How Will Forests Affect Mountain Snow Storage in a Warming Climate?

Susan Dickerson-Lange
susan@naturaldes.com
Natural Systems Design

Collaborators:

Rolf Gersonde – Seattle Public Utilities
Timothy Link – University of Idaho
Jessica Lundquist – University of Washington
Anne Nolin – Oregon State University
Mark Raleigh – University of Colorado
Julie Vano – UCAR, Boulder, Colorado

Funding:

Northwest Climate Science Center (Dept of Interior)

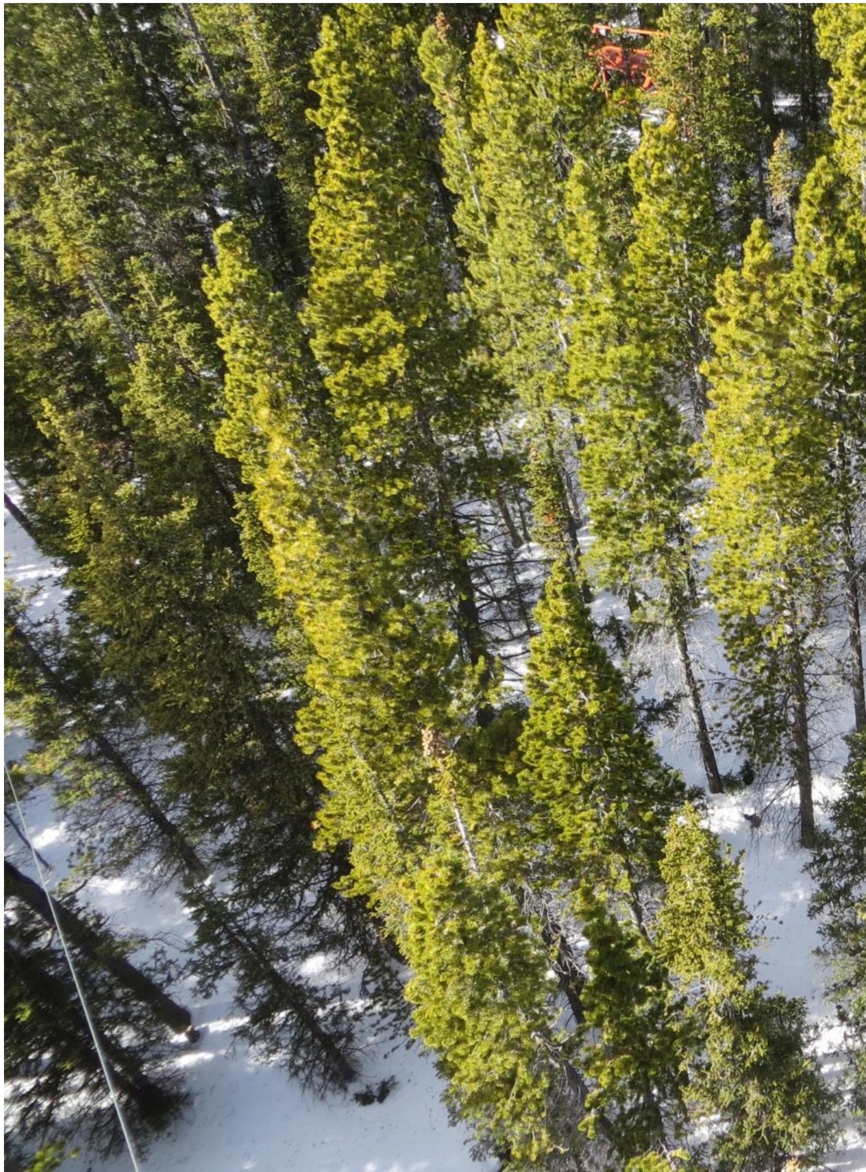
Overview

Motivation: Climate Change and Forest Change

Background: Forest-Snow Processes

Research: Snow Storage across the PNW

Application: Decision Tree and Examples



Conclusions

Motivation: Climate Change and Forest Change

Combined effects on snow important

Background: Forest-Snow Processes

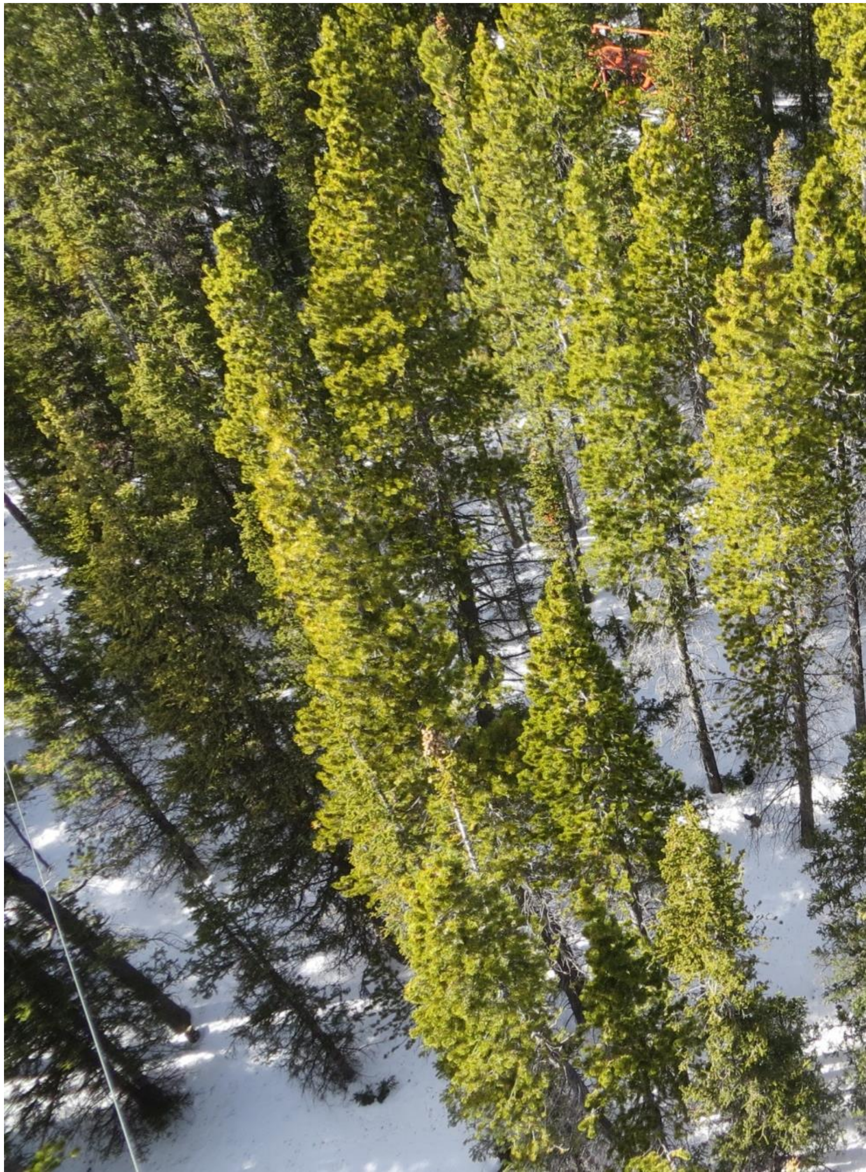
Vary in time and space

Research: Snow Storage across the PNW

Limitations… but there are patterns

Application: Decision Tree and Examples

Actions for today and future



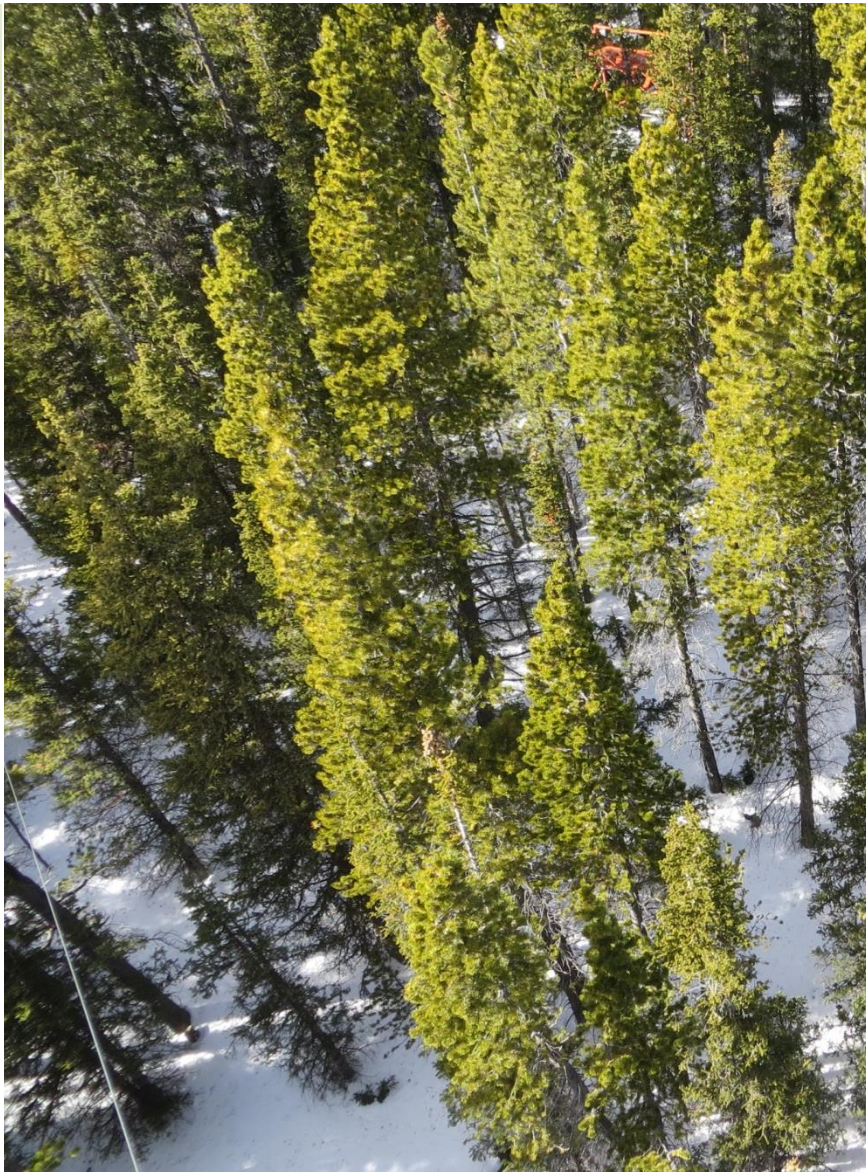
Overview

Motivation: Climate Change and Forest Change

Background: Forest-Snow Processes

Research: Snow Storage across the PNW

Application: Decision Tree and Examples



Motivation: Climate Change Effects on Streamflow

Yakima River near Parker

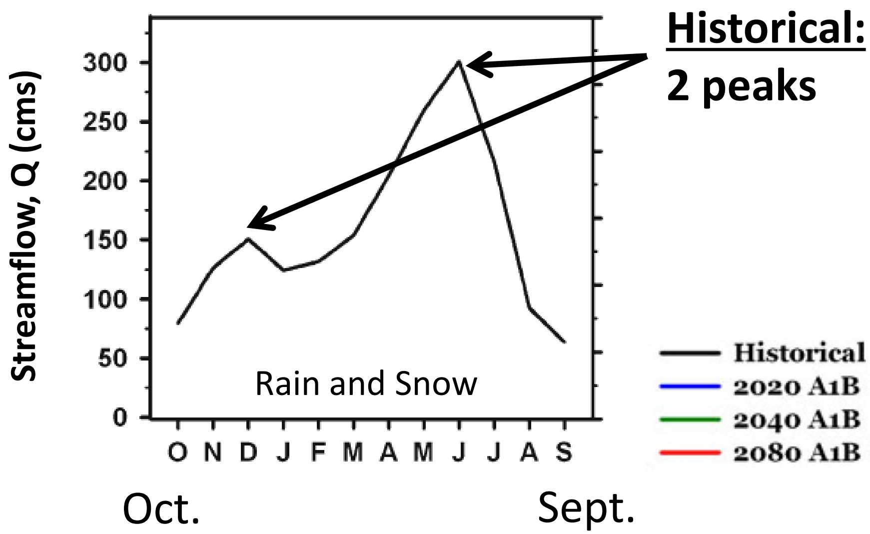


Figure 8, Elsner et al., 2010

Motivation: Climate Change Effects on Streamflow

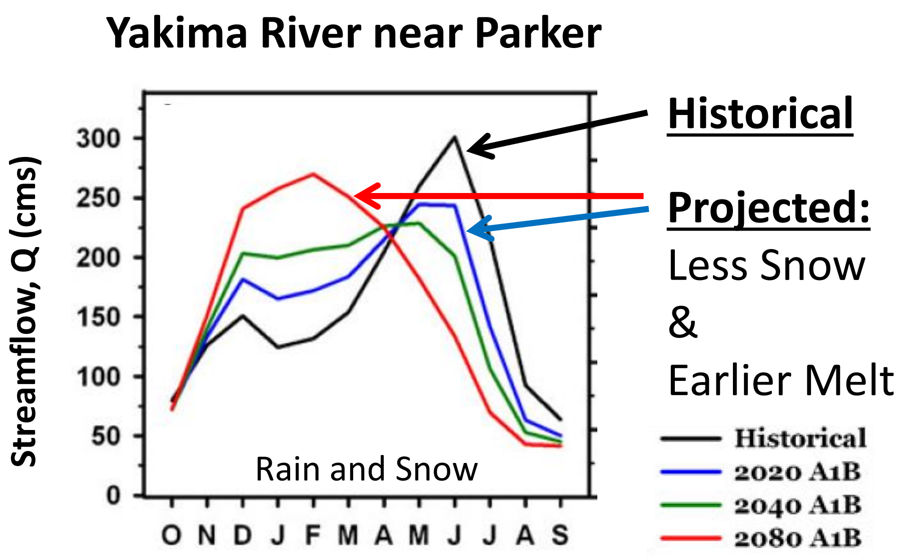


Figure 8, Elsner et al., 2010

Motivation: Climate Change + Forest Change

Yakima River near Parker

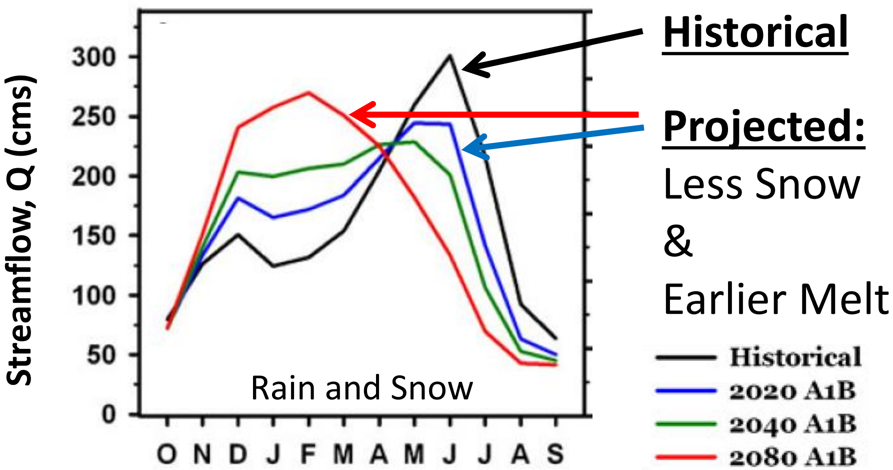
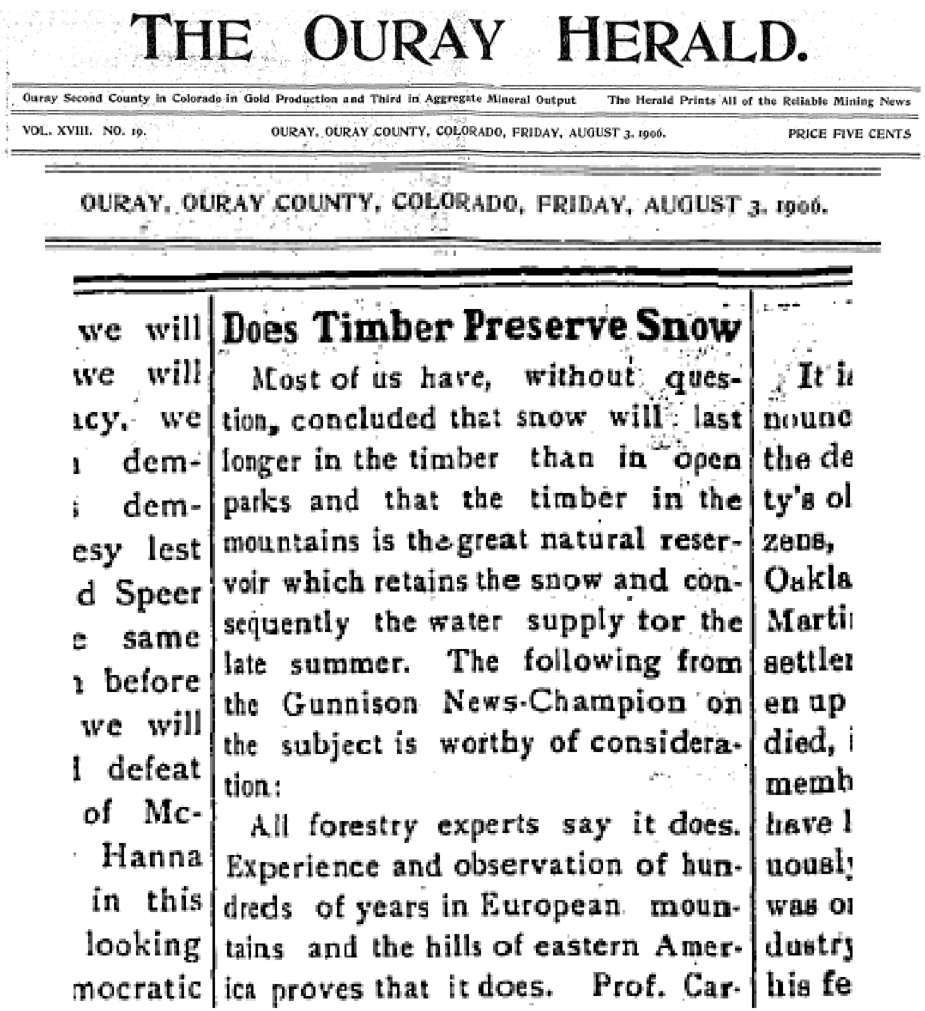


Figure 8, Elsner et al., 2010

Forest Effects on Snow Storage?

