

Background

Despite its importance for understanding snow-forest interactions, measuring snow interception is challenging. Consequently, most snow models use parametrizations based on a small number of observations from two locations (Lundquist et al. 2021).

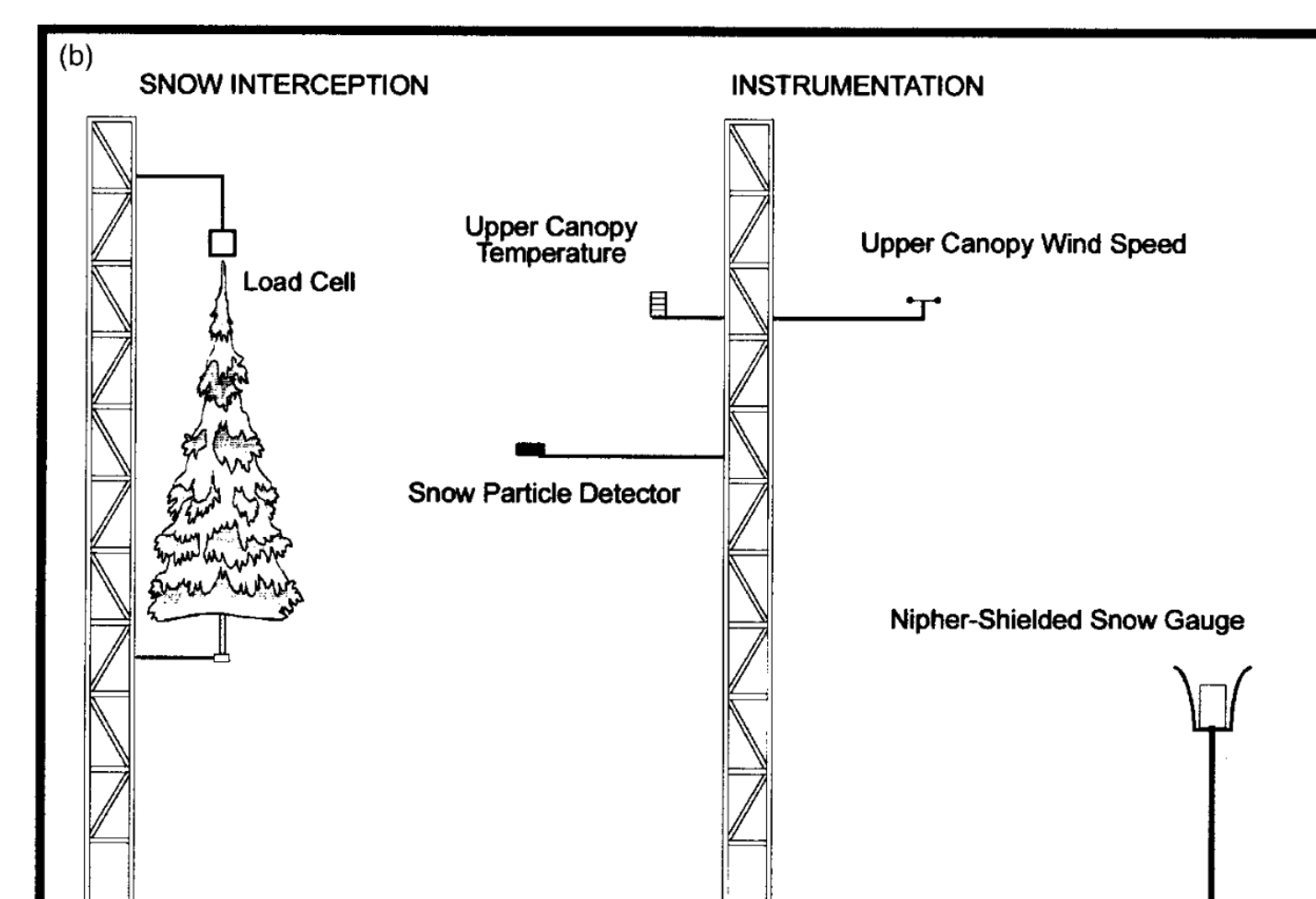


Figure 1: Common method for measuring snow interception; figure adapted from Hedstrom and Pomeroy (1998).

