Bark Beetle Infestations: Impacts to Water and Energy Processes in Forests

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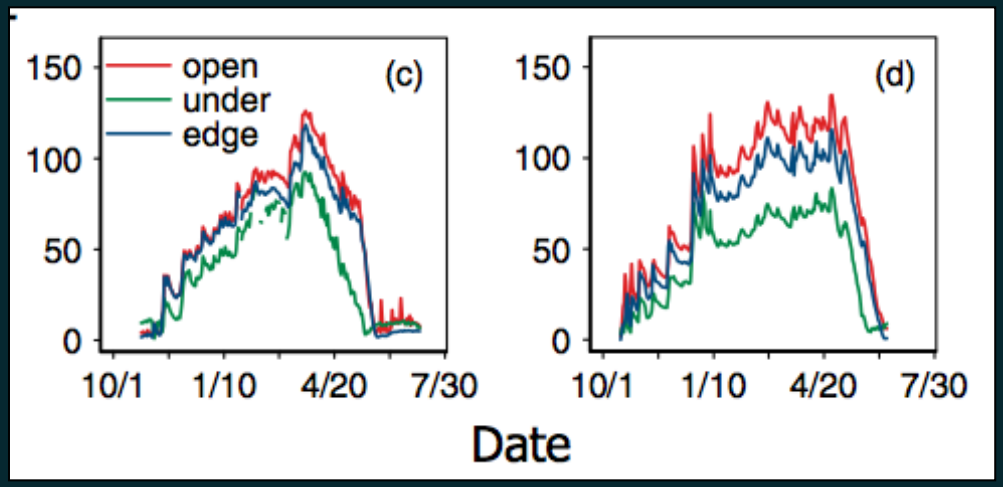
Forests are "sheltering" environments

- Less snow accumulates under trees than in clearings or edges
  - Interception
  - Sublimation
- Melt rates are faster in clearings and edges
  - More solar radiation
  - Faster wind speed