"Does Timber Preserve Snow", 1906



THE OURAY HERALD.

Ouray Second County in Colorado in Gold Production and Third in Aggregate Mineral Output — The Herald Prints All of the Reliable Mining News

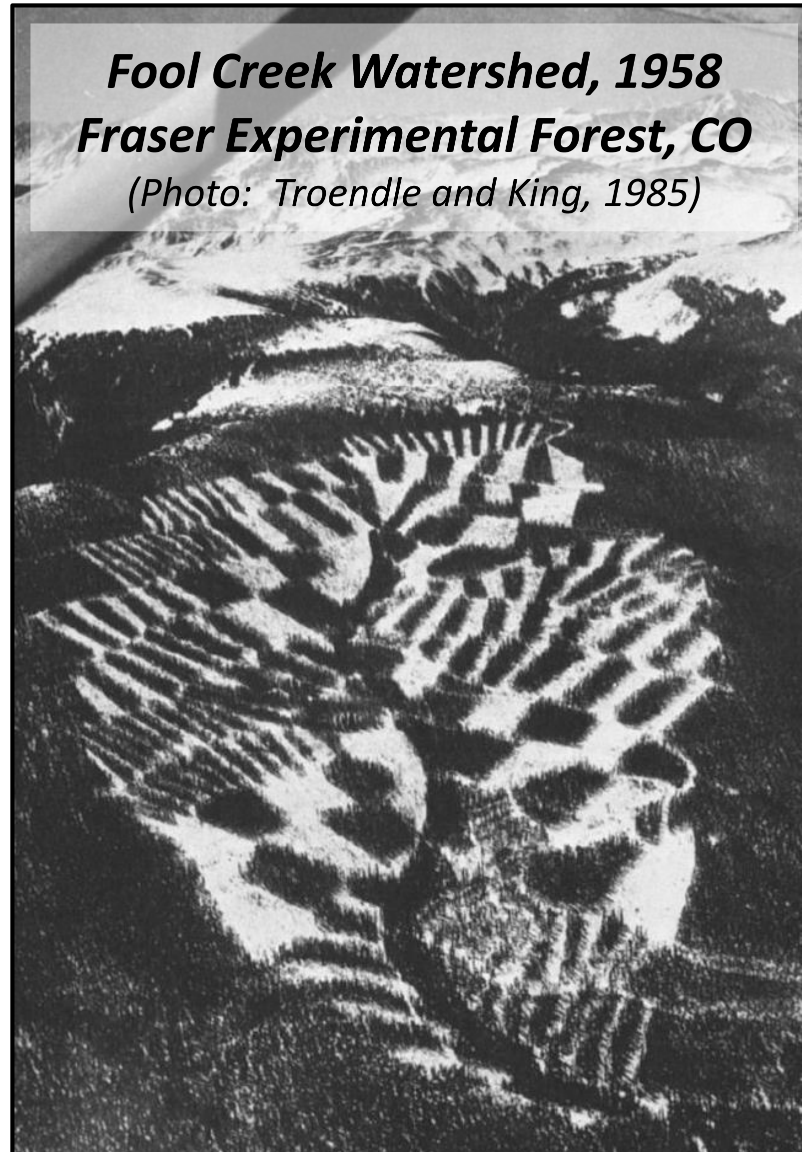
VOL. XVIII. NO. 19. — OURAY, OURAY COUNTY, COLORADO, FRIDAY, AUGUST 3, 1906. — PRICE FIVE CENTS

OURAY, OURAY COUNTY, COLORADO, FRIDAY, AUGUST 3, 1906.

Does Timber Preserve Snow

Most of us have, without question, concluded that snow will last longer in the timber than in open parks and that the timber in the mountains is the great natural reservoir which retains the snow and consequently the water supply for the late summer. The following from the Gunnison News-Champion on the subject is worthy of consideration:

All forestry experts say it does. Experience and observation of hundreds of years in European mountains and the hills of eastern America proves that it does. Prof. Car-



Fool Creek Watershed, 1958
Fraser Experimental Forest, CO
(Photo: Troendle and King, 1985)

