

Rocky Mountain Research Station

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Beetle Outbreaks in Subalpine Forests and What They Mean for Snowmelt

Sublimated snow is water lost from snow-dominated ecosystems

It is hard to overstate the importance of snowmelt as a source of fresh water in parts of the Rocky Mountain West, and great attention is paid to ecosystem water cycles in this region. Some of the snow that falls in the mountains goes directly from crystalline snow to water vapor, bypassing the liquid water phase. This phenomenon—sublimation—accounts for the loss of a large portion of the snowfall during the winter months in the Rocky Mountains. Snow intercepted by tree branches sublimates the fastest, often disappearing within a few days of a snowfall.

Starting in the mid-2000s, a spruce beetle outbreak caused widespread damage to an Engelmann spruce-subalpine fir forest in the Snowy Range Mountains of southeastern Wyoming. By 2010, the outbreak killed 75 to 85 percent of mature Engelmann spruce trees in some areas. The loss of the needles following the outbreak meant that less snow was being retained in the canopy and was instead falling through the tree branches and onto the ground. Snow on the ground has less surface area, which slows sublimation, while the loss of canopy increases the amount of wind and sunlight reaching the ground, speeding up the sublimation of the snowpack. Recently published work by Rocky Mountain Research Station (RMRS) Electronics Engineer John Frank and colleagues teases apart how the loss of spruce canopy affects the sublimation rates for snow both in the canopy and on the ground in these ecosystems. And these findings have some important implications to snow interception and retention.

A beetle outbreak reduced canopy leaf area, snow interception, and ultimately sublimation rates

The researchers used 17 years of data collected from the Forest Service's Glacier Lakes Ecosystem Experiments Site (GLEES) in Wyoming's Snowy Range for this study. They found that the spruce beetle outbreak caused 75 to 85 percent basal area mortality,



Engelmann spruce trees killed by spruce beetle (right) in Wyoming's Snowy Range have far fewer needles to catch snow, compared to the living subalpine fir on the left. Less snow in the canopy leads to lower sublimation rates and more water being retained in the forest. Photo credit: John Frank, USDA Forest Service.

significantly reduced needle surface area, and left the forest canopy's ability to intercept snow at one third of pre-beetle capacity. Less intercepted snow means less water lost by the forest through sublimation. In fact, the researchers measured 32 percent less water sublimated from the canopy. "Over the course of our research, we were able to detect a major reduction in sublimation in a subalpine forest—overall about 25 percent—that coincided with substantial mortality of large Engelmann spruce due to the spruce beetle outbreak," says Frank.

This decrease in the ecosystem's sublimation loss is a direct result from the decrease in the amount of snow the post-beetle forest canopy can intercept. Freshly fallen snow is caught and distributed three dimensionally throughout the canopy with an abundance of surface area exposed for sublimation. Snow that falls onto the snowpack is more two dimensional and therefore is much less likely to sublimate back to the atmosphere. Frank explains,

Management Implications

- Snow retained in tree canopies is quicker to sublimate (go directly from snow to water vapor) than snow on the ground, and ecosystem sublimation rates can be affected by factors that affect the amount of snow retained in the canopy.
- A spruce beetle outbreak in Wyoming's Snowy Range killed large numbers of Engelmann spruce and reduced leaf area, leading to a reduction in snow intercepted by the tree canopy.
- Research spanning almost two decades found that this decrease in snow interception led to a 25 percent decrease in sublimation rates in these beetle-affected forests.
- Overall, this leads to about 6 percent more snow being retained in the snowpack, and this increased amount of water is expected to be a part of the ecosystem for at least decades until the forests start to recover.

"The reduction in snow interception means that overall, about 6 percent more snow is retained by the snowpack." This excess water is expected to be a part of the ecosystem for decades (or centuries) until the forest canopy regrows. Already, in the decade since the beetle disturbance, the once mostly bare soil has been overgrown by understory plants and surviving trees have grown at unprecedented rates, in part due to the cumulative effect of an ecosystem that retains a bit more water year after year. This fundamental and long-term change in the annual water balance means that even as the trees regrow, the ecosystem may never resemble the forest that visitors have appreciated for centuries.

FURTHER READING

Frank, J.M.; Massman, W.J.; Ewers, B.E.; Williams, D.G. 2019. [Bayesian analyses of 17 winters of water vapor fluxes show bark beetles reduce sublimation](#). Water Resources Research. 55: 1598–1623.

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Frank, J.M.; Massman, W.J.; [et al.]. 2014. [Ecosystem CO₂/H₂O fluxes are explained by hydraulically limited gas exchange during tree mortality from spruce bark beetles](#). Journal of Geophysical Research: Biogeosciences. 119(6): 1195–1215.

LEAD SCIENTIST

John Frank is an Electronics Engineer who studies atmosphere-biosphere interactions, soils, snowpack, and plant physiology. Connect with him at <https://www.fs.usda.gov/rmrs/people/jfrank>.

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