Molotch et al., 2009, *Ecohydrology*

Beetle infestations reduce sheltering effects

Living

Red/Grey Phase Dead

Courtesy Evan Pugh

Sheltering affects water and energy budgets

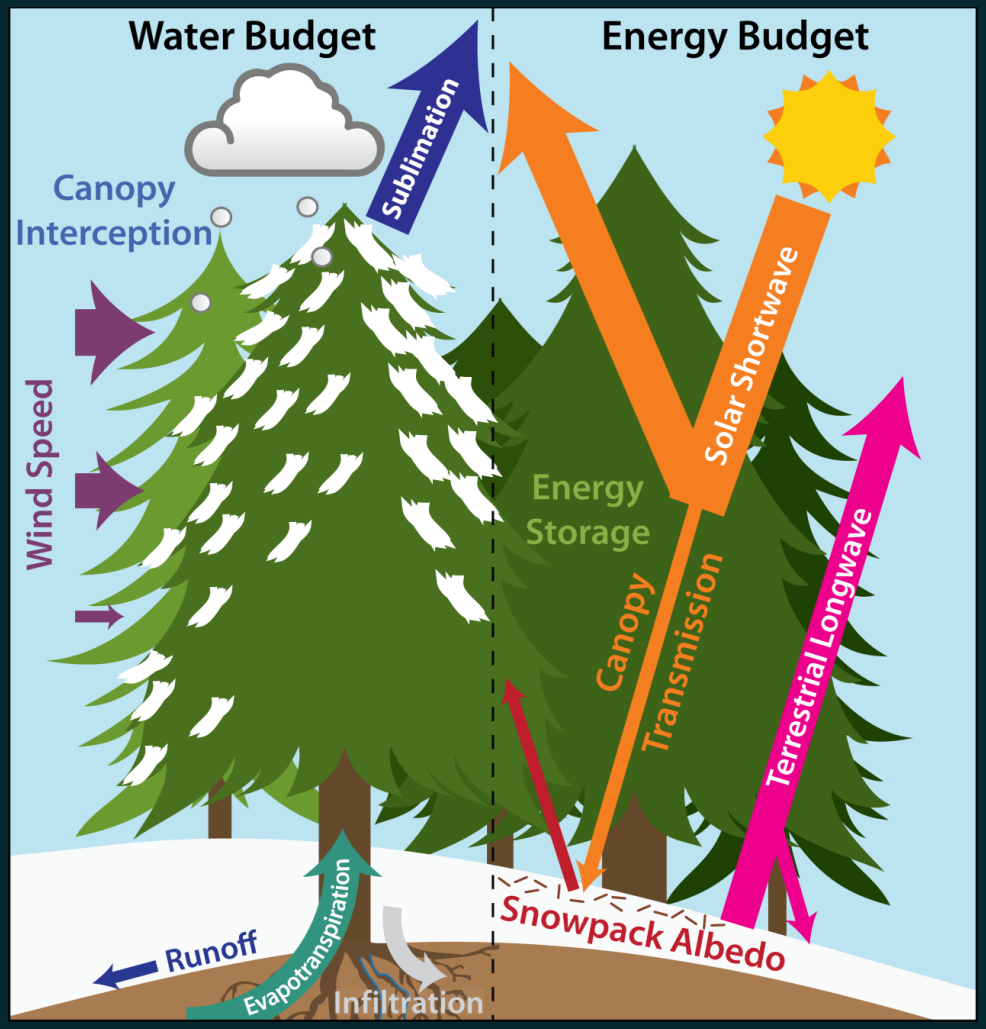
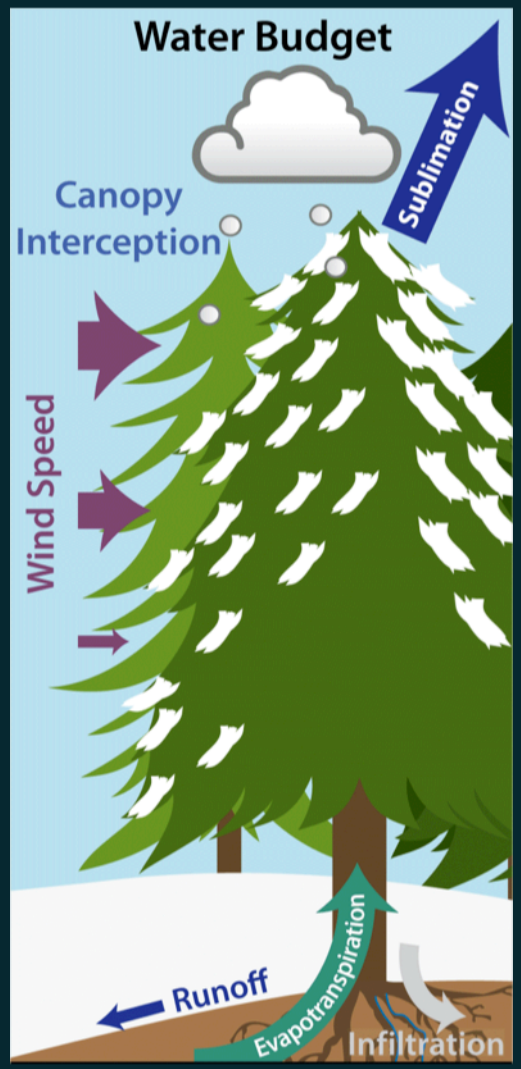
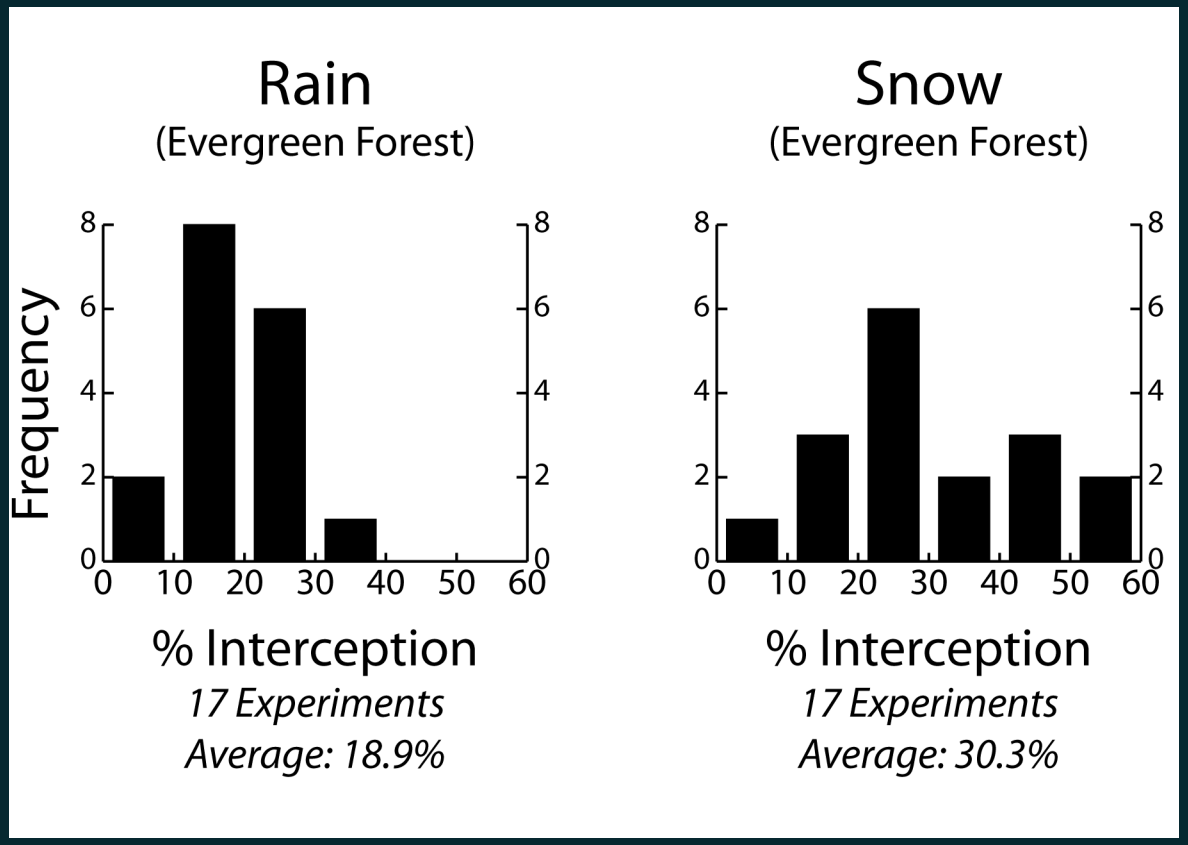


Image: Pugh E.T. and Gordon E.S. (2012), A conceptual model of water yield effects from beetle-induced tree death in snow-dominated lodgepole pine forests, *Hydrological Processes*. doi: 10.1002/hyp.9312