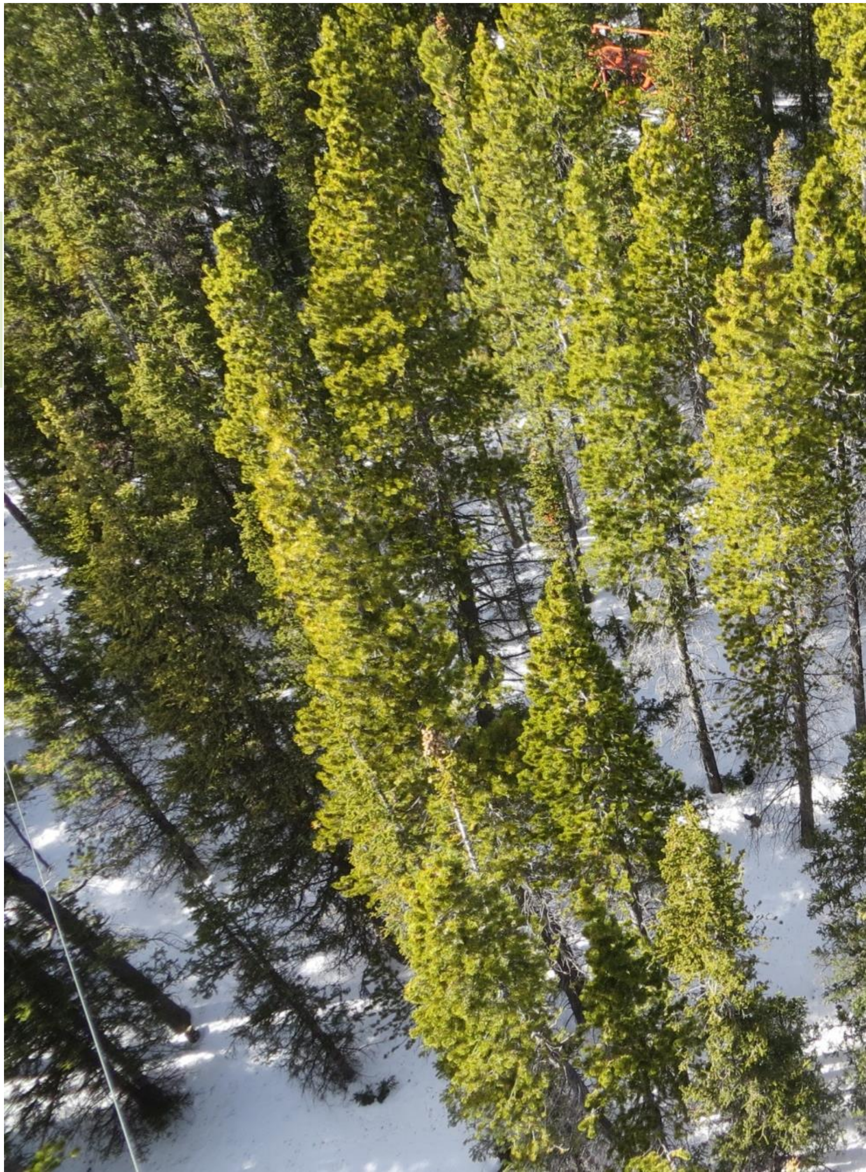
Overview

Motivation: Climate Change and Forest Change

Background: Forest-Snow Processes

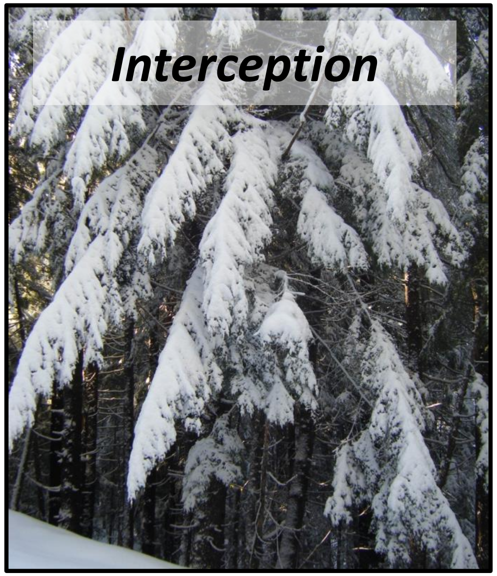
Research: Snow Storage across the PNW

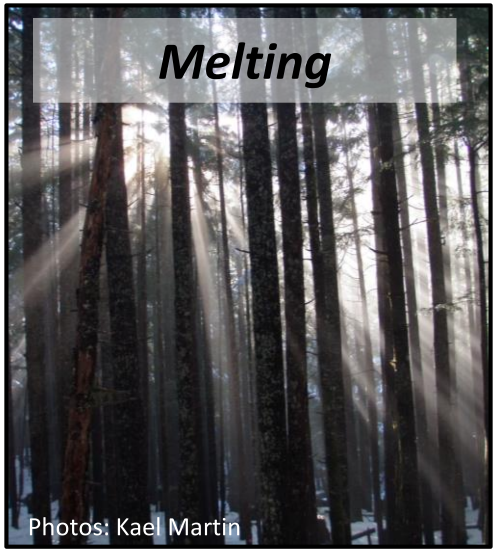
Application: Decision Tree and Examples



Background: Forest-Snow Processes

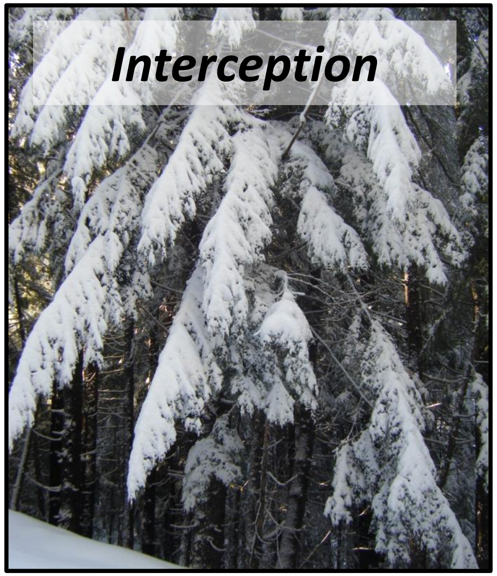
Processes

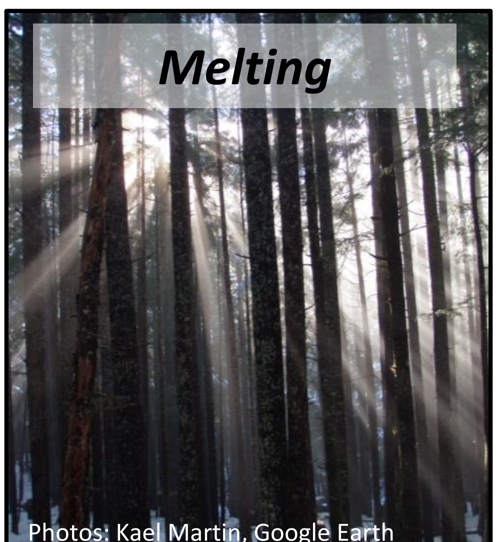




Background: Forest-Snow Processes

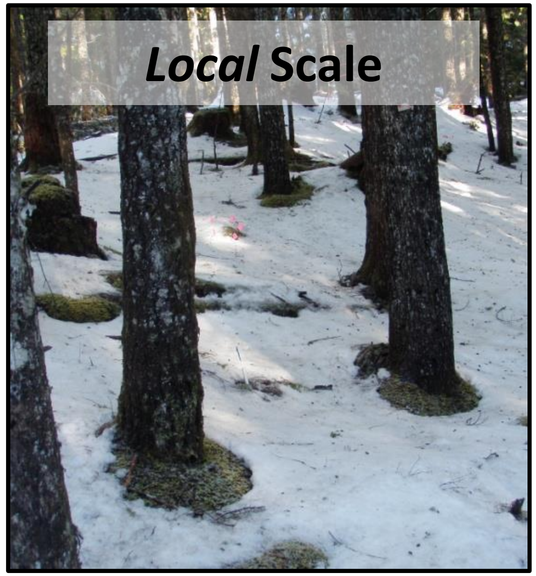
Processes





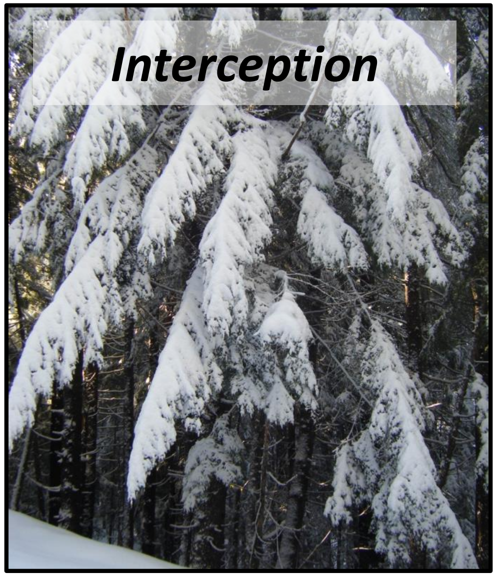
Photos: Kael Martin, Google Earth

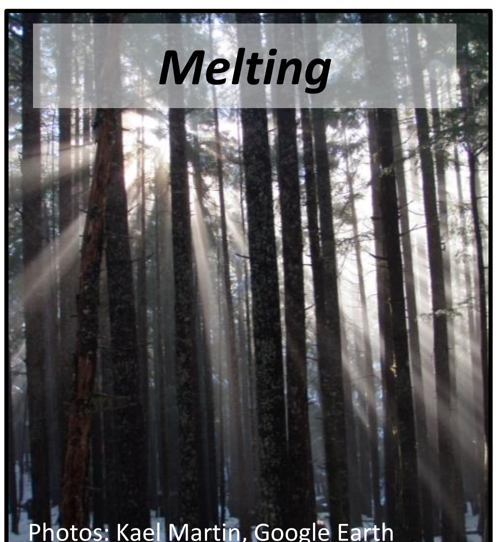
Effects



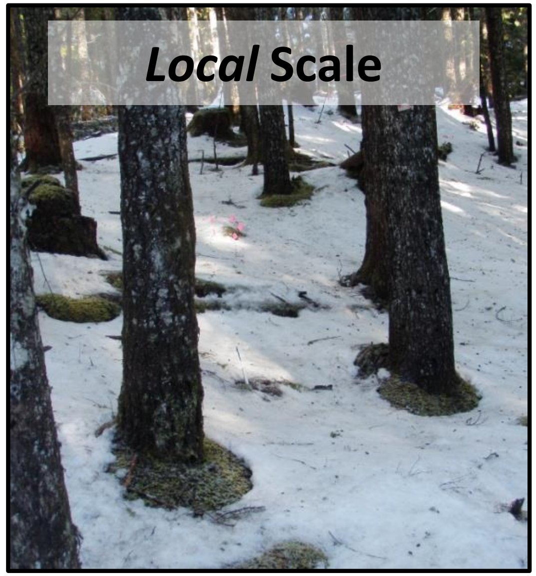
Background: Forest-Snow Processes

Processes





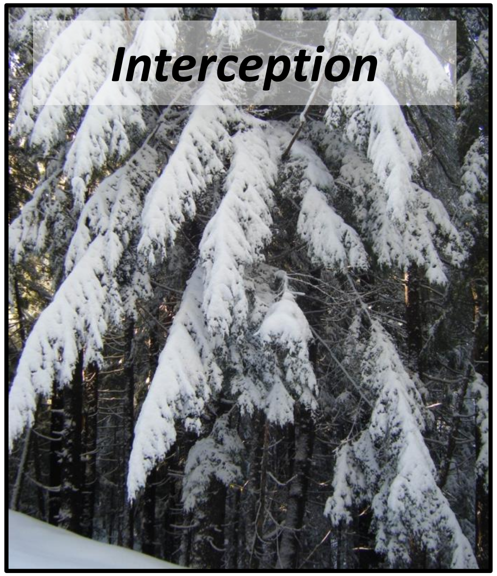
Effects

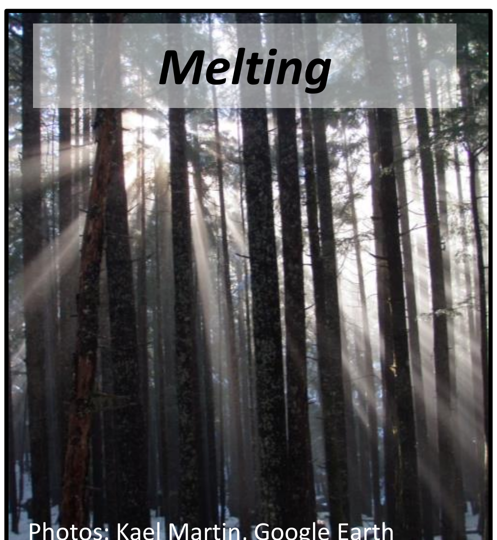


Watershed Impacts

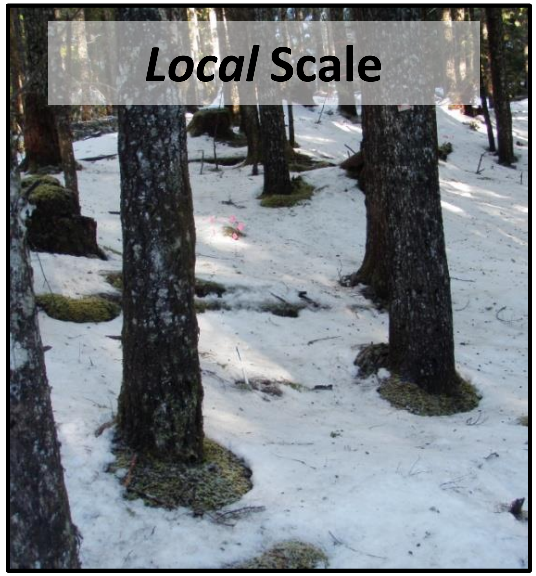
Background: Forest-Snow Processes

Processes





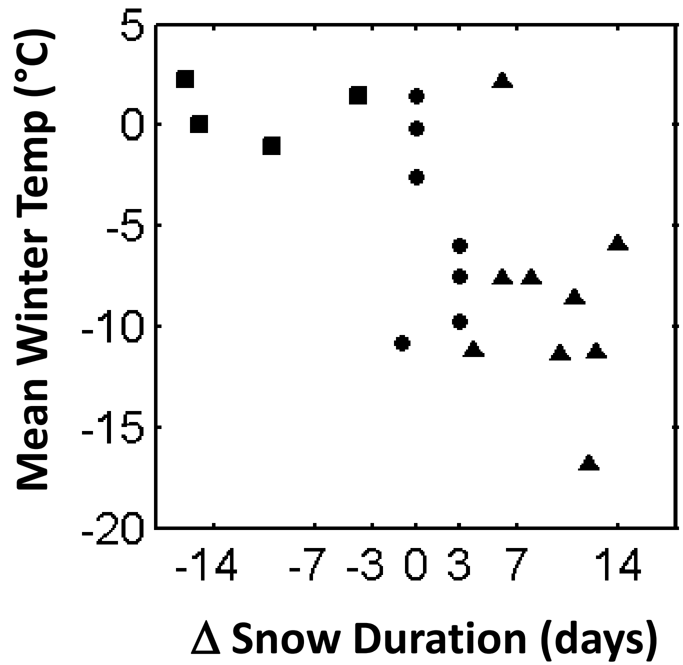
Effects



Watershed Impacts

Background: Forest-Snow Processes

Snow Storage Differences Relate to Temperature



4 week difference
between forested and open areas!

Figure 2a, Lundquist, Dickerson-Lange, Cristea, and Lutz, 2013

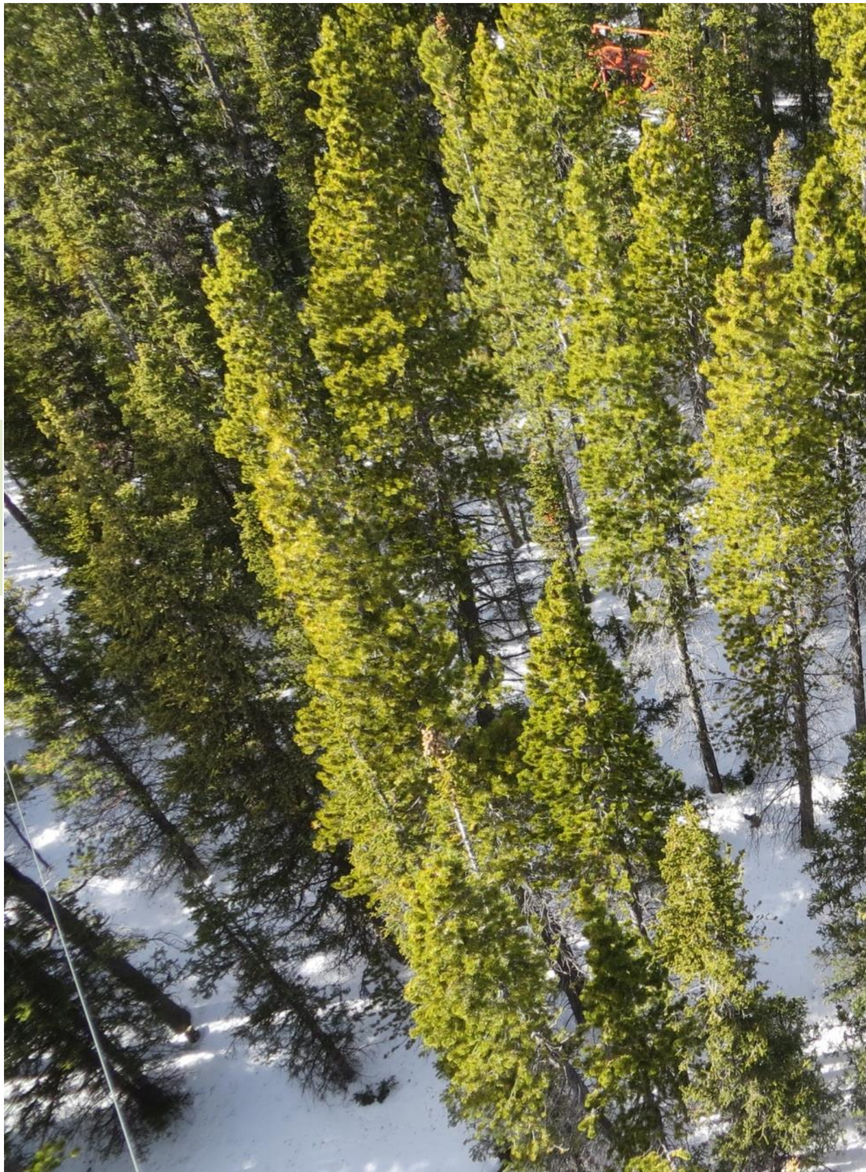
Overview

Motivation: Climate Change and Forest Change

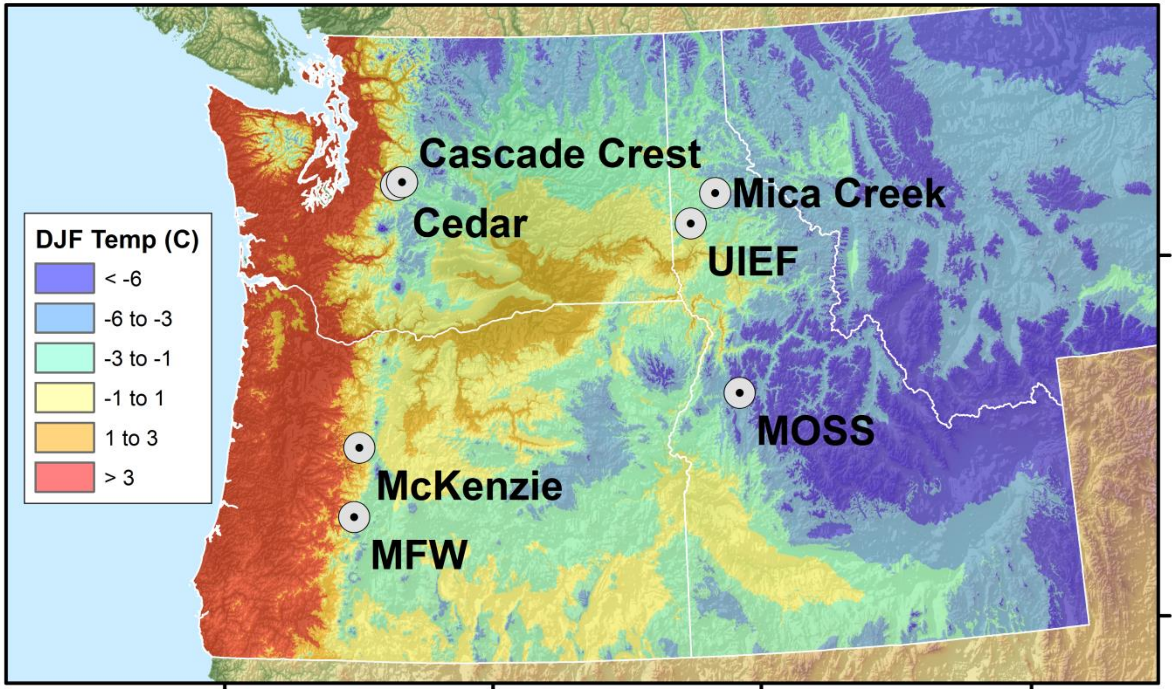
Background: Forest-Snow Processes

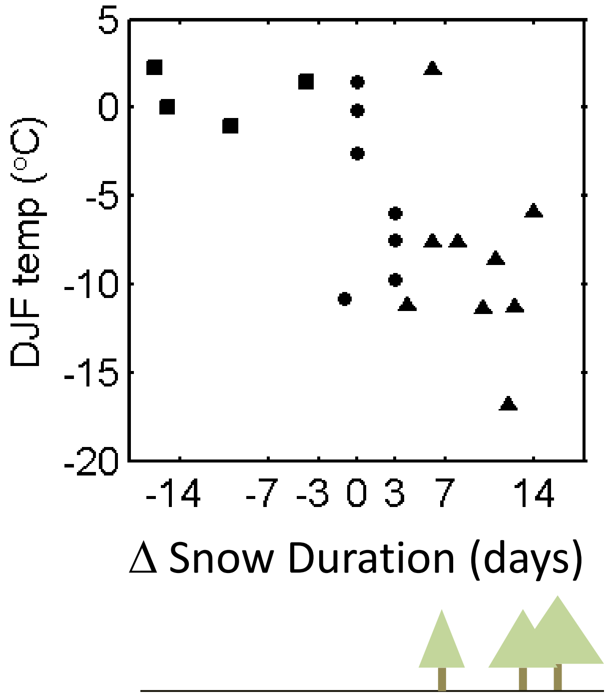
Research: Snow Storage across the PNW

Application: Decision Tree and Examples



Research: Questions



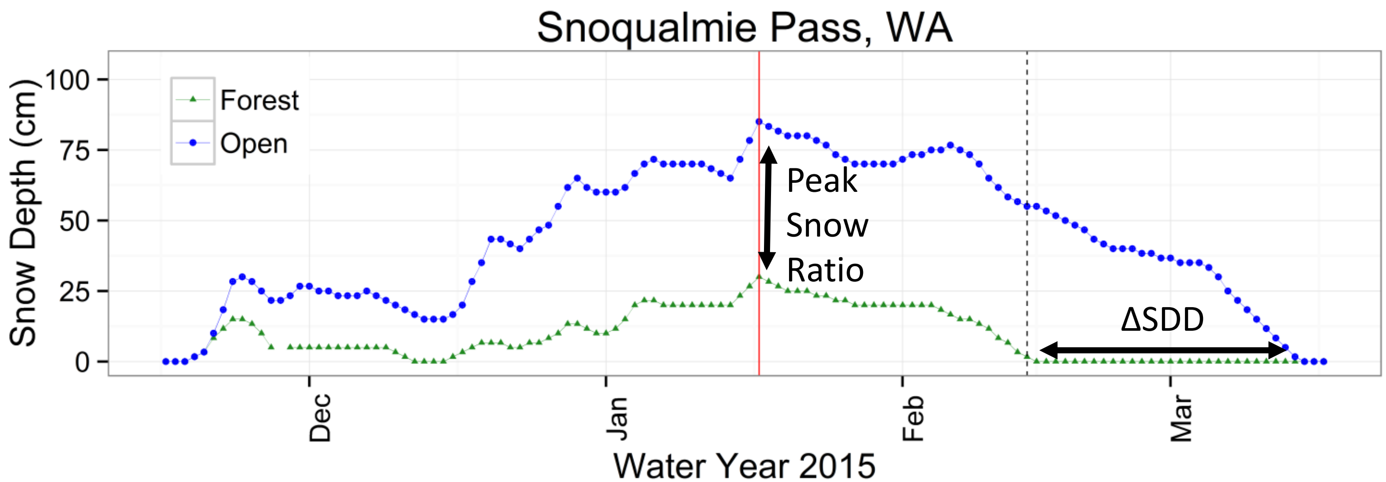


How do forests and forest change affect the magnitude and duration of snow storage across the PNW?

Today and in a warming climate?

