Influence of bushfire on Australian snowpack processes within Snow Gum forests

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1. Motivation

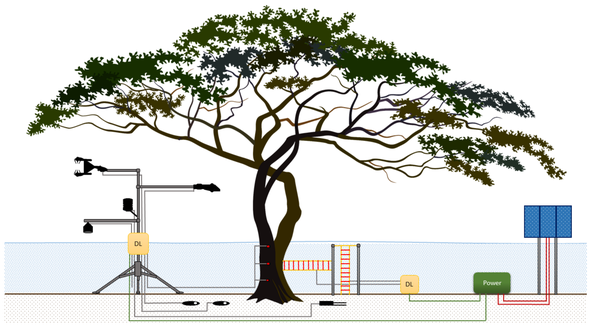
Increasing understanding of snowpack energy fluxes and thermodynamics will become more important as montane and boreal snowpacks develop marginal characteristics due to climate change[1].

Despite knowledge on the effects of forest stands on spatiotemporal patterns of snow depth and snow water equivalent, snowpack energy fluxes, and melt/ablation characteristics, the effects of bushfire on snowpack processes through forest disturbance has yet to be examined.

The aim of this work is to identify relationships between *Eucalyptus pauciflora* (Snow Gum) forests, the snowpacks contained within them, and changes to snowpack properties after bushfire disturbance. These relationships can serve as a proxy for future snowpacks in other regions that will develop the same marginal characteristics as the Australian snowpack due to climate change.

2. Methods

Thirty-minute measurements were obtained from snowpacks in an unforested area, an undisturbed *E. pauciflora* stand and a fire-disturbed *E. pauciflora* stand in Kosciuszko National Park, New South Wales, Australia from 1 June 2018 to 1 October 2019.



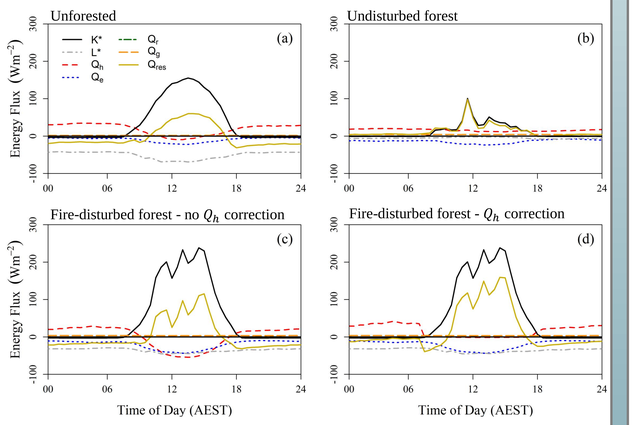
Snowpack Energy Fluxes: Sensible heat (Q_h), latent heat (Q_e), shortwave (K^*) and longwave radiation (L^*), and soil heat (Q_g) and rain (Q_r) heat flux were collected via eddy covariance towers.

Snowpack Temperature: Ten 100cm thermocouple ladders with measurements every 10cm were installed horizontally and vertically at each site. Horizontal ladders were attached to tree trunks on each side (North, South, East, West) and vertical ladders had the first measurement at 10cm AGL.

Snowpack Depth: Automated snowpack depth measurements were recorded every 30-minutes. Manual measurements of snowpack depth and density were taken during a 7 week field program in 2018.

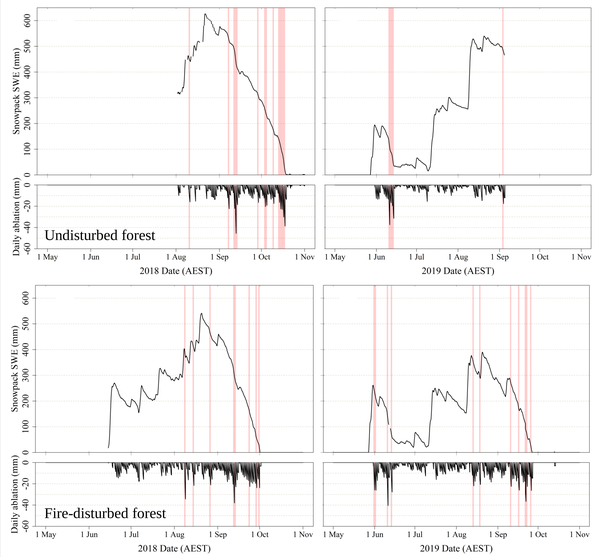
Tree Trunk Temperature: Three thermocouples were placed in tree trunks at 33cm, 66cm, and 99cm at each site.