Water balance in snow-dominated forests



Canopy interception controls the input of water to the forest system

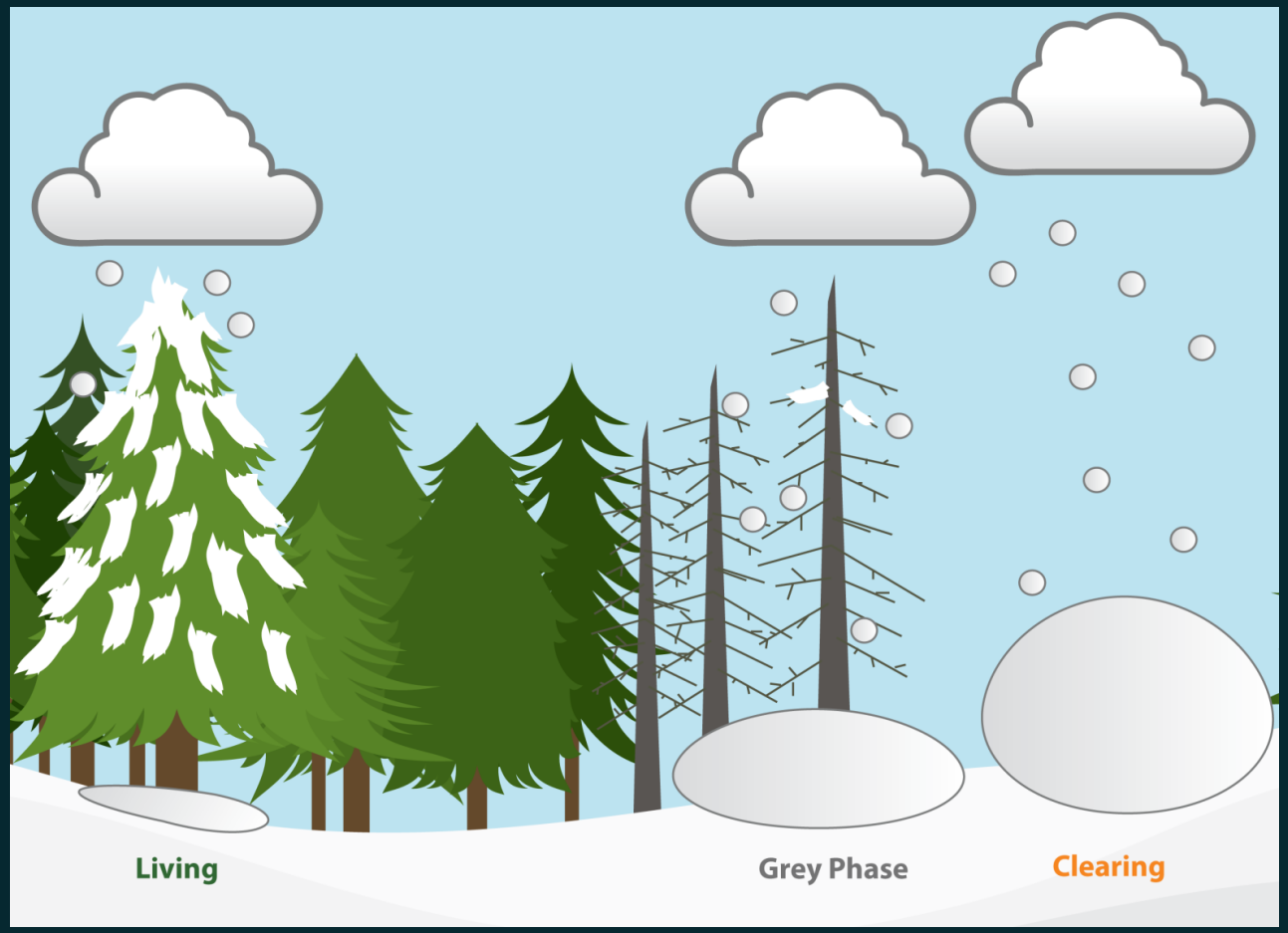


Courtesy Evan Pugh

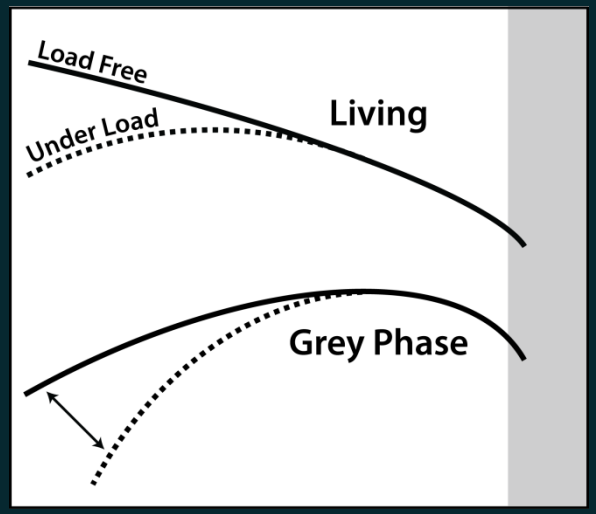
- Lots of variation due to stand species, age, climate, etc…
- More snow than rain is caught in conifer canopies
- Important process because more evaporation occurs from the canopy than the ground

Canopy snow interception

~20% more snow accumulation under dead pine stands (from numerous snow/beetle studies)