(2 journal articles in review/preparation)

Research: Paired Observations of Snow Depth



Research: Comparing Snow Depth

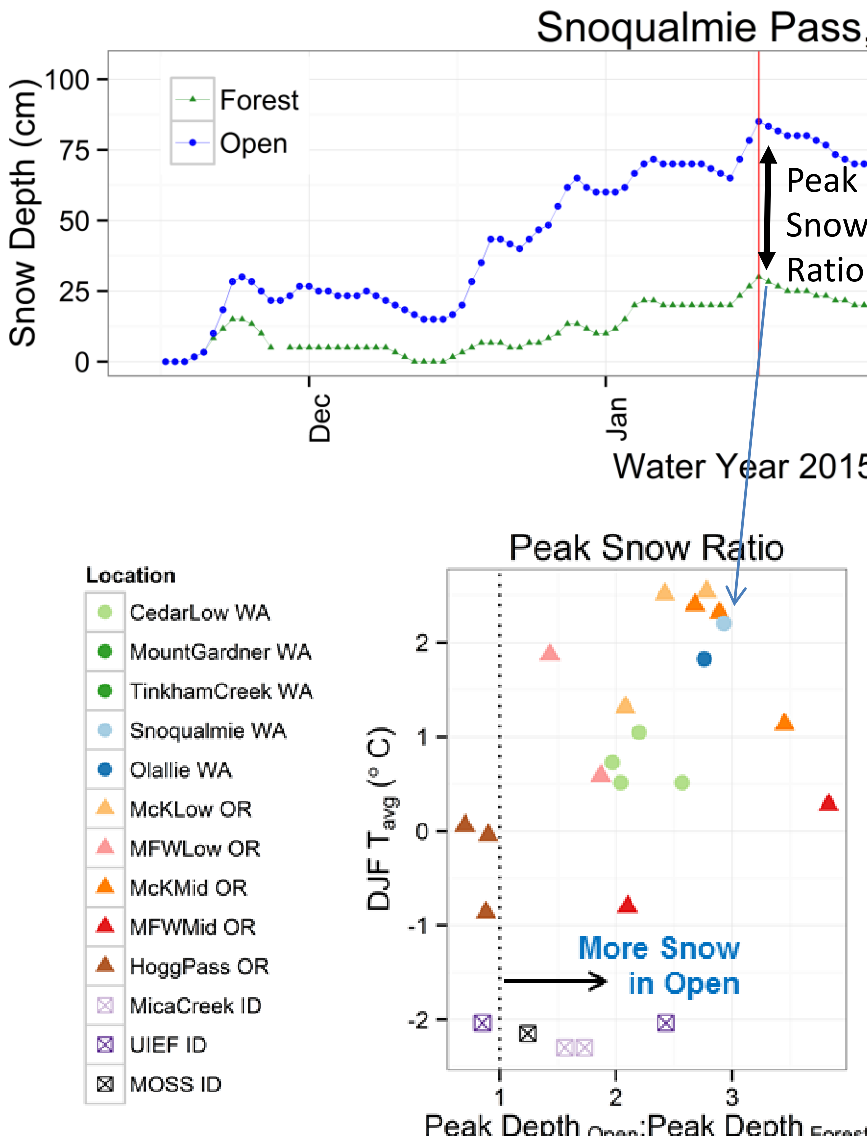
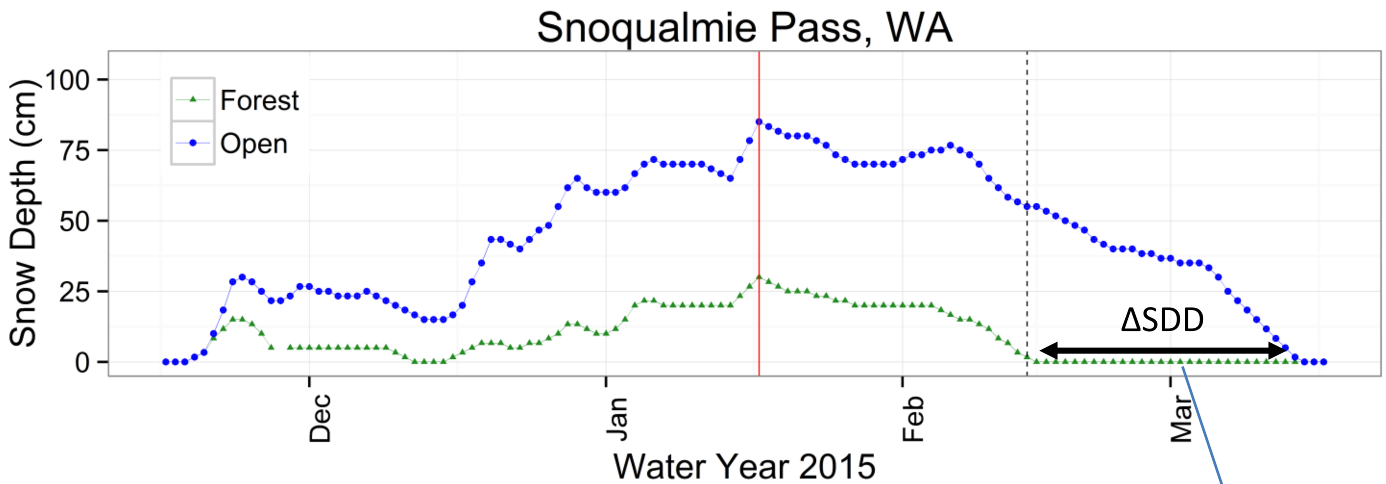


Figure 3, Dickerson-Lange, et al. 2016 (*in review*)

Comparing Peak Snow

- Ranges from ~1 to > 3
- Canopy snow interception
- Subsequent loss

Research: Comparing Snow Duration



<u>Comparing Difference in SDD</u>

- Ranges from snow lasting 5 weeks longer in forest…
- To snow lasting > 4 weeks longer in open

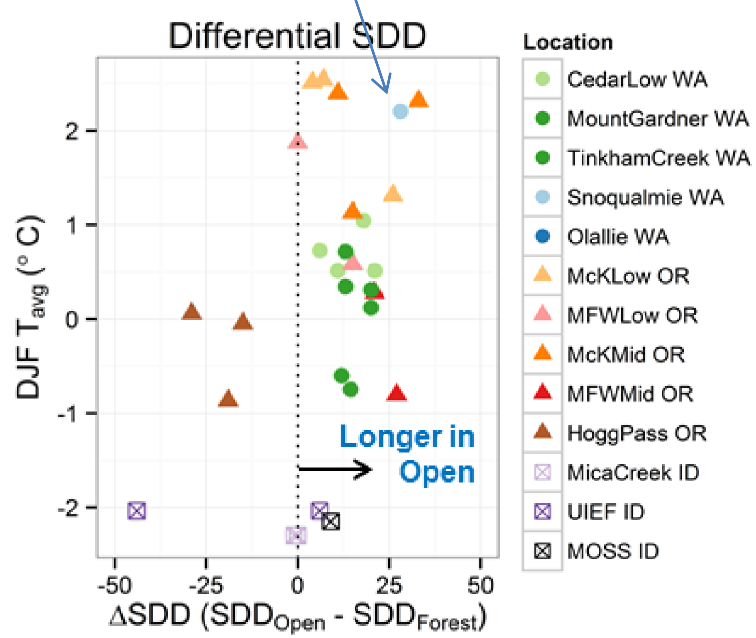
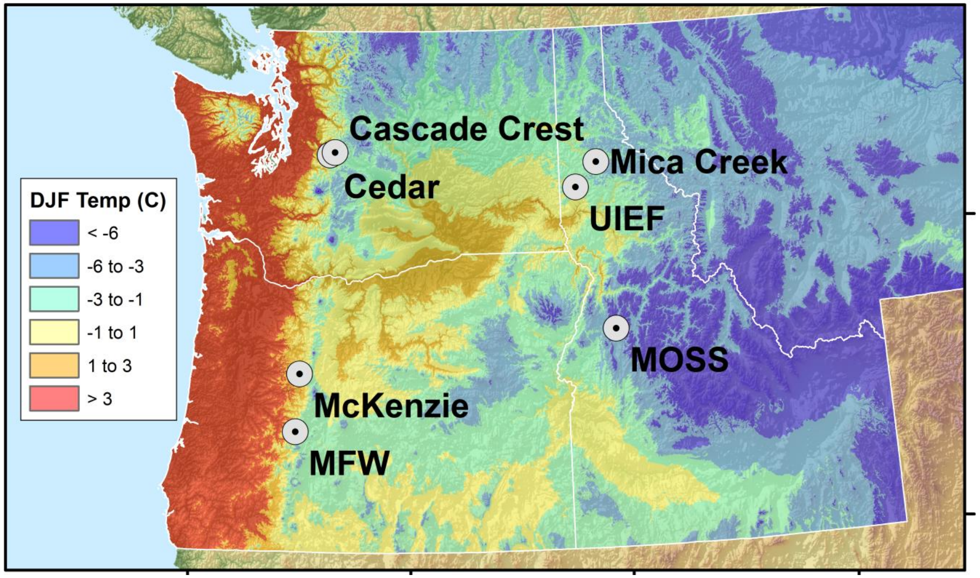


Figure 3, Dickerson-Lange, et al. 2016 (*in review*)

Research: Conclusions

Findings

- Process analysis: **hierarchy**
- Limitations: Inter-annual **variability**, spatial **data gaps**
- **Patterns** observed



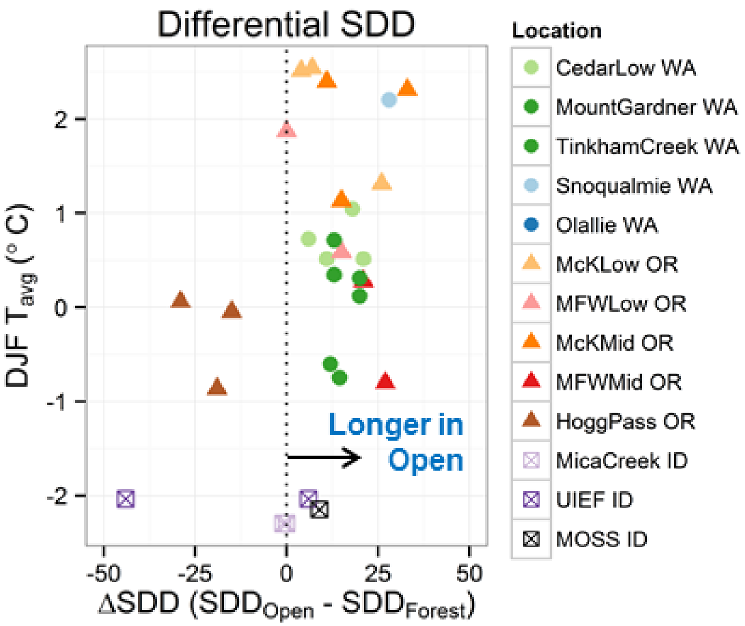


Figure 3, Dickerson-Lange, et al. 2016 (*in review*)