3. Snowpack Energy Budget



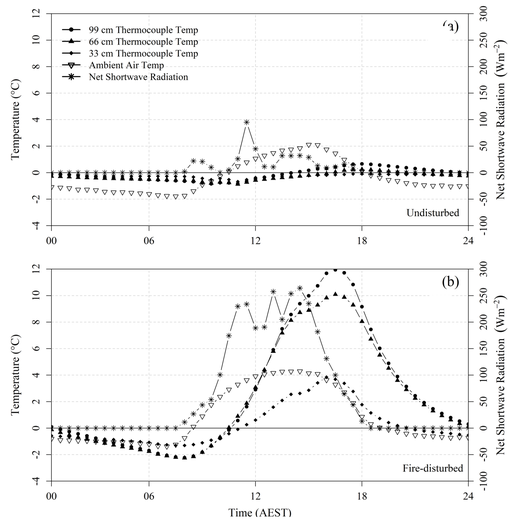
- Decaying tree stem debris increased snowpack albedo contributing to 347% more shortwave radiation at the fire-disturbed site (d).
- Canopy removal increased evaporation of snowpack by ~2%, resulting in reduced runoff.
- 21% of measured Q_h at the fire-disturbed forest was emitted by tree stems (c) and correction was needed (d) to accurately represent snowpack energy balance.

4. Accumulation and Ablation



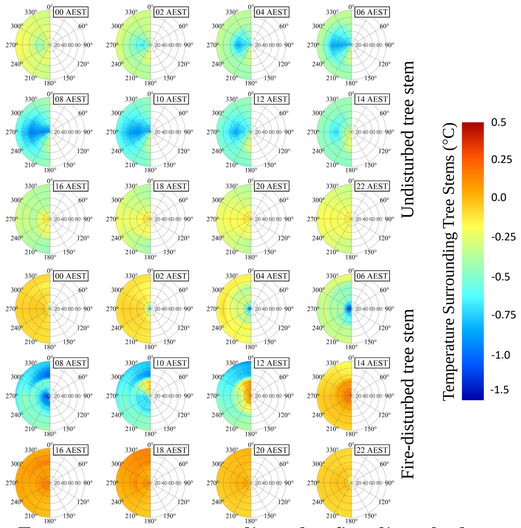
- Less snow accumulation (due to wind scour) and more high melt periods (highlighted red) occurs in fire-disturbed forests.
- Snowpack longevity is reduced after fire disturbance.

5. Stem Temperatures



- Average daily tree stem temperatures exceed air temperatures by an average of +5.33°C.
- Tree stem temperatures were governed by increased shortwave radiation from canopy loss and led to more melt around stems (tree wells) in the fire-disturbed stand

6. Snowpack Temperatures

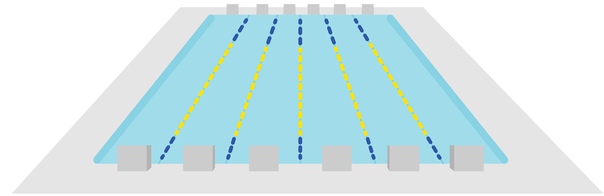


- Temperatures surrounding the fire-disturbed tree stem were an average of +0.18°C higher than those at the undisturbed forest stand.
- Higher variation in daily temperature patterns occurred at the fire-disturbed forest stand as greater intrusion of air occurred due to increased tree well development.

7. Effects on water resources

When the results of this study are applied to the areas burned in the 2019-2020 Black Summer Fires, a reduction of 26 GL (1%) per year of water occurs at the Murray Darling Basin (MDB) headwaters.

To put that in context, an Olympic swimming pool holds 2.5 ML of water. So, **an equivalent of 10,400 Olympic swimming pools of water will potentially be lost from MDB headwaters inflows as a result of the 2019-2020 bushfires** and their impact on snowpack.



10,400 Olympic swimming pools of water lost annually

8. Summary

- Removal of forest canopy by bushfire led to significant alteration of the snowpack contained in fire-disturbed forests. The primary changes are three-fold:
  1. Increased shortwave radiation and decreased snowpack albedo led to higher melt rates.
  2. Increased turbulent fluxes (Q_h & Q_e) caused increased evaporation of snowpack.
  3. Increased wind speeds led to reductions in snow accumulation and, hence, reduced snowpack longevity.
- The tree stem-snowpack interface is responsible for governing surrounding snowpack temperature. Bushfire results in an increase to temperature average and variation. This results in a snowpack that is more sensitive to changes in energy balance and is more likely to melt.
- Increased melt energy, reductions to depth and longevity, and increased sensitivity to meteorological changes result in significant declines in potential snowpack inflows in southeast Australia.

References

[1] Pachauri, R.K., et al., *Climate change 2014: synthesis report. Contribution of Working Groups I, II and III to the fifth assessment report of the Intergovernmental Panel on Climate Change*. 2014: IPCC.

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