Measurements of tree sway offer a new approach for estimate changes in canopy mass. By modeling a tree as a cantilever beam and controlling for thermal effects, changes in tree sway frequency can be related to changes in tree mass, enabling quantification of snow interception (Raleigh et al. 2022).

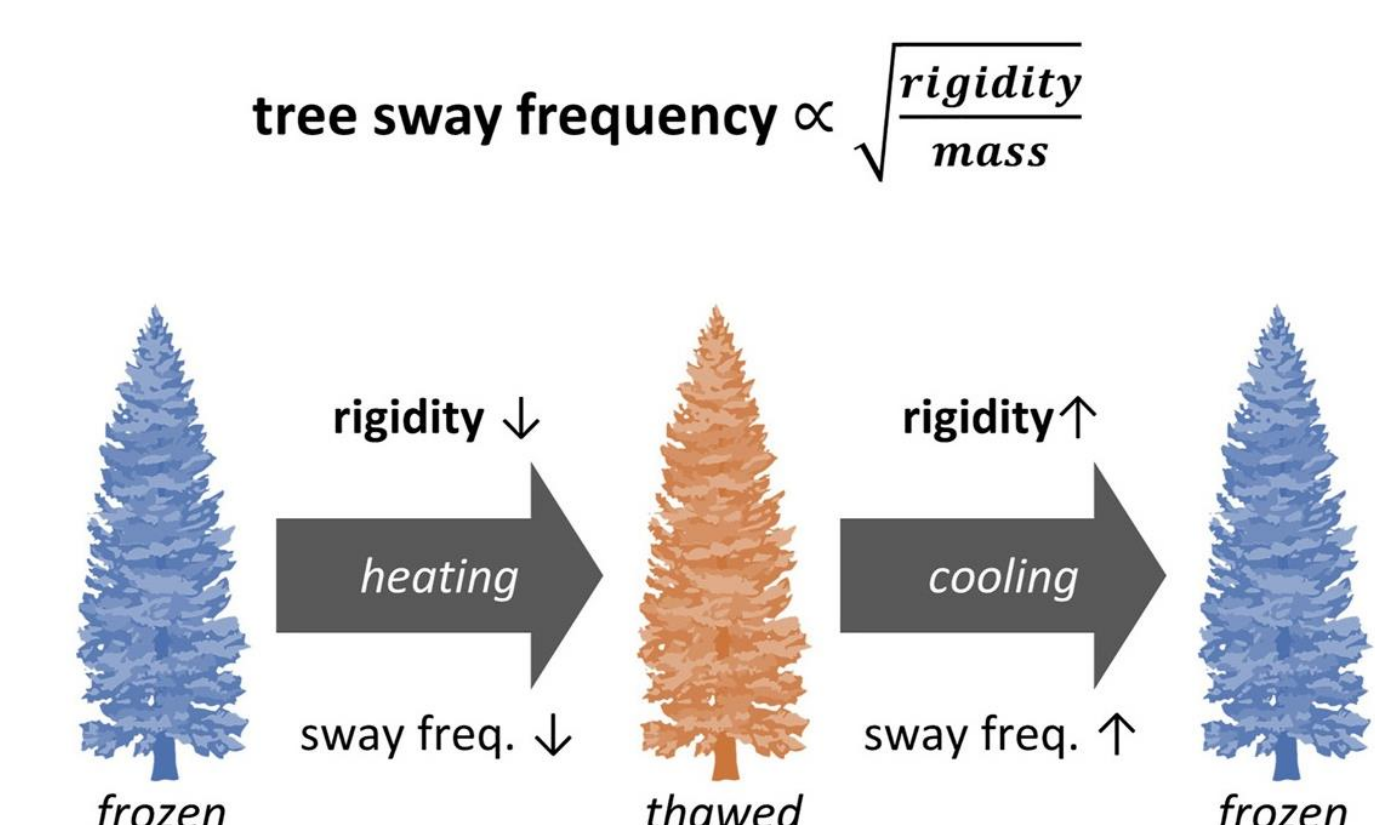
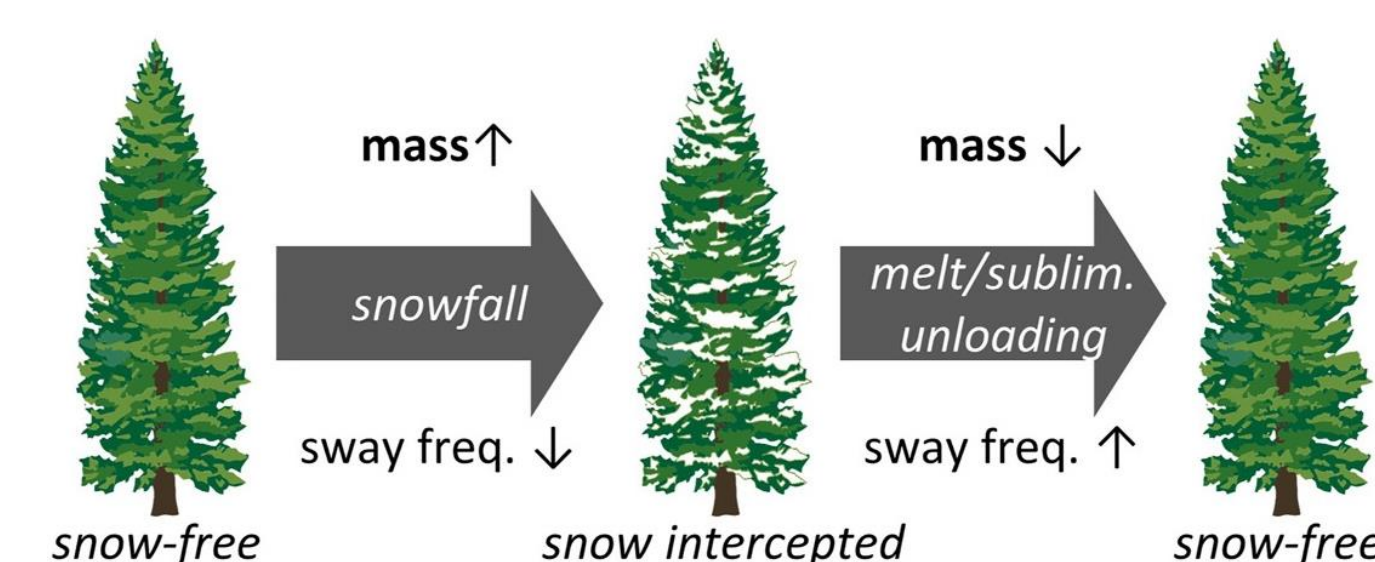