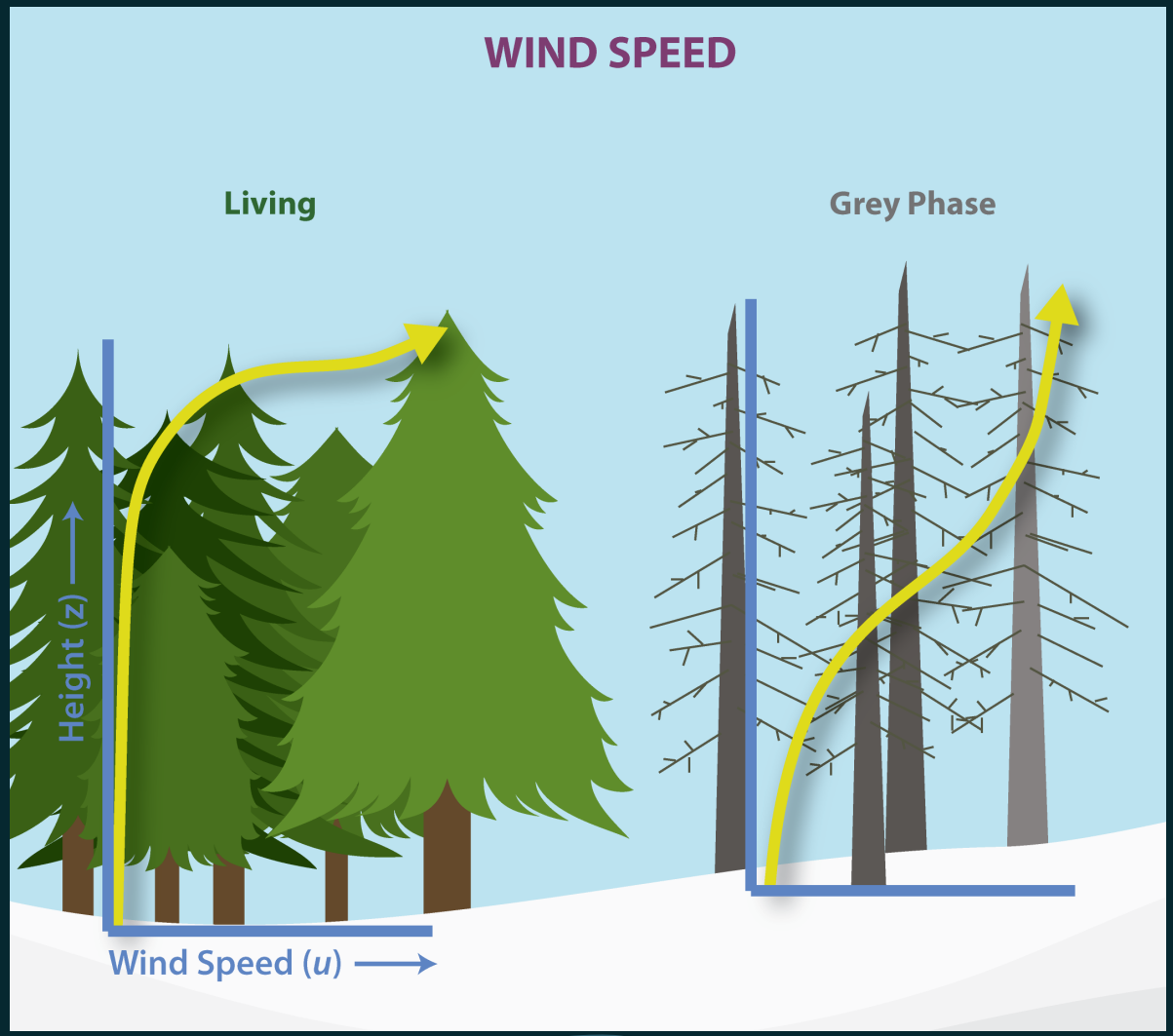


Snow bridging is reduced in dead forests

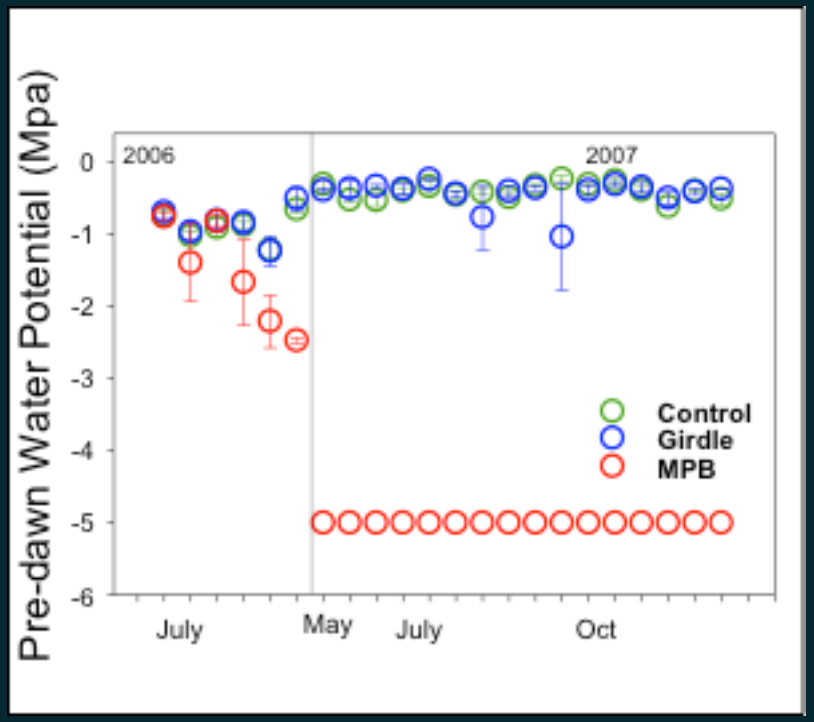


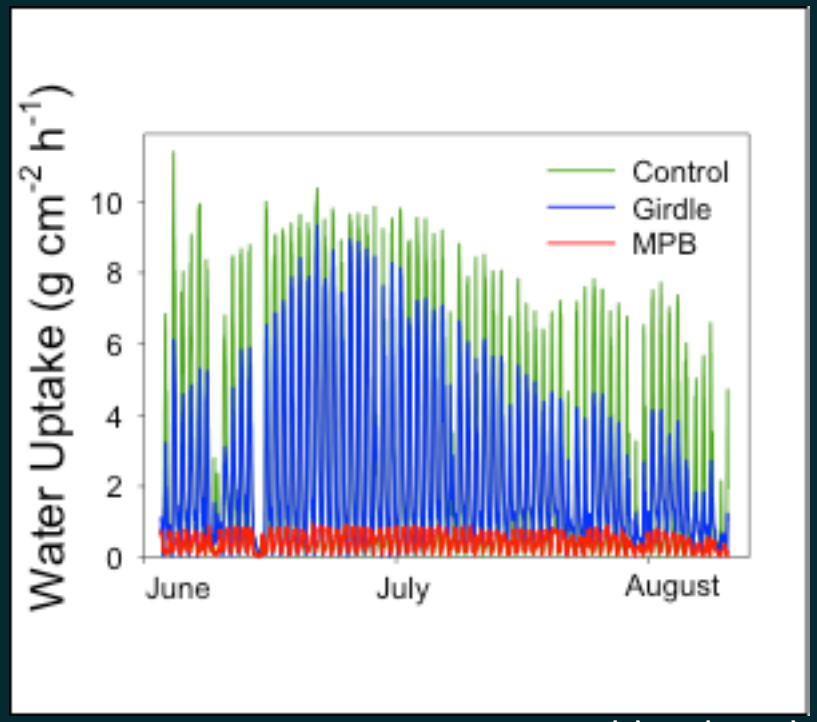
Canopy snow sublimation

More sublimation of intercepted snow in thinner canopies



