Supplemental file for: Canopy structure modulates the sensitivity of subalpine forest stands to interannual snowpack and precipitation variability

Max Berkelhammer[a], Gerald F Page[b,c], Frank Zurek[a], Christopher Still[c,d], Mariah S Carbone[e,d], William Talavera[a], Lauren Hildebrand[a], James Byron[a], Kyle Inthabandith[a], Angellica Kucinski[a], Melissa Carter[a], Kelsey Foss[a], Wendy Brown[d], Rosemary WH Carroll[f], Austin Simonpietri[e], Marshall Worsham[g], Ian Breckheimer[h,d], Anna Ryken[i], Reed Maxwell[j,k], David Gochis[l], Mark Raleigh[m], Eric Small[n], and Kenneth H Williams[o,d]

[a]Department of Earth and Environmental Sciences, University of Illinois Chicago, 845 W Taylor St. Chicago, IL 60607
[b]School of Environmental and Conservation Sciences, Murdoch University, 90 South St, Murdoch, Western Australia, 6150
[c]Forest Ecosystems and Society, Oregon State University, Corvallis, OR, 97331 USA
[d]Rocky Mountain Biological Laboratory, Crested Butte, CO
[e]Center for Ecosystem Science and Society, Northern Arizona University, Flagstaff, AZ, USA
[f]Division of Hydrologic Sciences, Desert Research Institute, Reno, NV
[g]Energy and Resources Group, University of California, Berkeley, CA, USA
[h]Western Colorado University, Gunnison, CO
[i]Hydrologic Science and Engineering, Colorado School of Mines, Golden, Colorado, USA
[j]High Meadows Environmental Institute, Princeton University, Princeton, NJ 08544, United States of America
[l]Research Applications Laboratory, National Center for Atmospheric Research, Boulder, Colorado, USA
[k]Department of Civil and Environmental Engineering, Princeton University, Princeton, NJ 08544, United States of America
[m]College of Earth, Ocean, and Atmospheric Sciences, Oregon State University, Corvallis, OR, 97331, USA
[n]Department of Geological Sciences, CU Boulder, Boulder CO
[o]Lawrence Berkeley National Laboratory, Berkeley, CA, USA

Correspondence: Max Berkelhammer (berkelha@uic.edu)

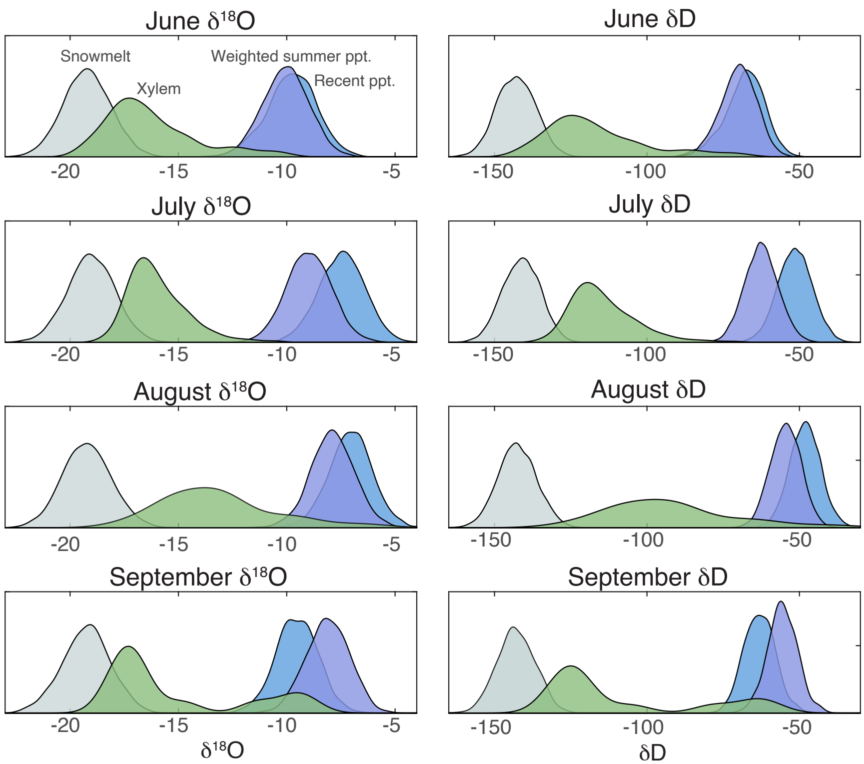

Figure S1. Distribution of the three isotopic end members across the different months of the growing season (top to bottom corresponds to June-September) and for the different isotopes (left is oxygen and right is deuterium). The green distribution captures the measured xylem water samples and where these values plot relative to the end members.

