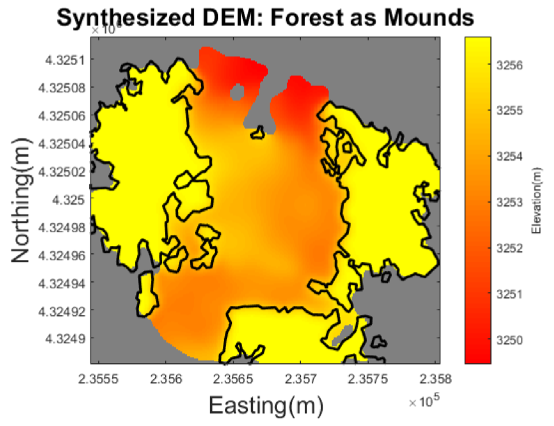


Figures 4a, 4b. (a) At Site K, depth appears to be positively correlated to distance from canopy, out to 24m. Note* low snow depths at 0-3m may reflect that edge delineation needs to be more sensitive to low canopy height, rather than snow accumulation/ablation processes. (b) Illustration of distance scale at Site K.

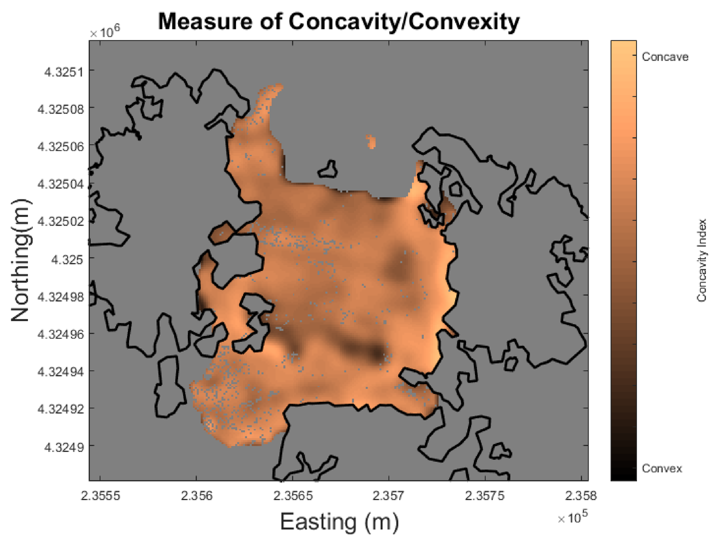
4. Influence of bare earth concavity

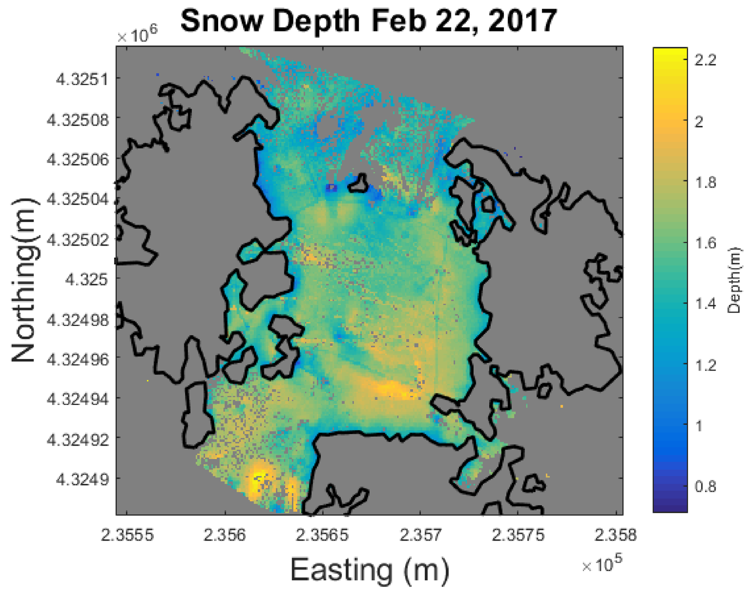


Impute elevation values for within canopy boundary as maximum site elevation, then ***smooth with Gaussian filter***



Calculate concavity index using Laplacian of Gaussian (LoG) 2D filter (measure of second derivative of elevation change)





Compare concavity to snow depth:
Preliminary results indicate no statistical correlation (Pearson's Correlation Coefficient = +0.075) between concavity and snow depth. Perhaps optimizing the LoG filter and considering aspect, slope and other topographical attributes using a multilinear regression will yield better correlation.

Next Steps

Patch and edge dynamics
1. Optimize topographical metrics, i.e concavity.

Canopy height model at tree scale

More sites2. Individual tree segmentation.
3. Derive statistics from each patch:
- i.e. stems/acre, height distribution, patch size

4. Analyze more sites

Run Statistics
5. Regression analysis to assess influential canopy and topography metrics on snow depth.

Citations

Anderson, B.T., McNamara, J.P., Marshall, H.P., Flores, A.N. (2014), Insights into the physical processes controlling correlations between snow distribution and terrain properties, *Water Resources Research*, 50, 4545-4563.
Deems, J. S., S. R. Fassnacht, and K. J. Elder (2006), Fractal distribution of snow depth from LIDAR data, *J. Hydrometeor*., 7(2), 285 - 297.
Dickerson-Lange, S., Gersonde R., Hubbart, J., Link, T., Nolin, A., Perry, W., Roth, T., Wayand, N., Lundquist, J., (2017), Snow disappearance timing is dominated by forest effects on snow accumulation in warm winter climates of the Pacific Northwest, United States. *Hydrological Processes*, DOI: 10.1002/hyp.11144
Trujillo, E., Ramirez, J. and K. Elder (2007), Topographic, meteorologic, and canopy controls on the scaling characteristics of the spatial distribution of snow depth fields. *Water Resourc. Res.*, 43 W07409, doi:10.1029/2006WR005317

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