Figure 2: Relationship between tree sway and mass (top) and tree sway and temperature (bottom); adapted from Raleigh et al. (2022).

However, existing point methods for measuring tree sway are difficult to scale, limiting the number of observations that can be collected.

Video processing provides a scalable, cost-effective, and non-invasive method for measuring tree sway frequency, posing to improve the spatial scalability of snow interception measurements at the branch, tree, and stand scales.

Methods: from video to vibration

Videos encode changes in brightness across space and time, effectively providing an array of motion sensors. The sway frequency of a pixel can be computed by finding the peak of the pixel brightness power spectrum.

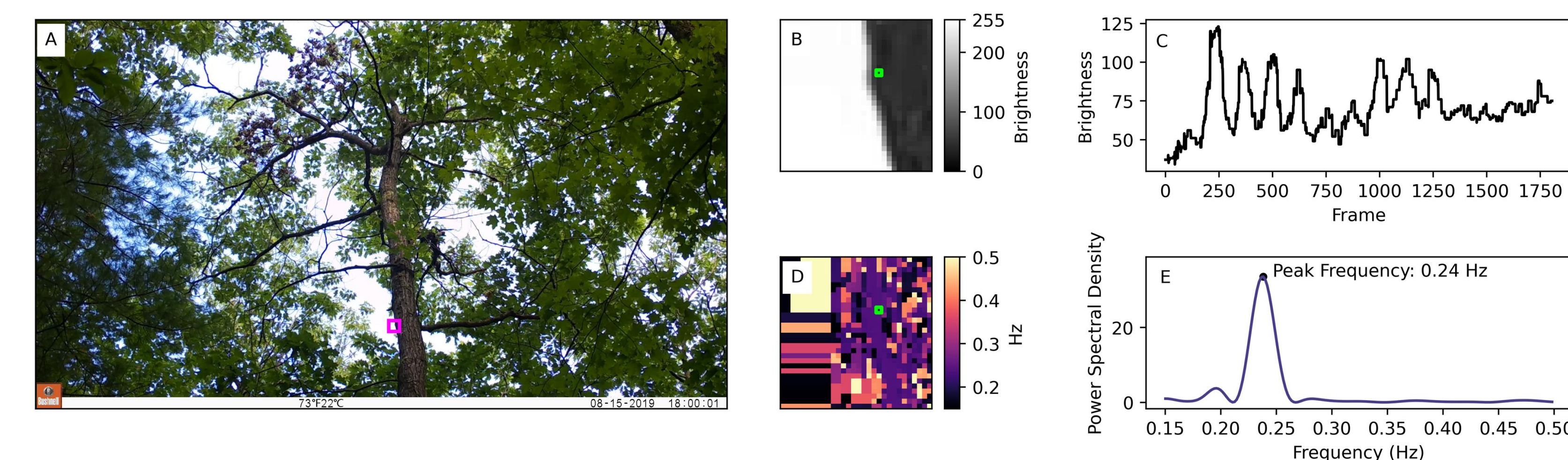


Figure 3: Video vibration signals in the time (B, C) and frequency (D, E) domains for an oak tree in Trout Lake, Wisconsin. B and D correspond with the pink ROI in A. C and E correspond to the green sample pixel in B and D.

Once the frequency of each pixel has been found:

- Can aggregate frequencies across a region of interest (ROI) to output a single frequency
- Can build a sway frequency heat map to evaluate frequency across space

Results: ±0.03 Hz accuracy compared to accelerometers

- Video processing had ±0.03 Hz accuracy based on comparisons of video and accelerometer sway data for 4 trees using twelve 30-60s videos