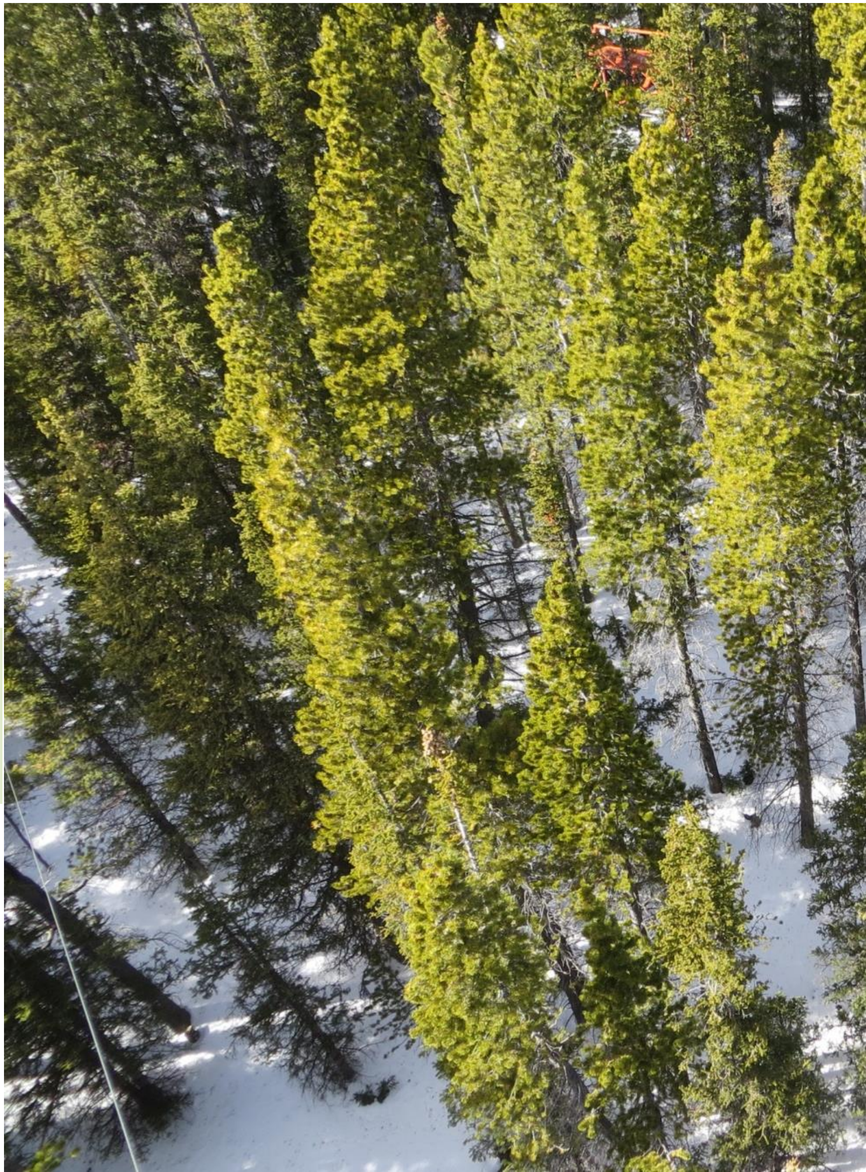
Overview

Motivation: Climate Change and Forest Change

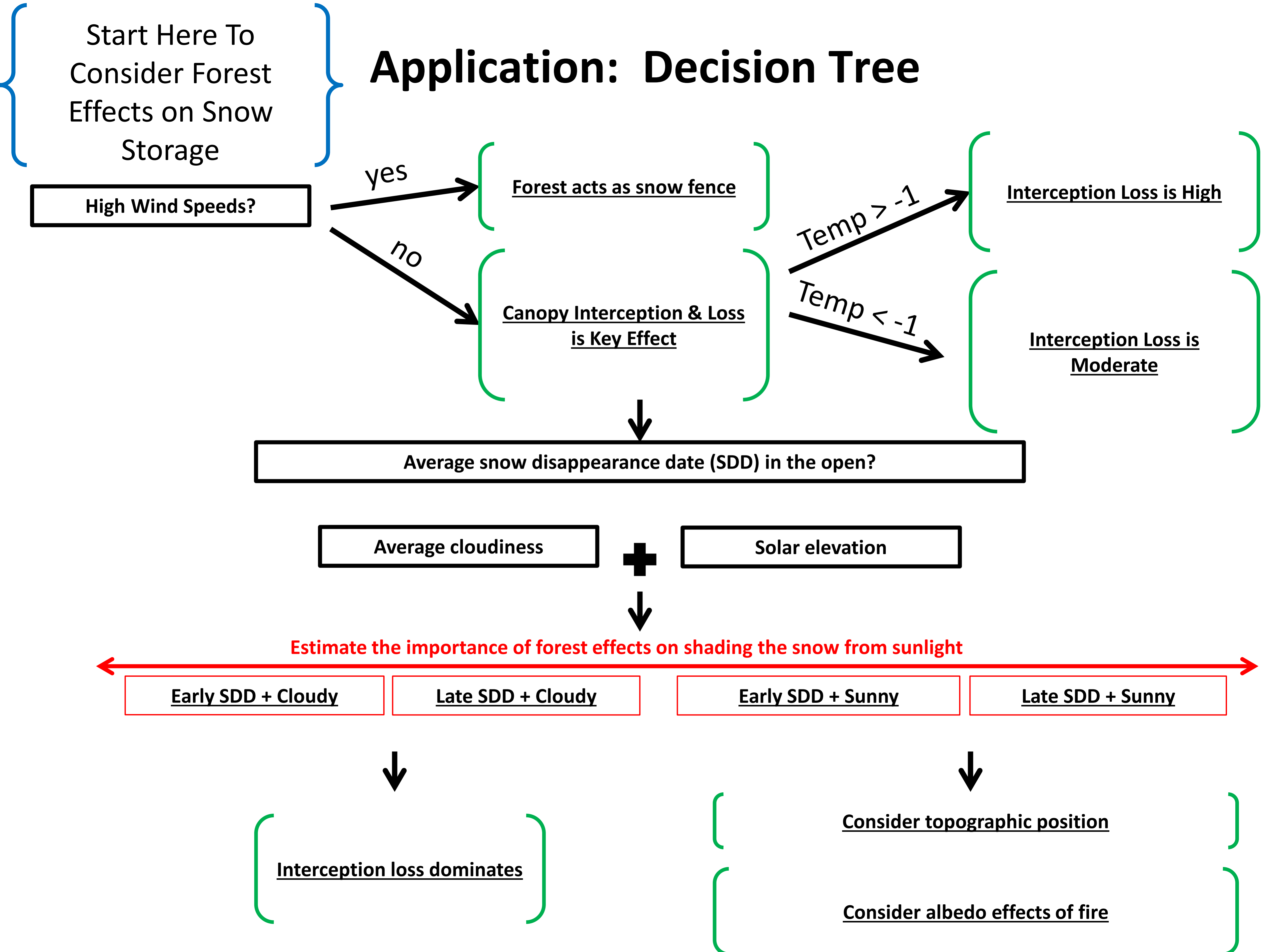
Background: Forest-Snow Processes

Research: Snow Storage across the PNW

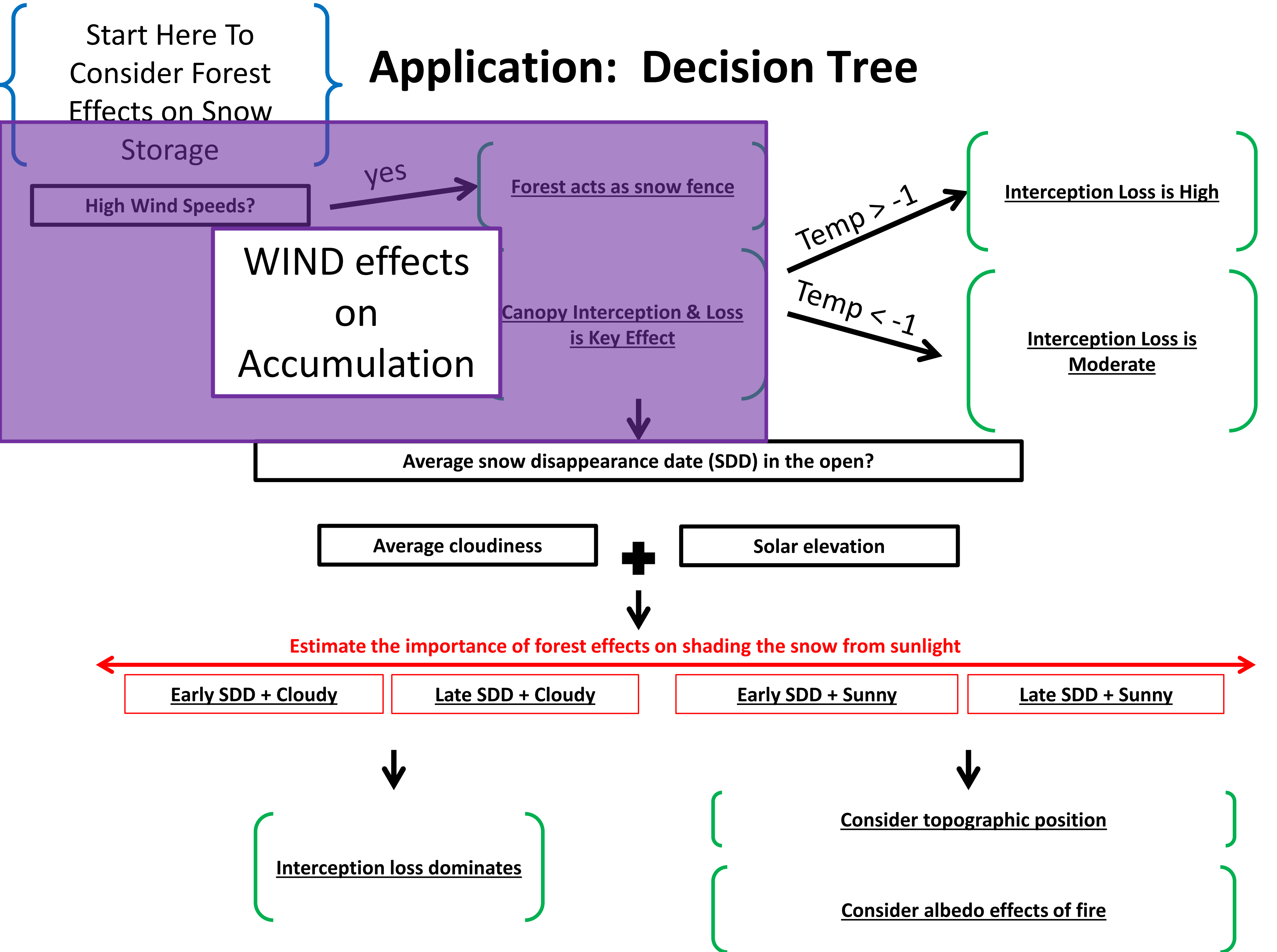
Application: Decision Tree and Examples



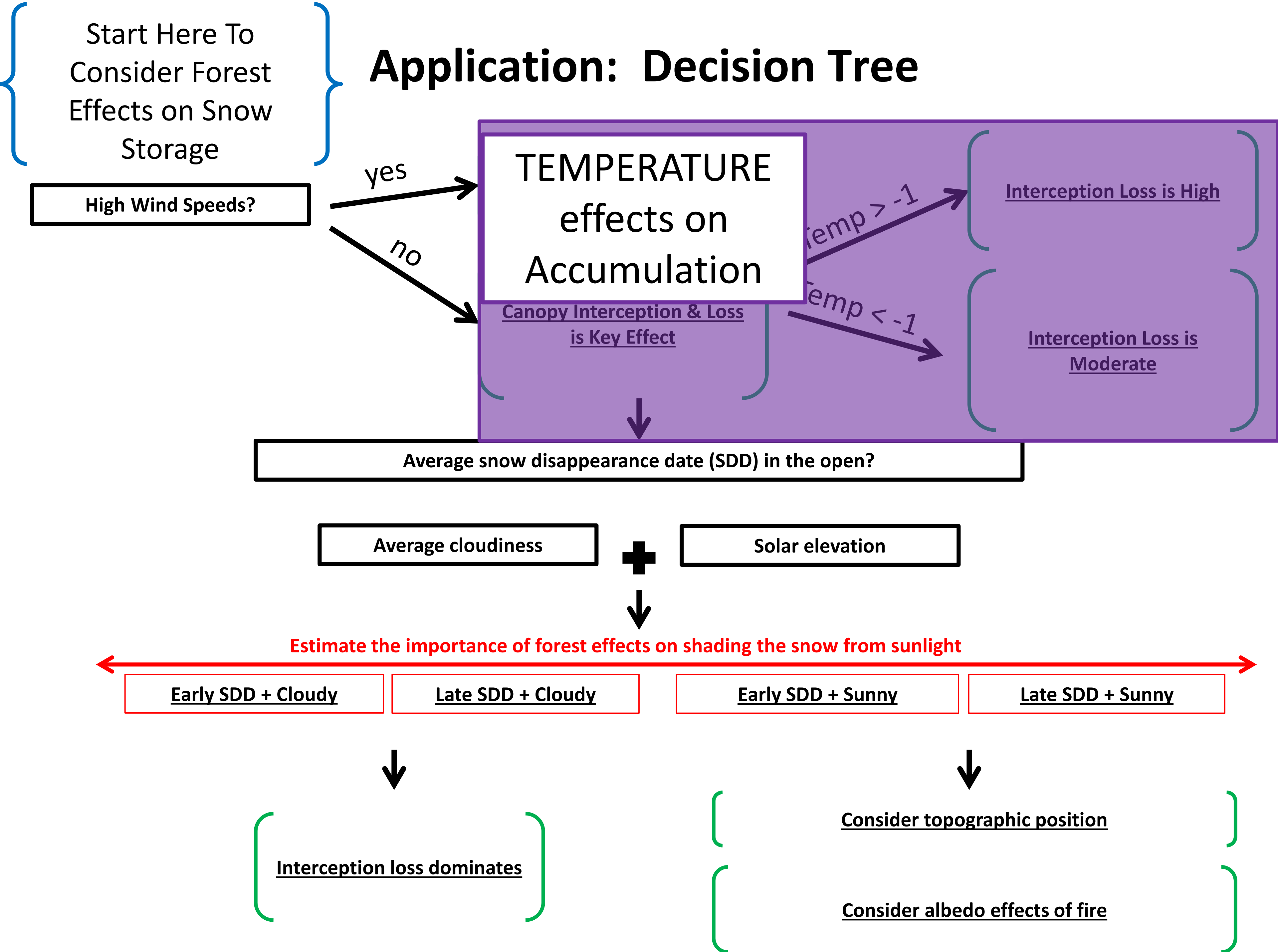
Application: Decision Tree



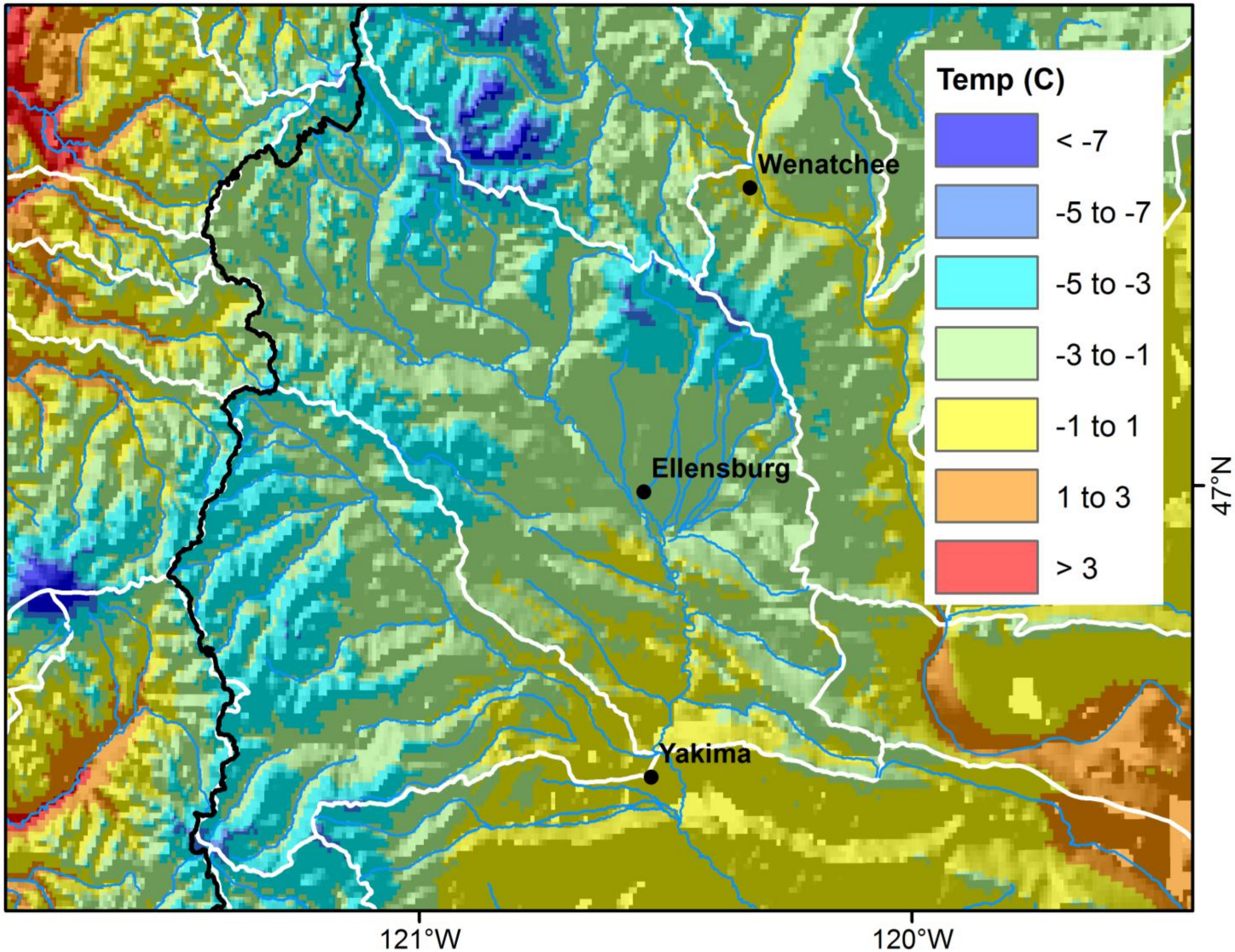
Application: Decision Tree



Application: Decision Tree

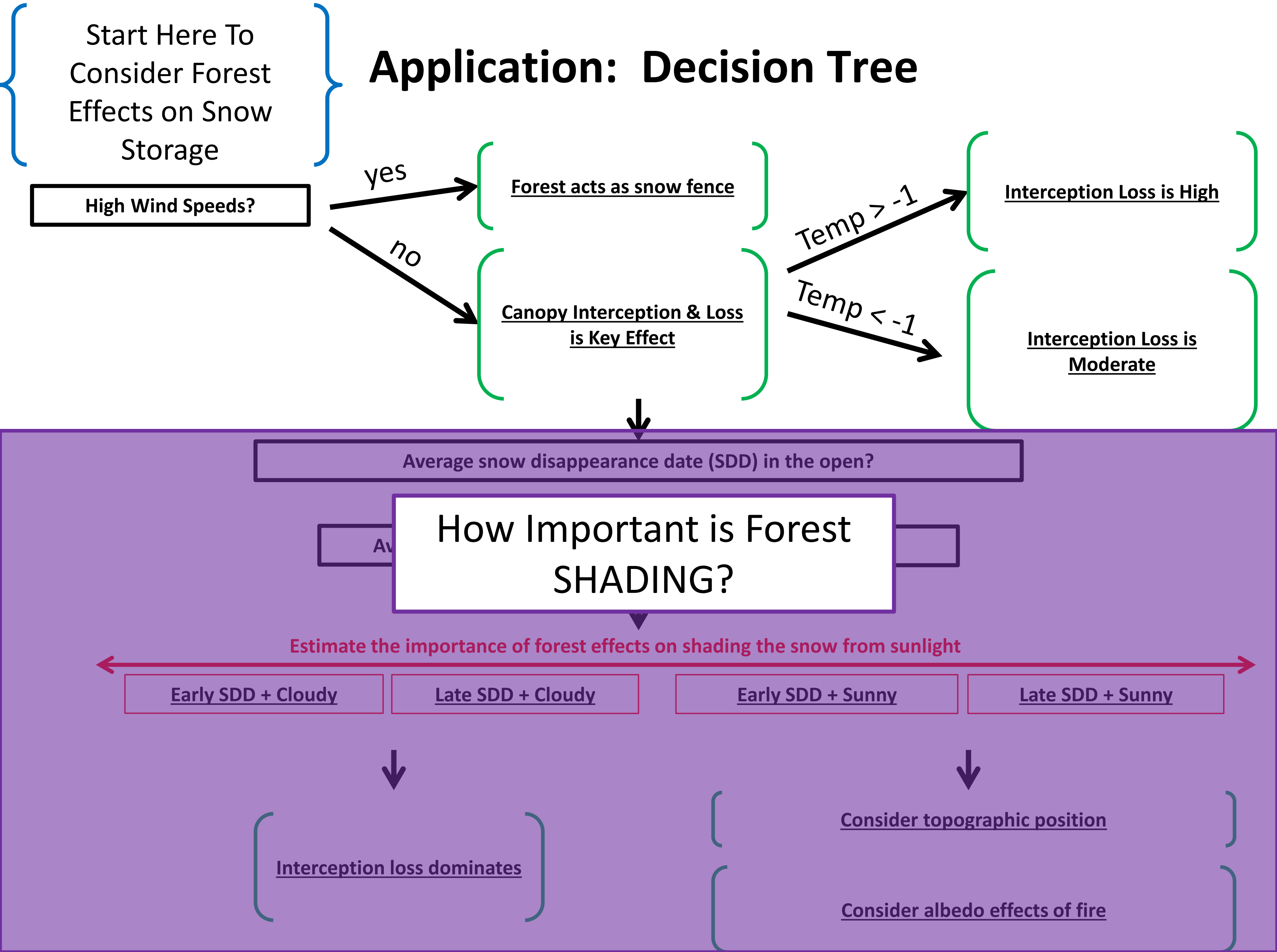


Winter Temperature

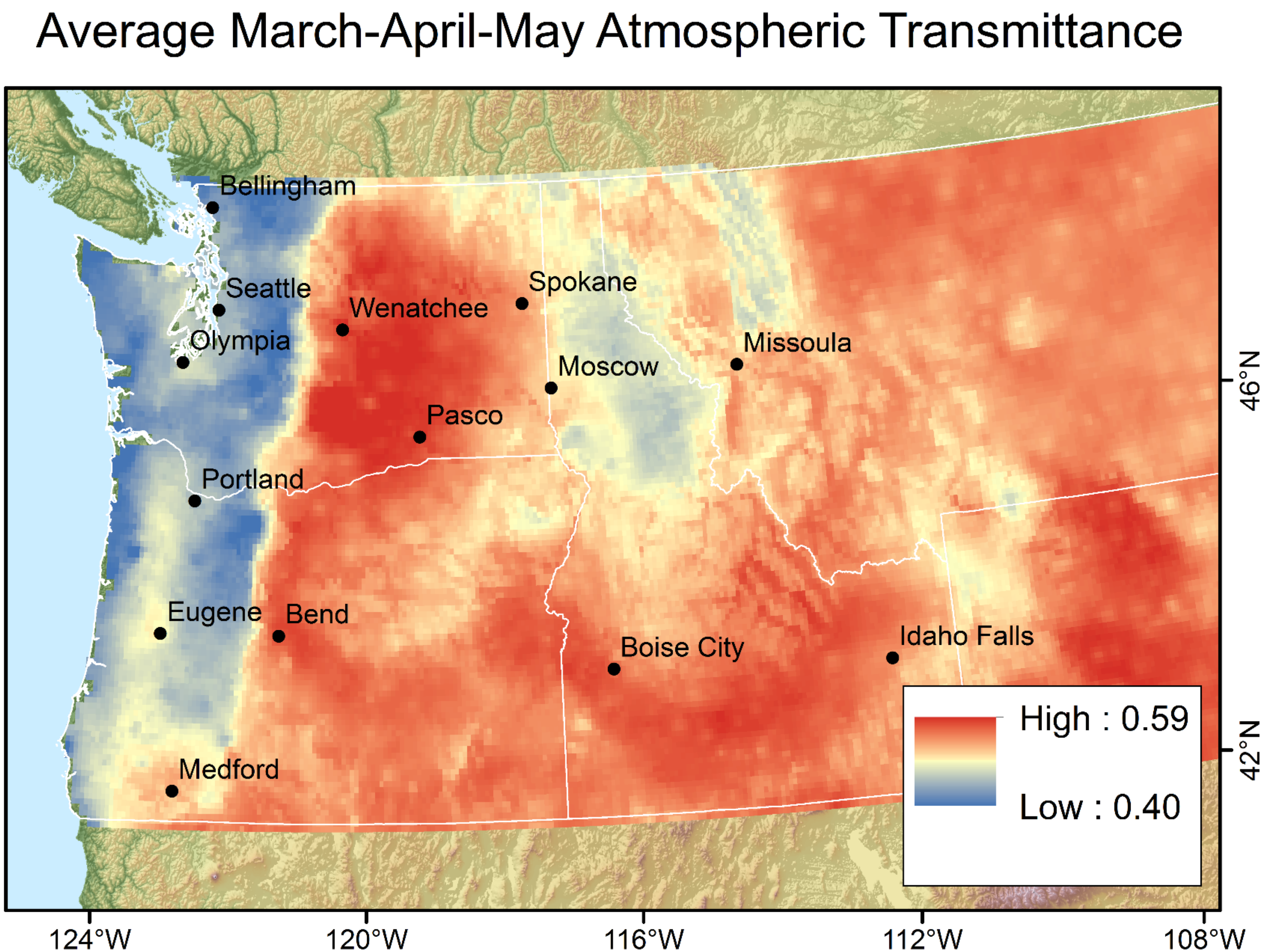


Temperature data from PRISM Climate Group. Cloudiness based on Bristow & Campbell (1984) equation applied to Livneh, et al. (2015) data.