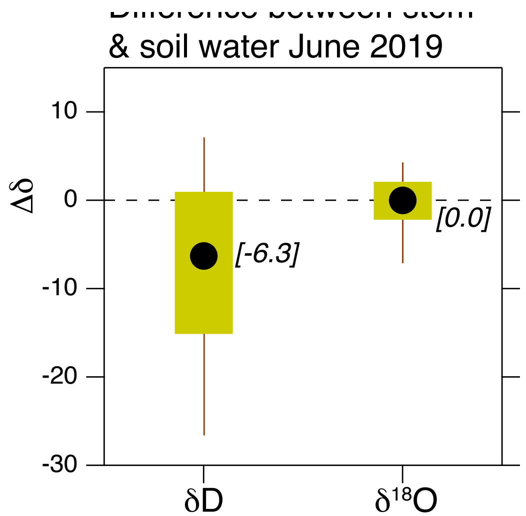

Figure S2. The difference (i.e. Δ) between the isotopic ratio of xylem water samples and coeval 10 cm soil water samples take in early June 2019 just following snowmelt from across the network of sites (Figure 1). The box and whisper plots capture the quartiles, 5th and 95th% of the measured offset between xylem and soil water. The left box and whisper plot shows the offset for deuterium and the right shows the same for oxygen-18. This result implies a small fractionation present in the deuterium of xylem waters that is not present for oxygen.

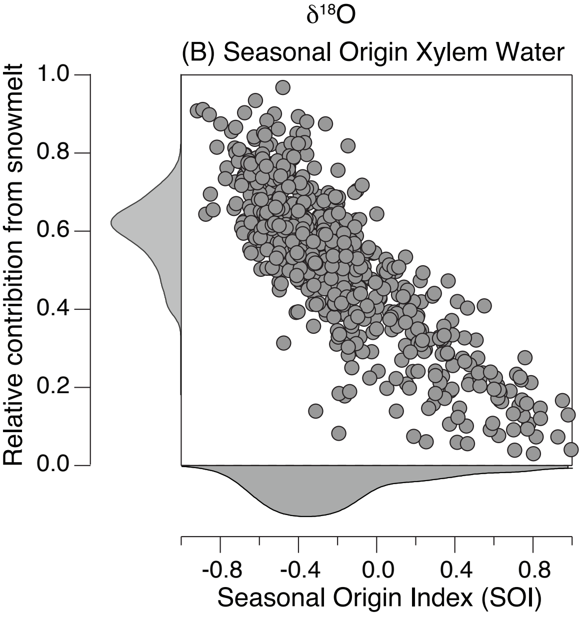

Figure S3. A comparison between all measured values for snowmelt reliance generated from the 3 end member mixing model (y-axis) and the Seasonal Origin Index (x-axis).

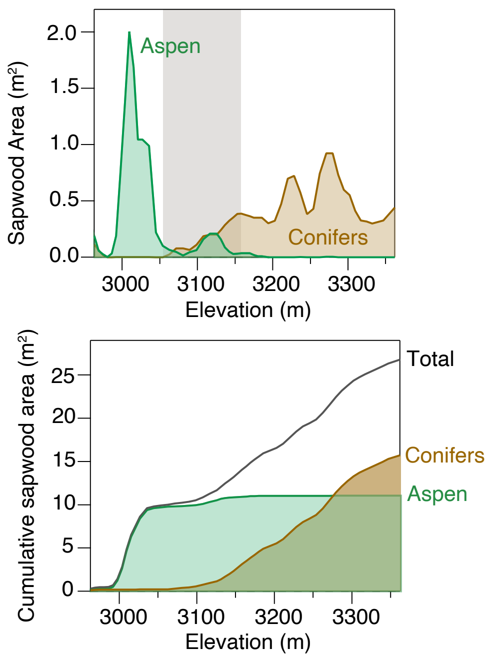

Figure S4. (Top) The distribution of sapwood area along a transect in 10 m increments connecting the lowermost to the uppermost sites in the network. Sapwood was estimated as described in the paper through estimating tree type (deciduous vs. coniferous) and height, then estimating DBH and finally the sapwood area. The results show the transition between aspen to conifer dominant forests with a small cross-over band around 3150 m. (Bottom) Cumulative sapwood area based on the top figure showing the overall higher coverage of conifer sapwood on the hillslope.