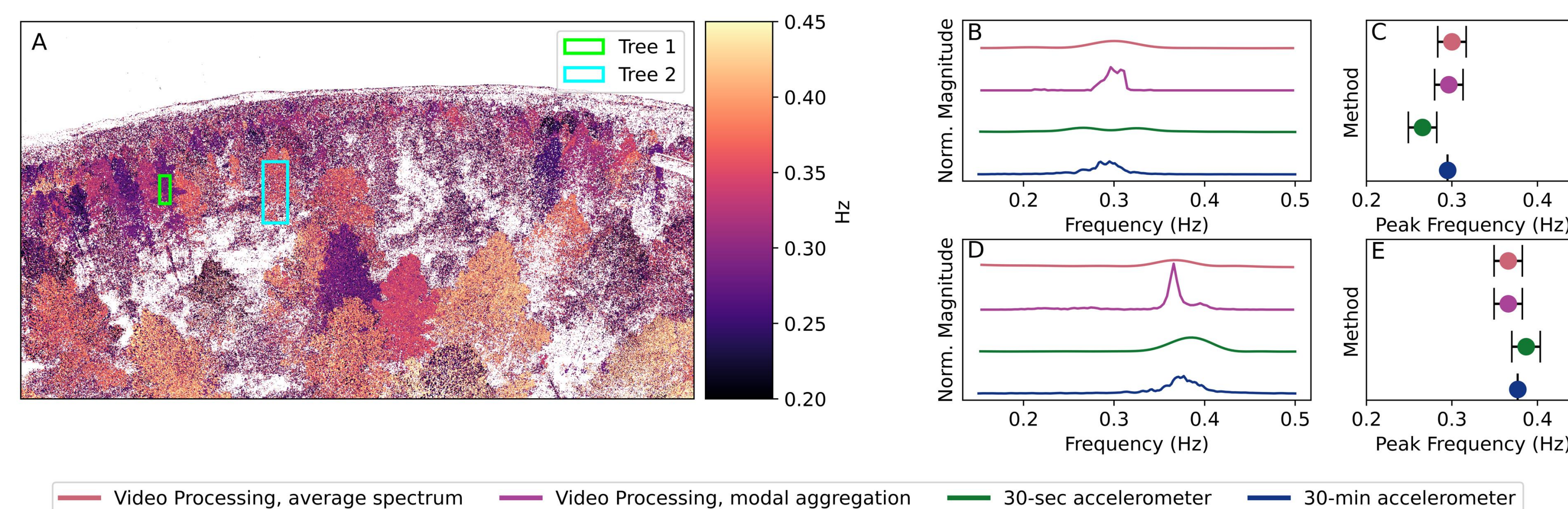


Figure 4: (A) Sway frequency heat map for a stand of trees at the Manitou Experimental Forest in Colorado. (B, C) Spectra and peak frequencies for Tree 1. (D, E) Spectra and peak frequencies for Tree 2.