Application: Decision Tree

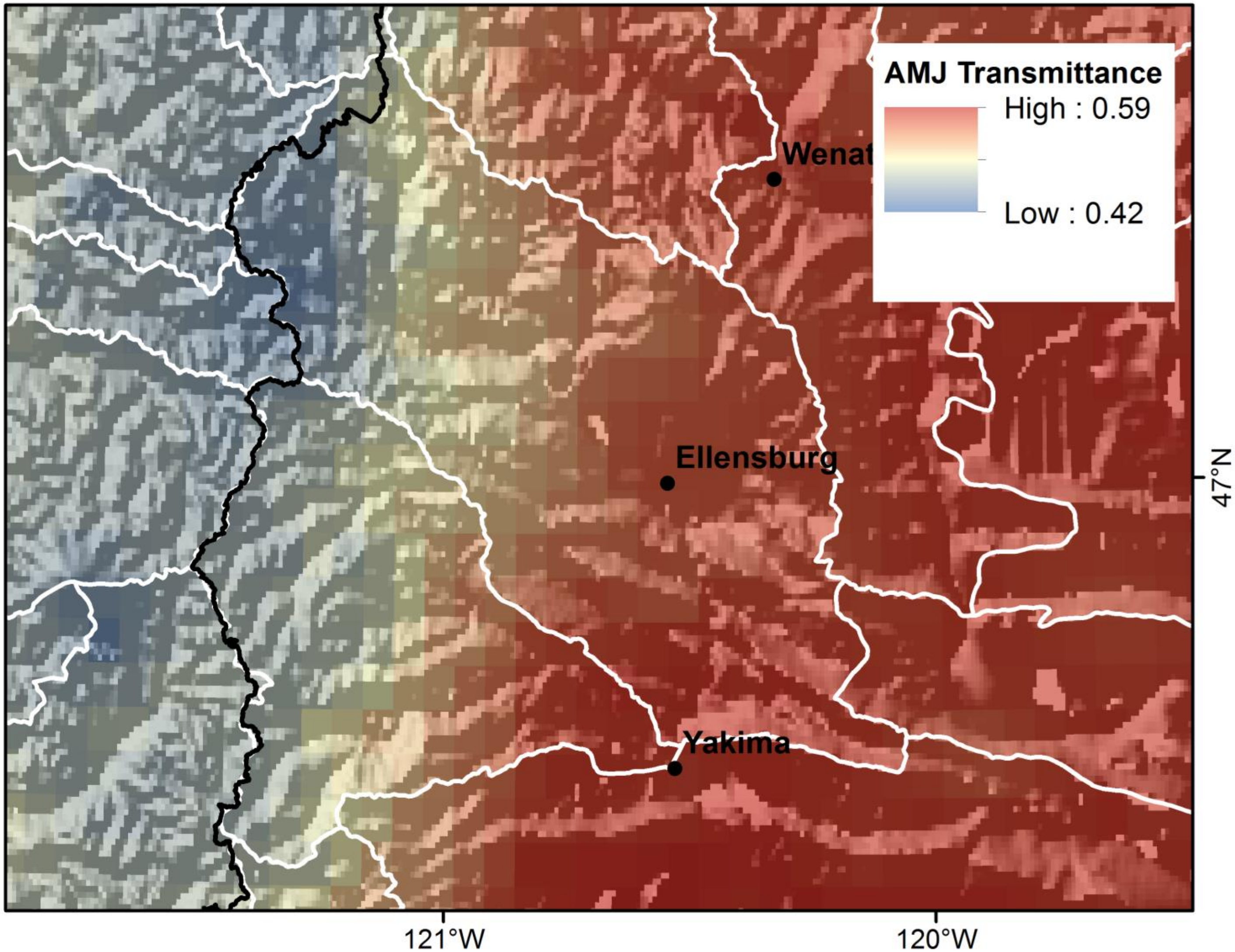


Cloudiness



Cloudiness based on Bristow & Campbell (1984) equation applied to Livneh, et al. (2015) data.

Cloudiness



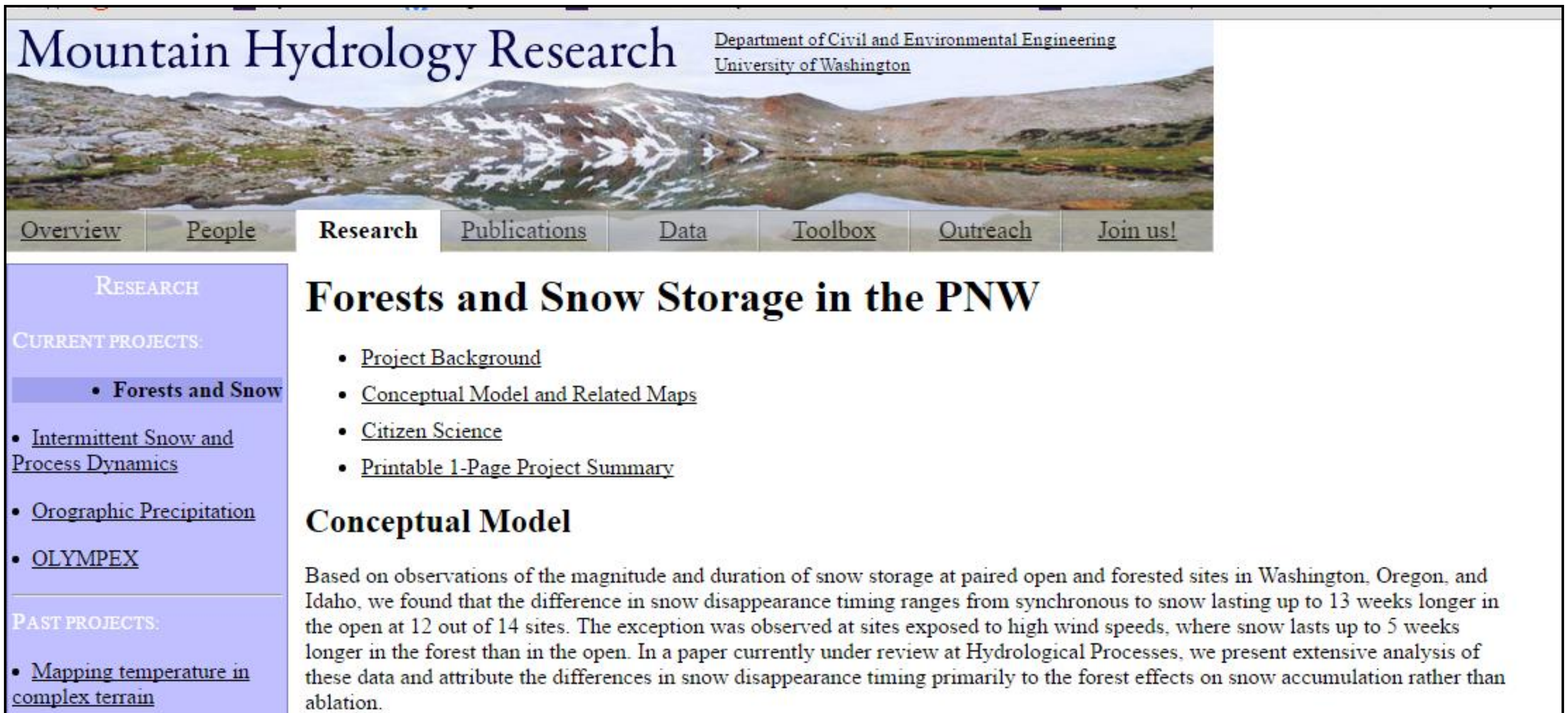
Cloudiness based on Bristow & Campbell (1984) equation applied to Livneh, et al. (2015) data.

Application: Decision Tree and Maps

Decision Tree and Maps are available (Beta Versions!):

http://depts.washington.edu/mtnhydr/research/PNWsnowforestmap.shtml

- Decision Tree
- Maps: Images, Google Earth, Rasters
- Webinar Overview



Application: Maximize PNW Snow Storage

	Characteristics	Today	Climate Change	Consider:
Western Cascades	Warm Winter + Cloudy Spring: • Interception & loss dominates • Shading effect minimized • Snow duration longer in open			

Application: Maximize PNW Snow Storage

	Characteristics	Today	Climate Change	Consider:
Western Cascades	Warm Winter + Cloudy Spring: • Interception & loss dominates • Shading effect minimized • Snow duration longer in open	Open canopy (gaps, thinning)		

Application: Maximize PNW Snow Storage

	Characteristics	Today	Climate Change	Consider:
Western Cascades	Warm Winter + Cloudy Spring: • Interception & loss dominates • Shading effect minimized • Snow duration longer in open	Open canopy (gaps, thinning)	Open canopy	Consider: Rising rain/snow Line

Application: Maximize PNW Snow Storage

	Characteristics	Today	Climate Change	Consider:
Western Cascades	Warm Winter + Cloudy Spring: • Interception & loss dominates • Shading effect minimized • Snow duration longer in open	Open canopy (gaps, thinning)	Open canopy	Consider: Rising rain/snow Line
Eastern Cascades	Cold Winter + Sunny Melt Season: • Less interception • Shading effect important • Snow duration equal			

Application: Maximize PNW Snow Storage

	Characteristics	Today	Climate Change	Consider:
Western Cascades	Warm Winter & Cloudy Spring: • Interception & loss dominates • Shading effect minimized • Snow duration longer in open	Open canopy (gaps, thinning)	Open canopy	Consider: Rising rain/snow Line
Eastern Cascades	Cold Winter + Sunny Melt Season: • Less interception • Shading effect important • Snow duration equal	Forest thinning	Open canopy on north slopes	Earlier ablation in future?

Application: Maximize PNW Snow Storage

	Characteristics	Today	Climate Change	Consider:
Western Cascades	Warm Winter & Cloudy Spring: • Interception & loss dominates • Shading effect minimized • Snow duration longer in open	Open canopy (gaps, thinning)	Open canopy	Consider: Rising rain/snow Line
Eastern Cascades	Cold Winter + Sunny Melt Season: • Less interception • Shading effect important • Snow duration equal	Forest thinning	Open canopy on north slopes	Earlier ablation in future?
Northern Idaho	Cold Winter + Cloudy Melt Season:			
Cascade Crest	High Wind Exposure:			

Conclusions

Motivation: Climate Change and Forest Change

Combined effects on snow important

Background: Forest-Snow Processes

Vary in time and space

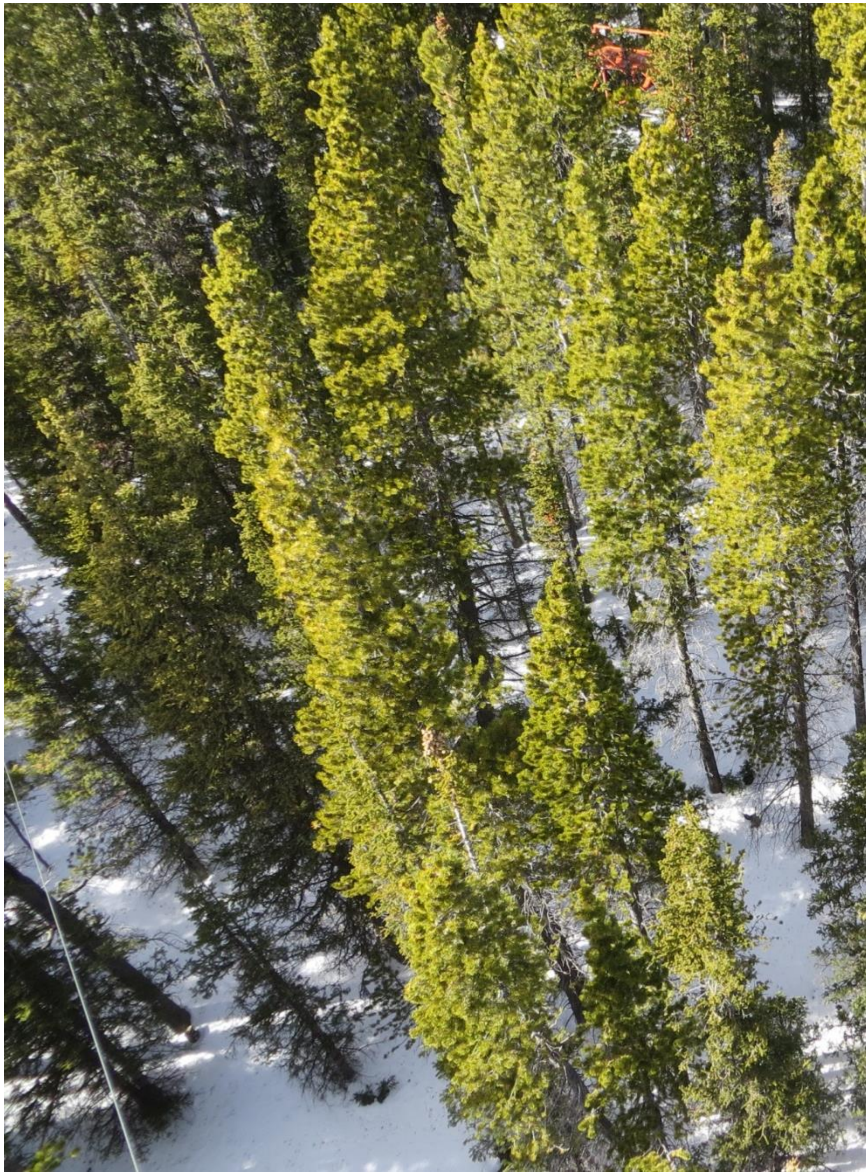
Research: Snow Storage across the PNW

Limitations… but there are patterns

Application: Decision Tree and Examples

Actions for today and future

depts.washington.edu/mtnhydr/research/PNWsnowforestmap.shtml



Thanks!