Change in tree water use (pine)

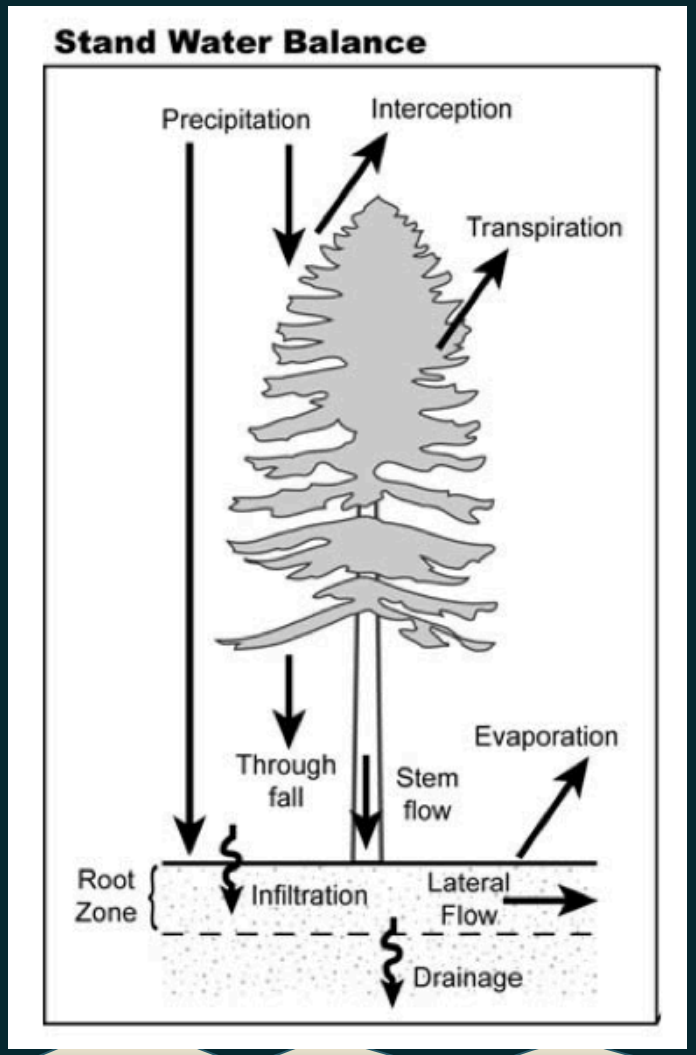




Hubbard et al.

- Transpiration drops ~50% within 3 weeks of beetle attack
- Water status of girdled trees unchanged – continued growing for 1 year after attack