Application: change in sway across snow unloading event

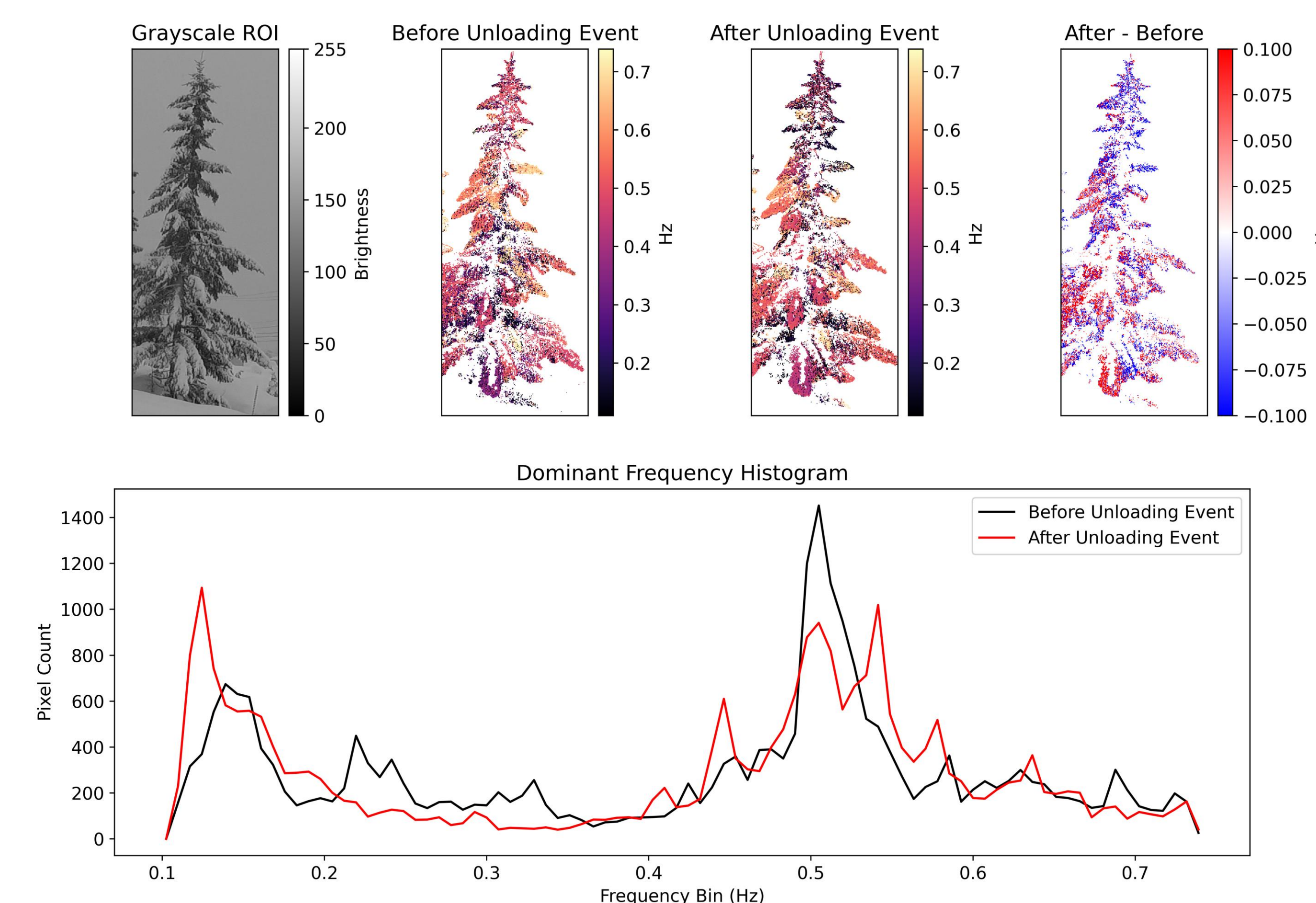


Figure 5: (Top, left to right) Target tree on Snoqualmie Pass in Washington, frequency heat map before unloading, frequency heat map after unloading, and pixel-wise change in frequency. (Bottom) Pixel frequency distribution before and after snow unloading event

- Video processing resolved changes in sway due to changes in canopy mass
- Changes in sway close to video-to-video sway variability; need longer videos for better signal-to-noise ratio (SNR)
- Branches have different responses, a surprising result that highlights the spatial benefit of using video processing

Limitations and deployment considerations

1. Long videos (2-10 min.) needed for strong SNR and sufficiently small frequency resolution → large memory burden
2. Works best on tall, slender trees whose trunk sway dominates branch sway
3. Can only measure sway during daylight hours
4. Vibration signals are sensitive to camera motion and changes in lighting
5. Video vibration signals tend to be noisy; can be difficult to disentangle branch and trunk sway signals

References

Hedstrom, N.R. and Pomeroy, J.W. (1998). Measurements and modelling of snow interception in the boreal forest. *Hydrol. Process.*, 12: 1611-1625. [https://doi.org/10.1002/\(SICI\)1099-1085\(199808/09\)12:10<1611::AID-HYP684>3.0.CO;2-4](https://doi.org/10.1002/(SICI)1099-1085(199808/09)12:10<1611::AID-HYP684>3.0.CO;2-4)
 Lundquist, J. D., Dickinson-Lange, S., Gutmann, E., James, T., Lumbruso, C., & Reynolds, D. (2021). Snow interception modeling: Isolated observations have led to many land surface models lacking appropriate temperature sensitivities. *Hydrological Processes*, 35(17), e14274. <https://doi.org/10.1002/hyp.14274>
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Acknowledgements: Joseph Ammatelli and Jessica Lundquist received funding support from NASA Grant NN177AL59G. Joseph received additional funding from the Desert Research Institute. For Ethan Gutmann, this material is based upon work supported by the National Center for Atmospheric Research, which is a major facility sponsored by the National Science Foundation under Cooperative Agreement No. 1852077. Holly Barnard and Sidney Bush received funding support from the National Science Foundation (NSF 2012559) and the University of Colorado – Boulder Research and Innovation Office. Contributions from Dominick Ciruzzi and Steven Loheide II were sponsored by the National Science Foundation Division of Earth Sciences (NSF EAR-1700983). Mark Raleigh was supported by the National Science Foundation (NSF EAR Award 1761441).