Susan Dickerson-Lange

susan@naturaldes.com

http://depts.washington.edu/mtnhydr/research/PNWsnowforestmap.shtml

MOUNTAIN HYDROLOGY RESEARCH

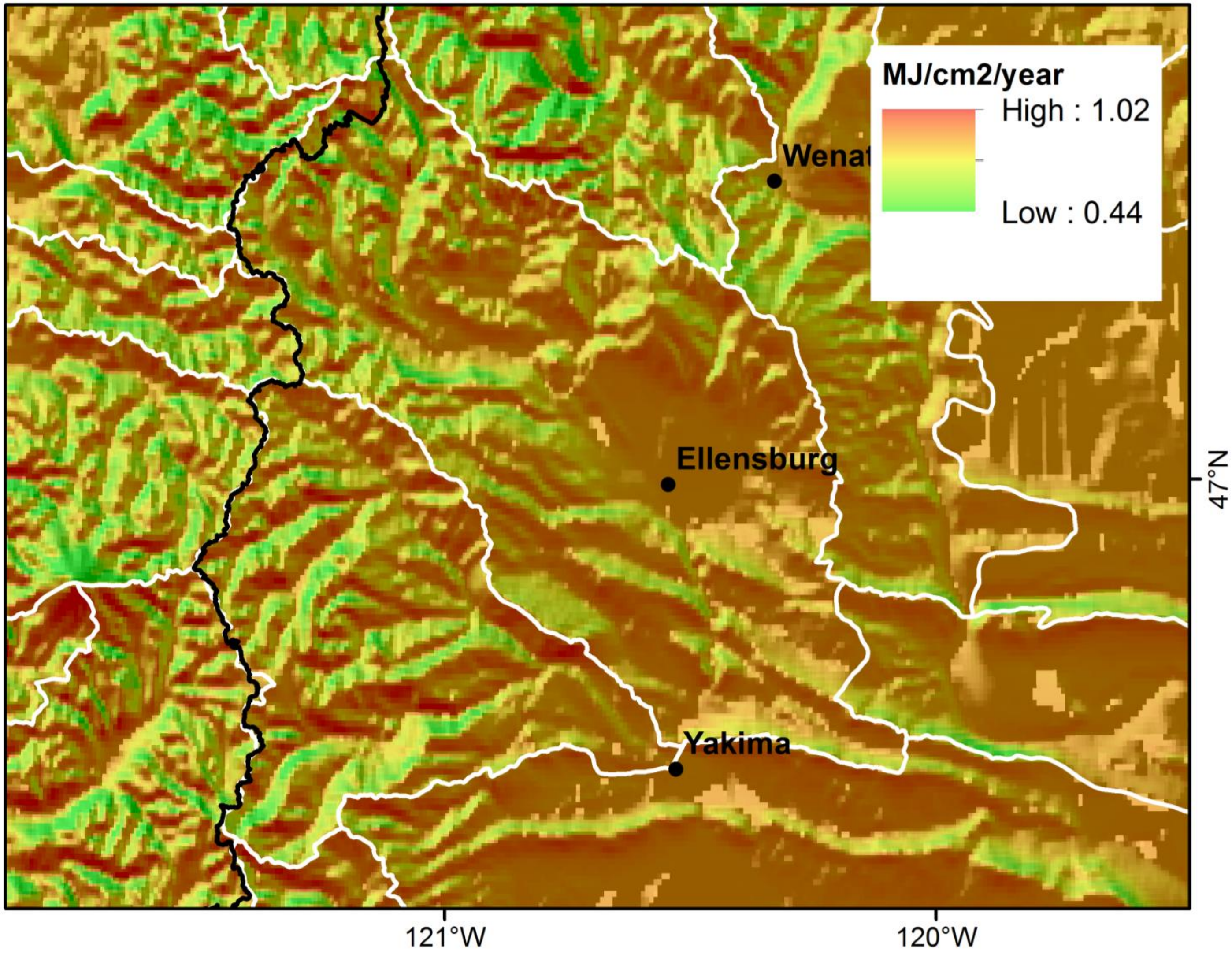
Natural Systems Design

Funding:

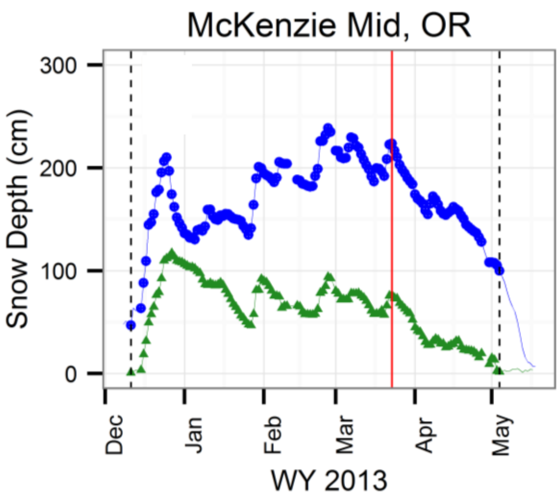
Northwest Climate Science Center (Dept of Interior)

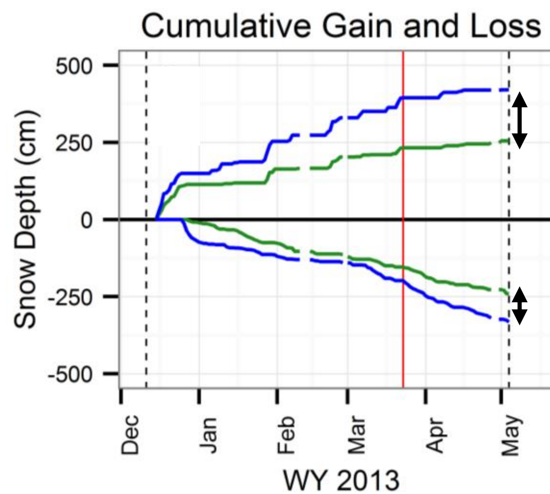
NW CSC Northwest Climate Science Center

Topographic Position



Analysis: How Do Forest-Snow Processes Vary?



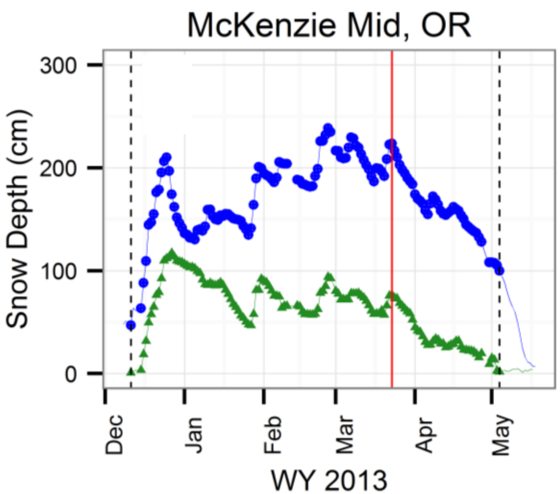


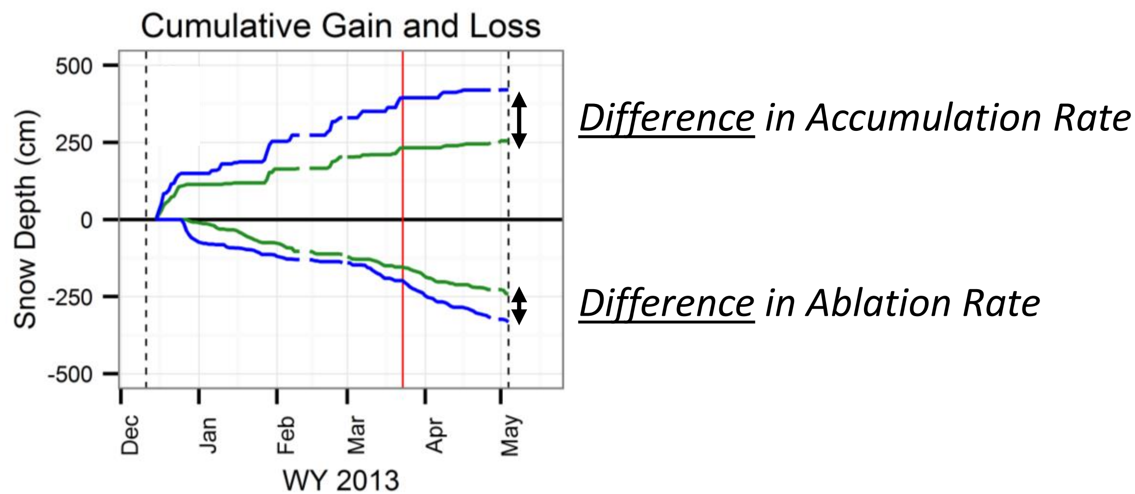
<u>Difference</u> in Accumulation Rate

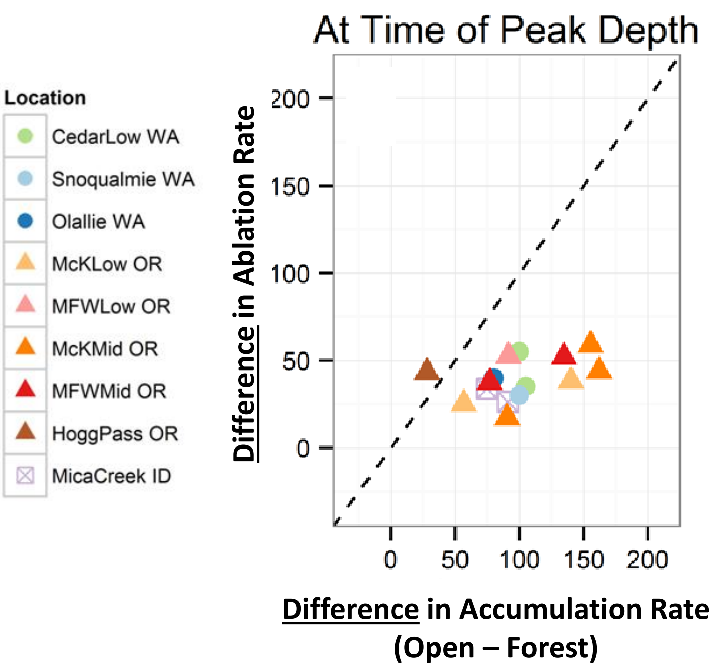
<u>Difference</u> in Ablation Rate

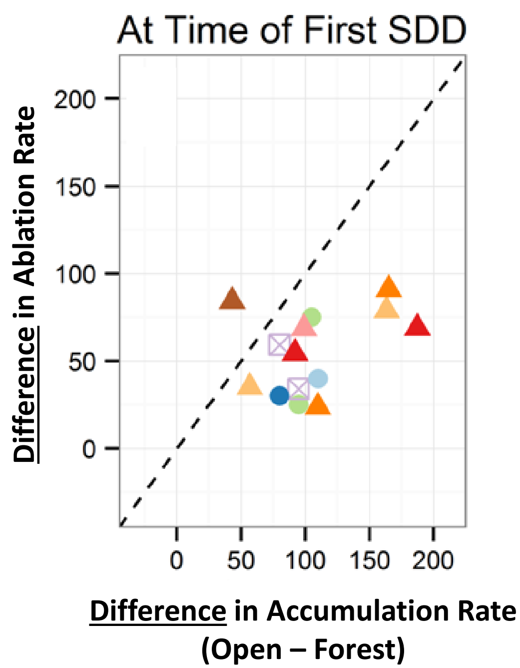
<u>Results:</u>
Accumulation
<u>and</u>
ablation rates higher
in open

Results: More difference in accumulation rates









Results

Δ accumulation rates

larger than

Δ ablation rates

at peak accumulation

and

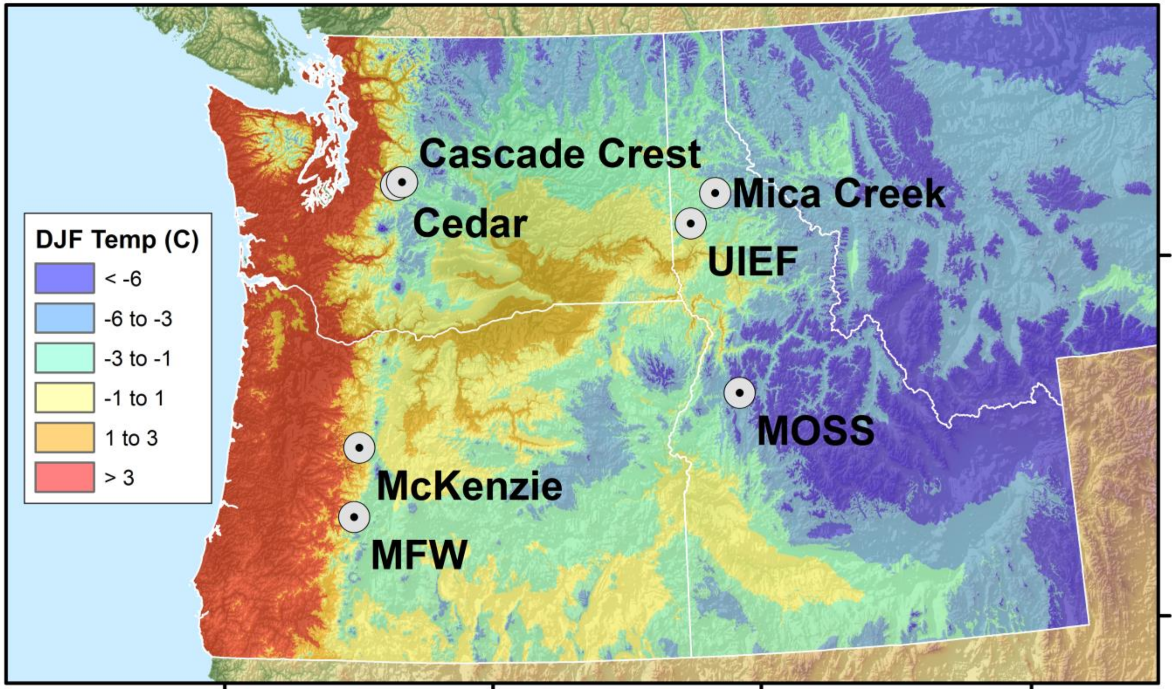
at 1st snow disappearance

Figure 5, Dickerson-Lange, et al. 2016 (*in review*)

Conceptual Model: Possible Approaches

How do forests and forest change affect the magnitude and duration of snow storage across the PNW?

Today and in a warming climate?



Empirical Model

Lundquist et al. 2013

Robles et al. 2014

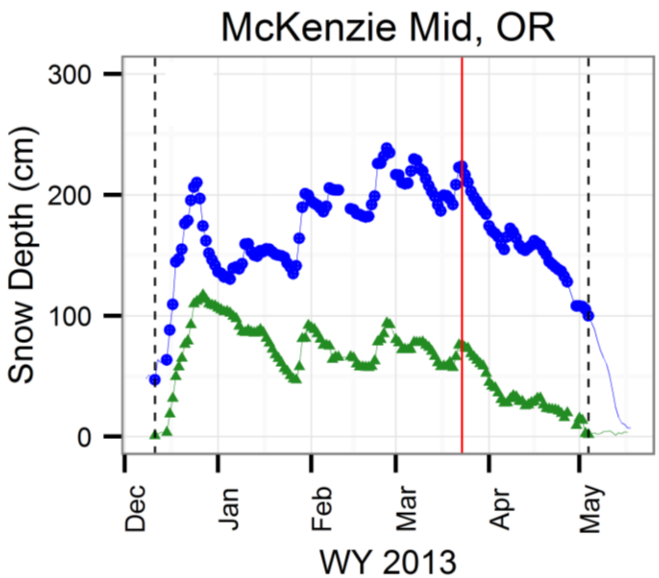
Distributed Model

Ellis et al. 2013

Du et al. 2016

Conceptual Model

1a. Canopy Snow Interception and Loss



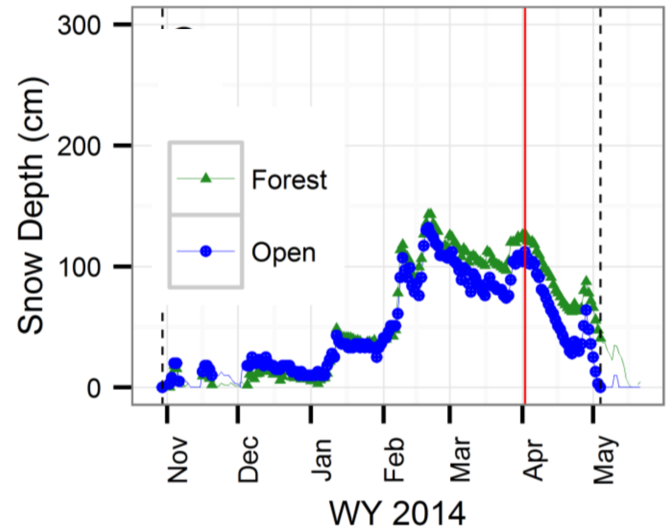
<u>Canopy Snow Interception & Loss</u>

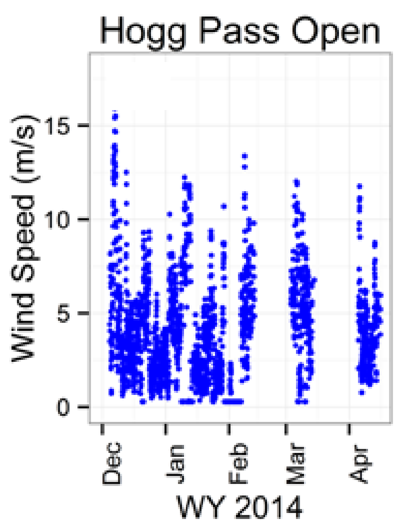
- Forest canopy intercepts snow
- Snow melts, sublimates, or drops to snowpack

Figure 3, Dickerson-Lange, et al. 2016 (*in review*)

1b. Wind Effects

Example: Hogg Pass, OR – Cascade Crest





<u>Wind-driven Snow Deposition</u>

- High deposition of snow within forests
- Other mechanisms:
  - Redistribution?
  - Wind unloading?