Water balance changes due to beetle infestation



Needles Falling

↓ tree water use

↓ transpiration

faster melt

Needles Gone

↓ interception

↓ sublimation

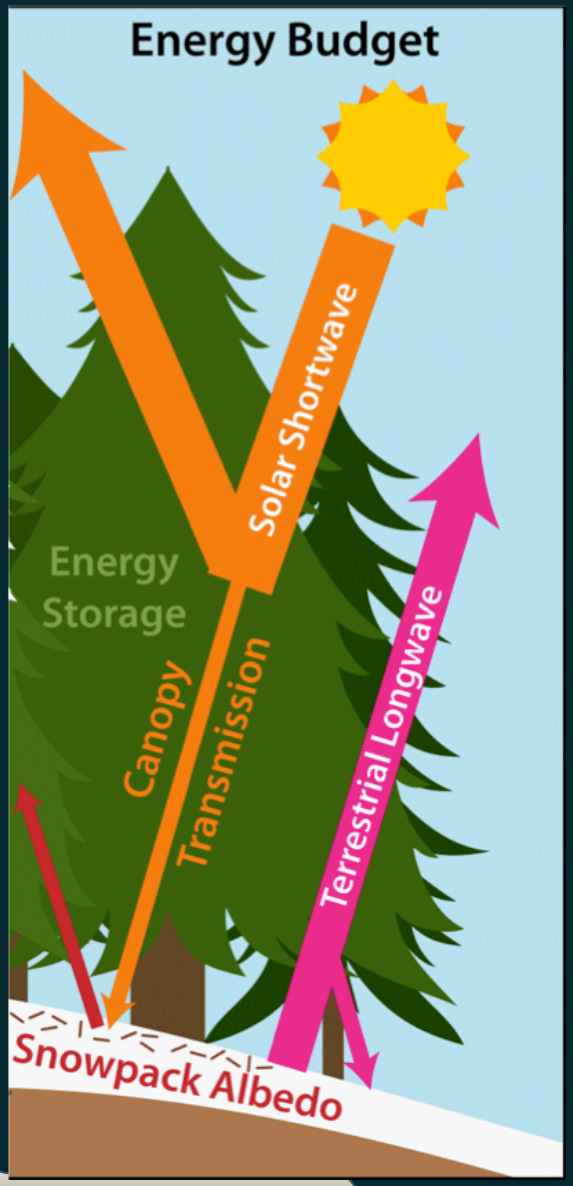