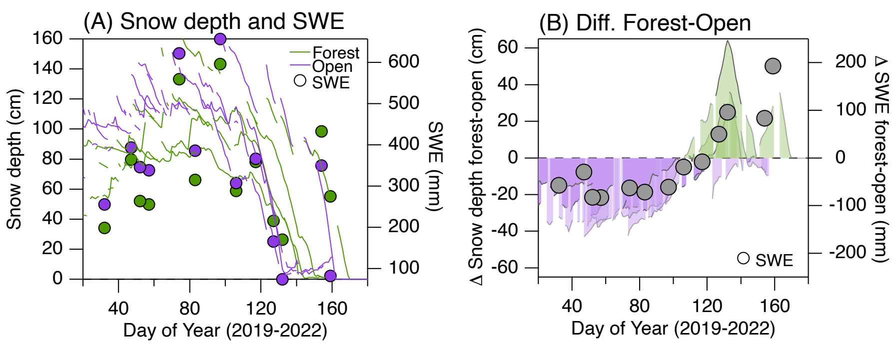

Figure S5. (A) Seasonal trends in snow depth (left axis) and SWE (right axis) derived from continuous snow depth sensors and periodic snow pit measurements for adjacent open and forested sites as indicted on the map in Figure 1. (B) The average difference in snow cover between the forest and open sites for both snow depth (left axis) and SWE (right axis). The results indicate that while the forest site had generally lower snow during the winter starting from day of year 120 to day 160, there is a persistently larger snow pack in the forested site.

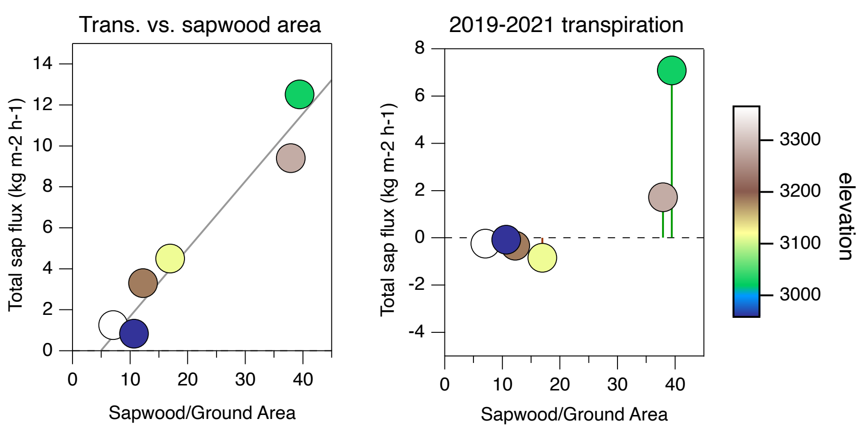

Figure S6. (Left) Total transpiration estimated for each site by multiplying the sap velocity by sapwood area vs. sapwood to ground area. There is a strong linear relationship indicating the strong control of stand density on transpiration rates. (B) The difference in 2019 and 2021 transpiration for these sites as a function of sapwood to ground area. As discussed in the paper this illustrates that stand density had a strong control over whether a site responded positively or negatively to the large snowpack year of 2019. The negative response of the open sites has a much smaller amplitude than the positive responses in the dense sites owing to the much high overall transpiration rates in the dense stands.

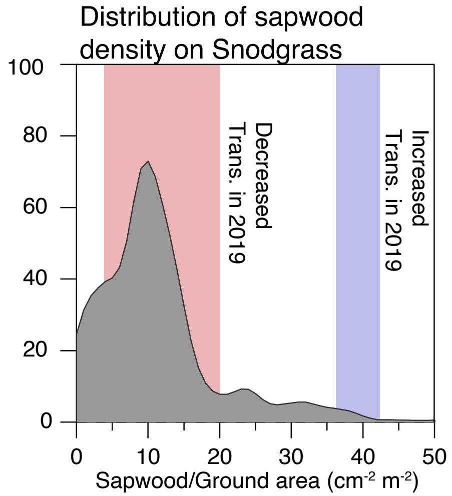

Figure S7. Distribution of sapwood density along the transect of sites in Figure 1. Based on the range of stand densities captured by the site network we identify how most of the hillslope was similar to the open sites and would have responded negatively to 2019 vs. 2021/2022. The dense sites capture the outer range of stand densities for this hillslope.