Figure 3, Dickerson-Lange, et al. 2016 (*in review*)

1b. Wind Effects

Example 2: Palouse Region of north-central Idaho

1b. Wind Effects

Controls

- Topographic exposure
- Region
- Opening size & fetch

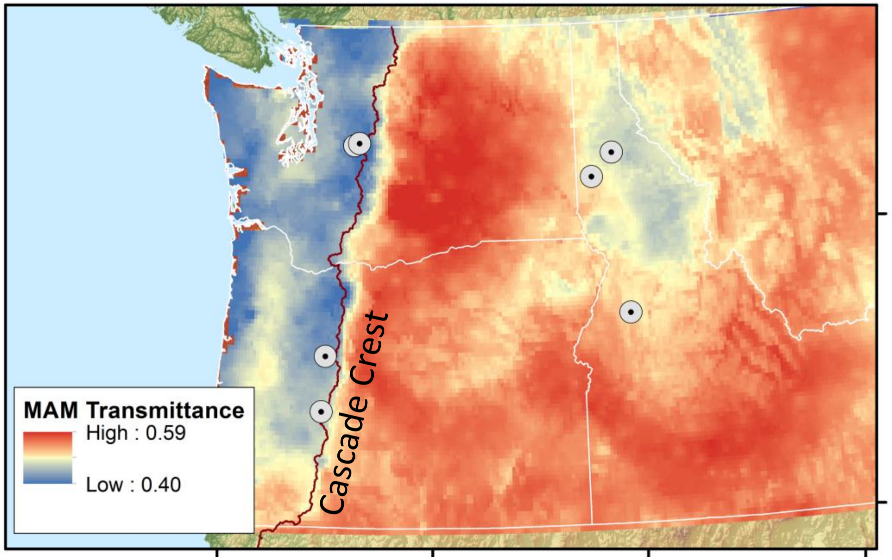
See: Hiemstra *et al.*, 2002
Geddes *et al.*, 2005
Qiu *et al.*, 2011

2. Forest Effects on Snow Ablation

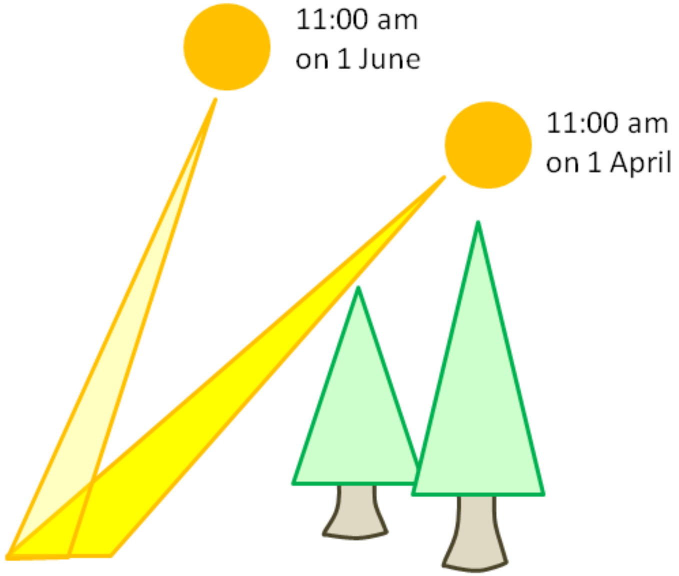
How much does forest shading modify ablation (melt) rates?

Depends on conditions during the snow ablation season

Spring Cloudiness



Solar Elevation

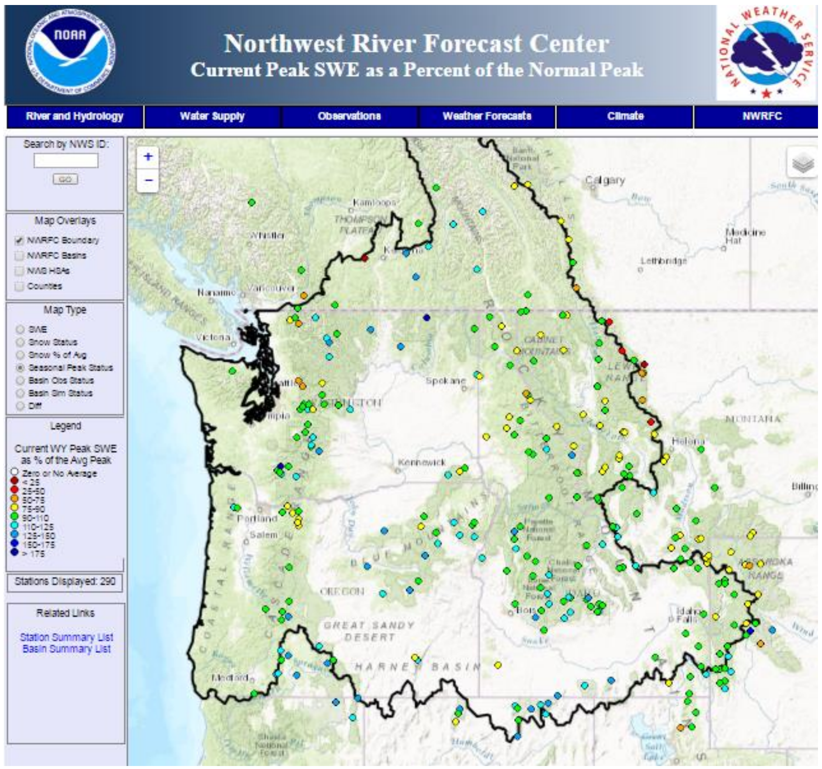


Average Snow Disappearance Timing

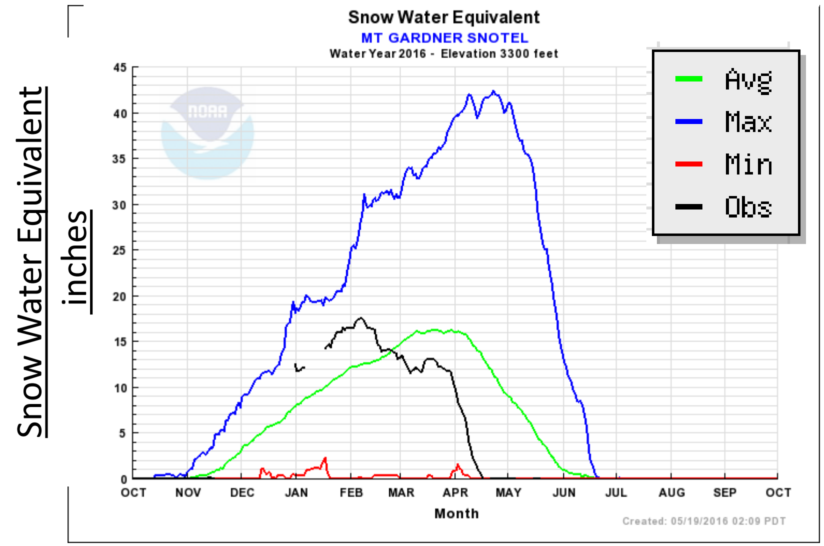
NRSC SNOTEL Data

NW River Forecast Center Interface

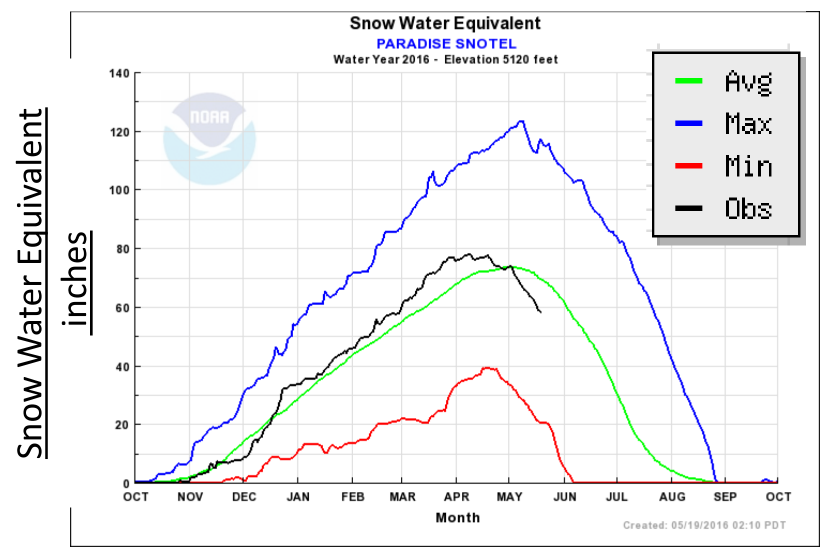
http://www.nwrfc.noaa.gov/snow/



Mt Gardner SNOTEL (elev 3300 feet)



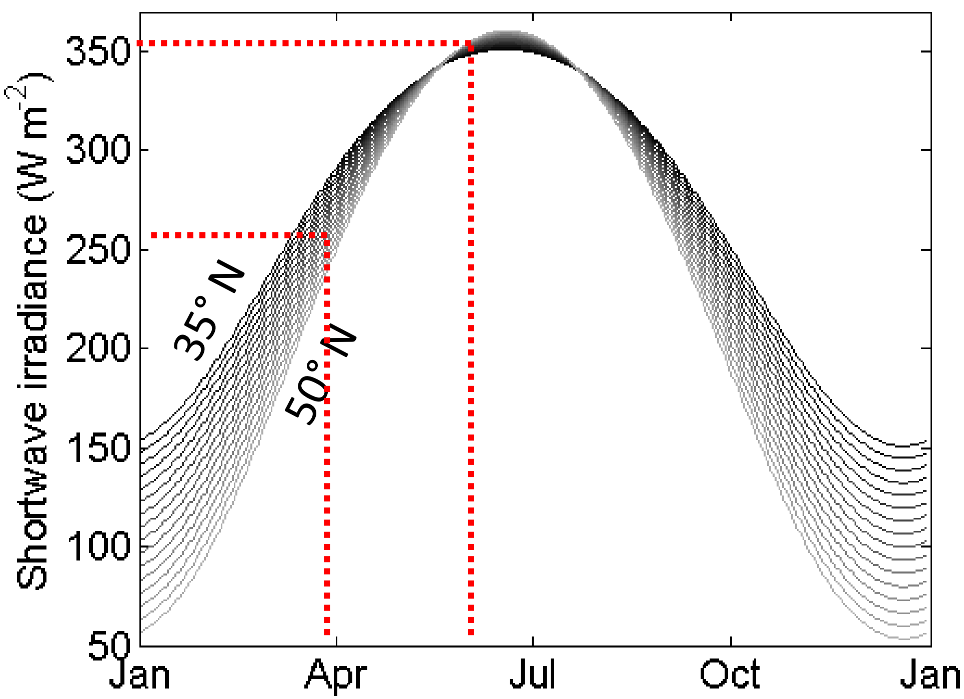
Paradise SNOTEL (elev 5120 feet)

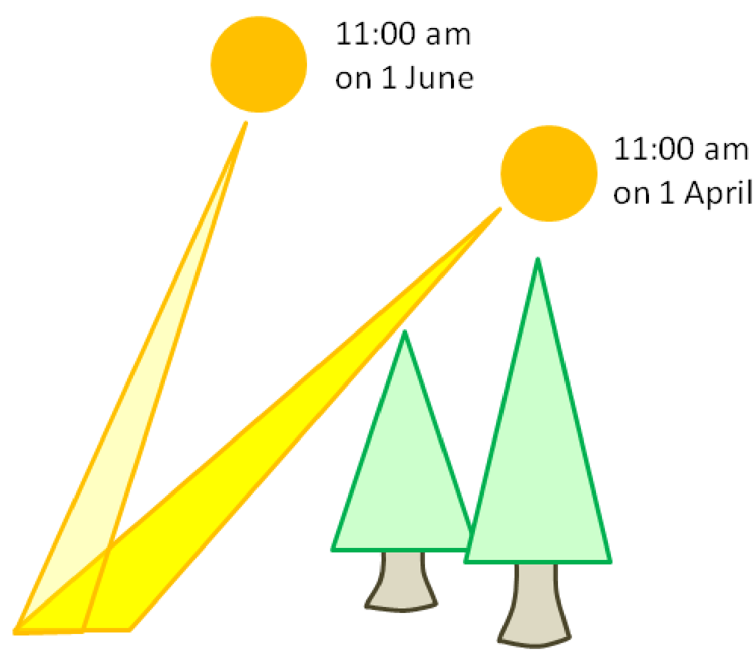


Solar Elevation

Solar elevation varies with time of year and latitude, and influences how important the forest is for shading

Earlier in the year:
less incoming solar radiation per unit area
AND
more likely to be shaded by topography and forest

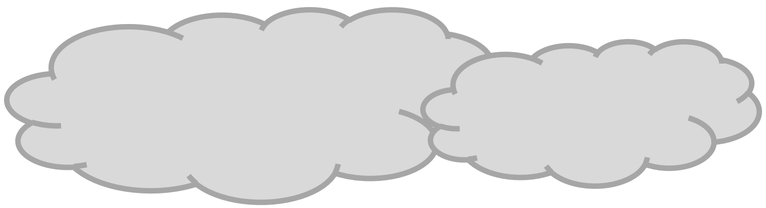


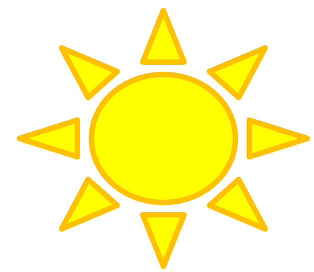


Cloudiness + Solar Elevation

How important is the forest for shading from sunlight?

Importance of forest effects on shading the snow from sunlight





Early SDD + Cloudy

Low
forest shading
effect

Late SDD + Cloudy

Low
forest shading
effect

Early SDD + Sunny

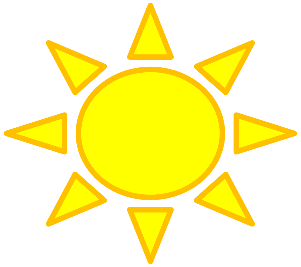
Medium
forest shading
effect

Late SDD + Sunny

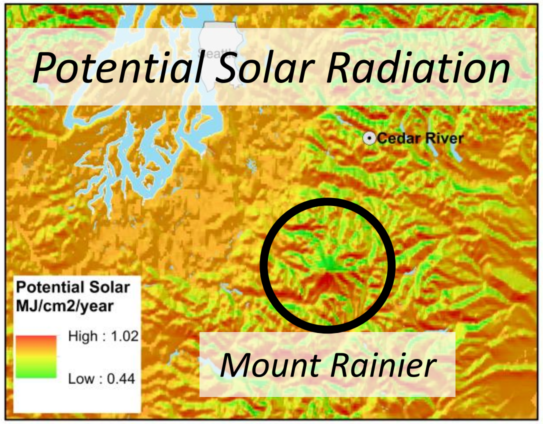
High
forest shading
effect

Cloudiness + Solar Elevation

How important is the forest for shading from sunlight?



Topographic Position

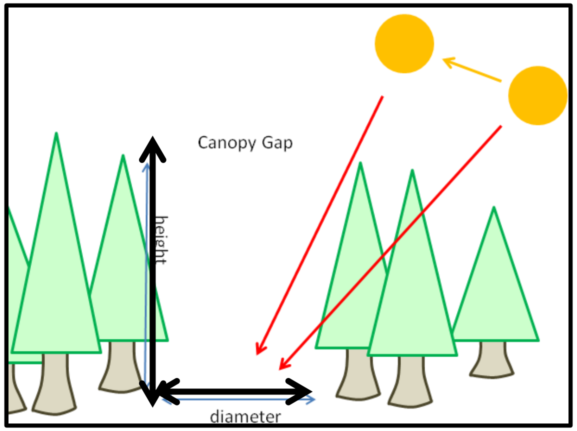


See:
Strasser *et al.*, 2011
Ellis *et al.*, 2013

Black Carbon from Fire

See:
Burles and Boone, 2011
Gleason *et al.*, 2013
Gleason *et al.*, 2016

Forest Gap Geometry



See:
Seyednasrollah & Kumar, 2014
Musselman *et al.*, 2015