↑ accumulation

faster melt

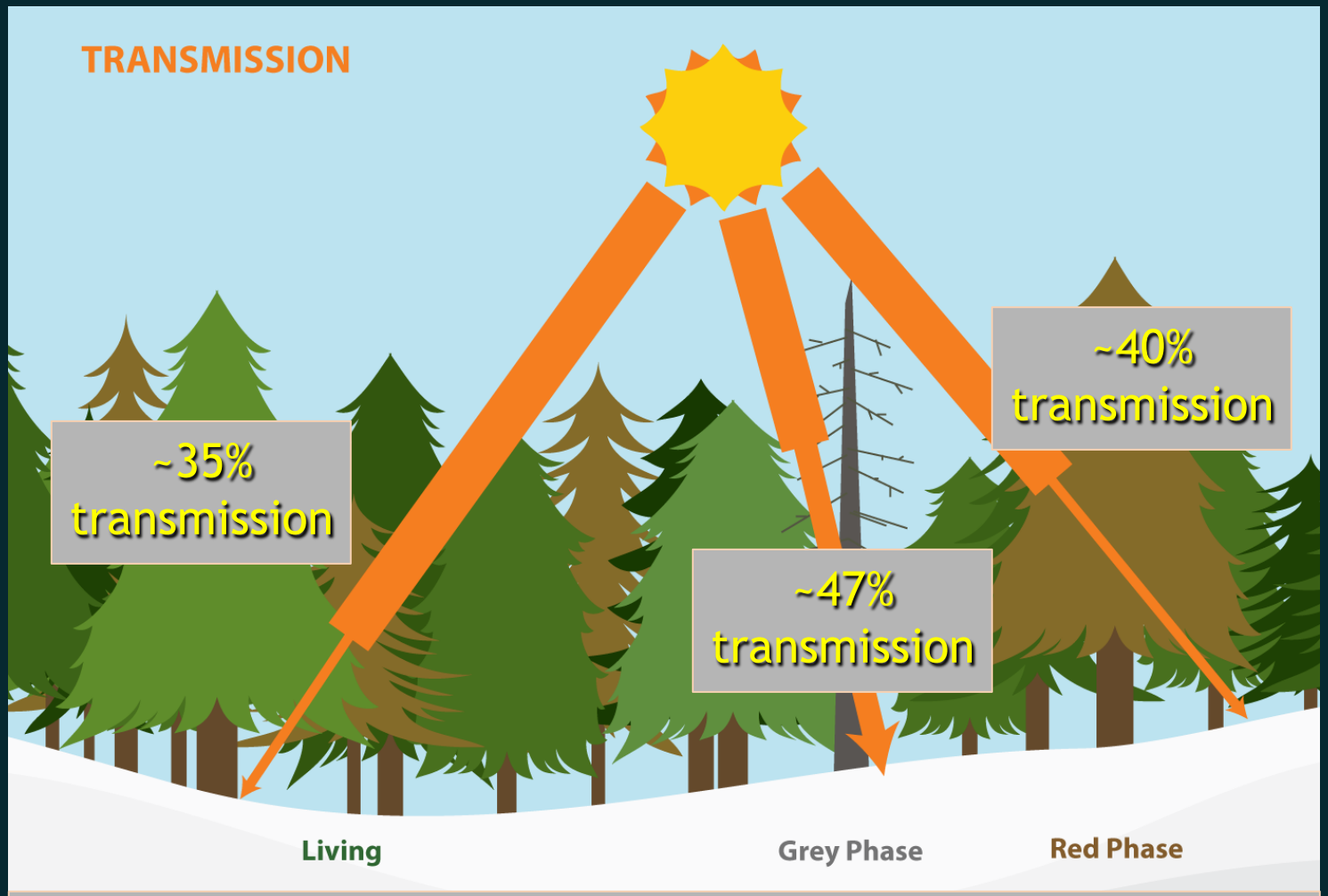
↓ transpiration

↓ tree water use

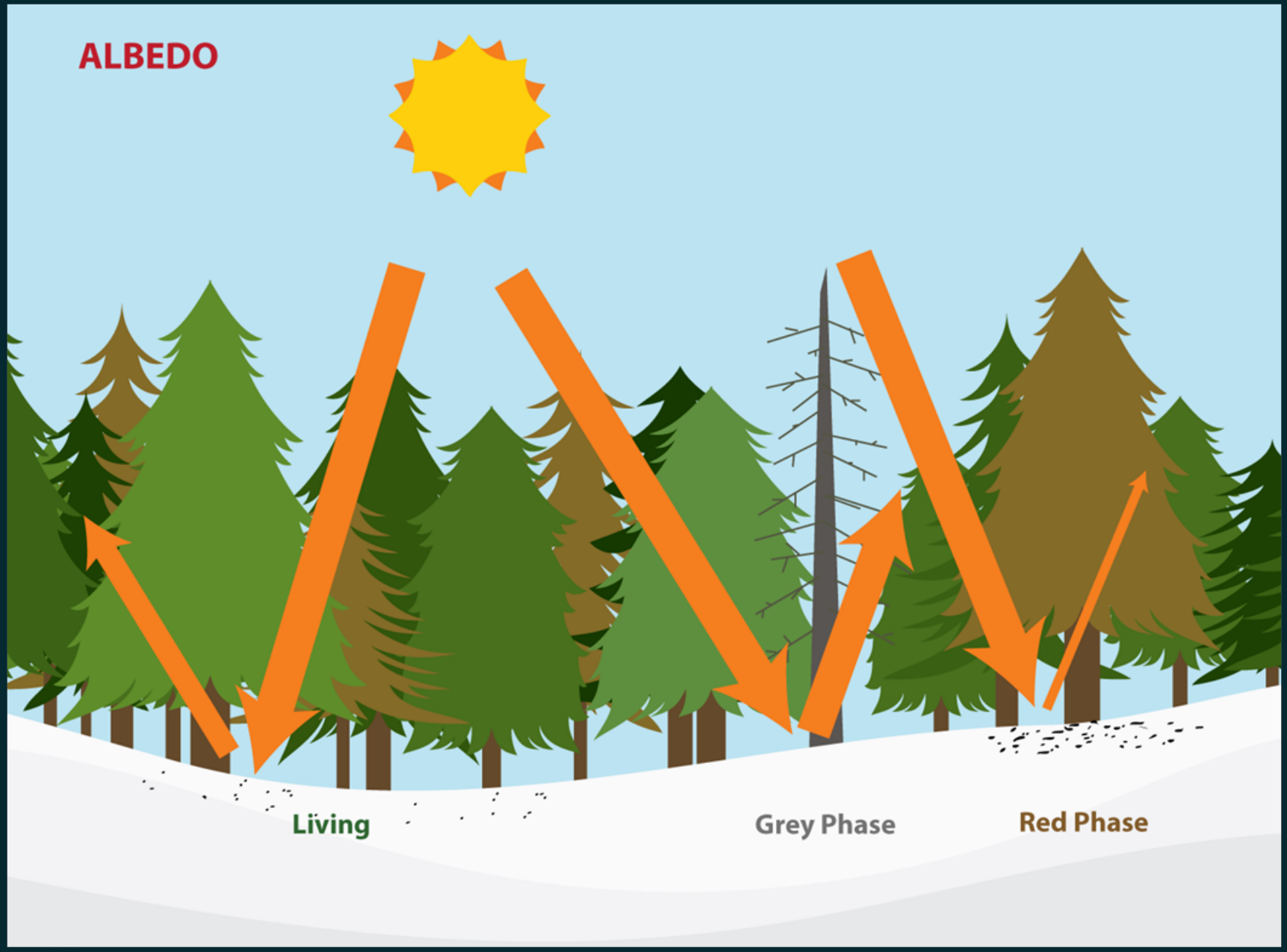
Energy balance in snow-dominated forests



Canopy Solar Transmission

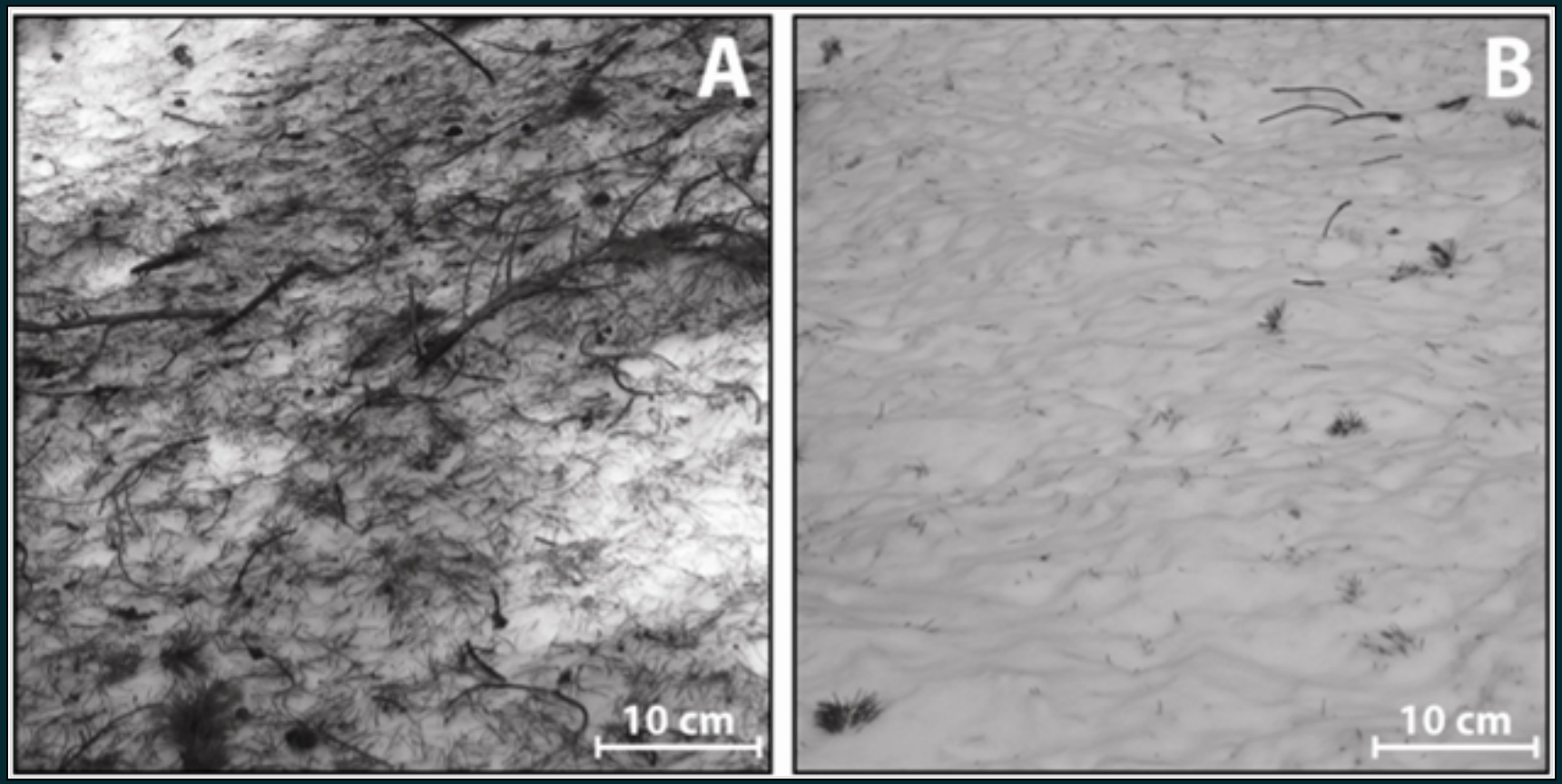


Thinned canopies let in more light!
Can expect: faster snowmelt, warmer ground


ALBEDO
Living
Grey Phase
Red Phase

Litter can strongly affect albedo

↓ albedo + ↑ solar is a powerful melt forcing



Pugh and Small, 2011, *Ecohydrology*

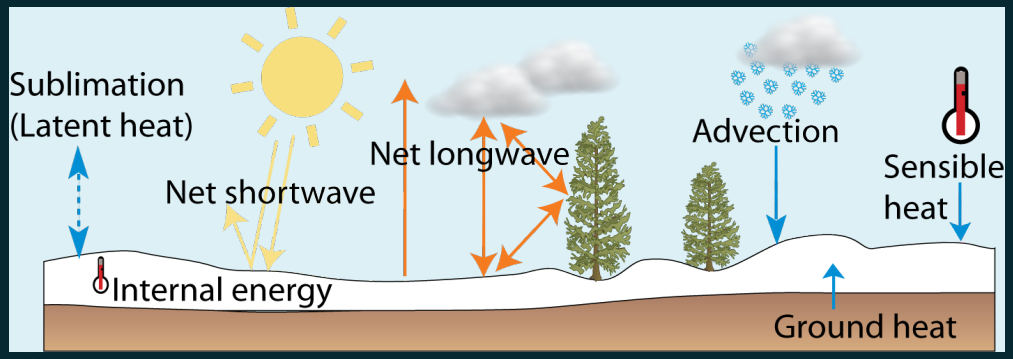
Summary: Snow Energy Balance Changes Due to Beetle Infestation

Needles Falling

- ↓ snow albedo
- ↑ solar transmission
- ↑ net solar input
- ↓ longwave

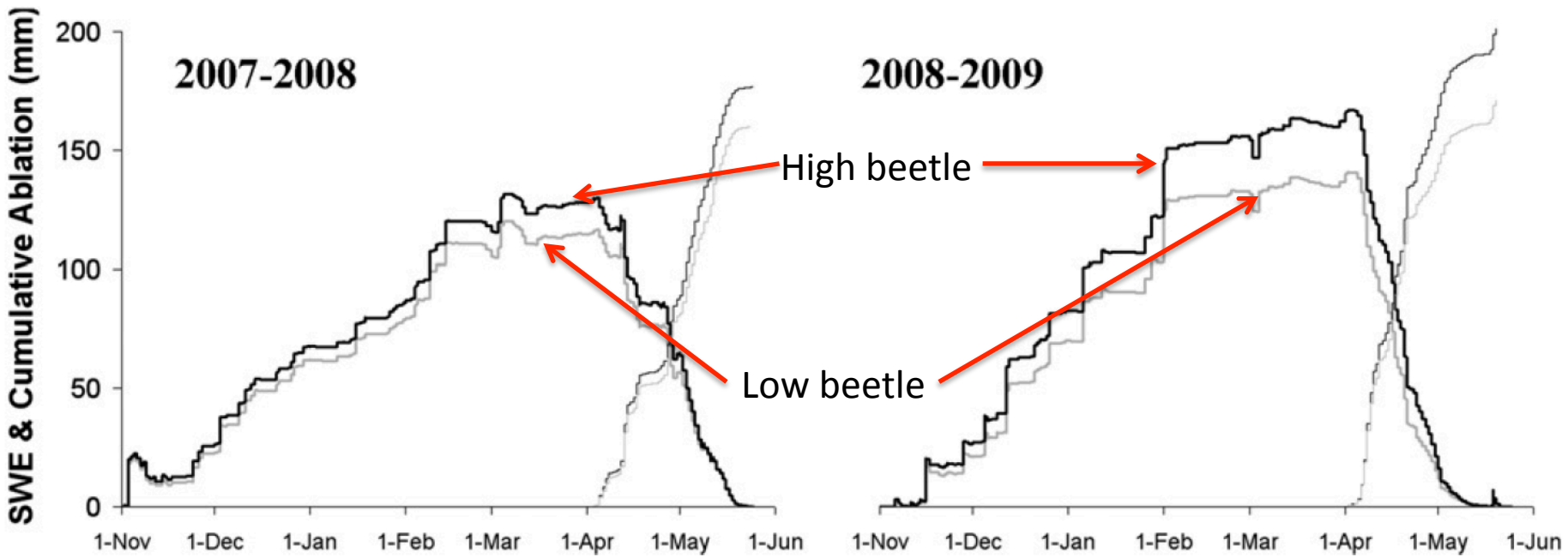
Needles Gone

- ↔ snow albedo
- ↑ solar transmission
- ↑ net solar input
- ↓ longwave
- ↑ wind speed
  - ↑ sensible gain & latent loss



Net changes in water & energy budgets

↑ SWE, ↑ melt rates with reduced canopy



Bewley et al., 2010

Conclusions from Lodgepole Pine

- Dead (grey phase) stands intercept less snow, leading to additional subcanopy accumulation (~20%)
- Grey phase forests transmit more solar radiation to the forest floor than either living or red phase
- Snow under grey phase stands may or may not be depleted more quickly than living stands – depends on snow year
- Addition of litter decreases albedo and speeds snowmelt
- Balance of impacts affected by stand, basin, meteorology

Scale

Study findings at the stand scale…

Scale

…may not be representative of watershed scale hydrology (alpine zones, meadows, etc)