An Investigation of the Processes that Produce Patterns of Snow Refugia in Complex Terrain

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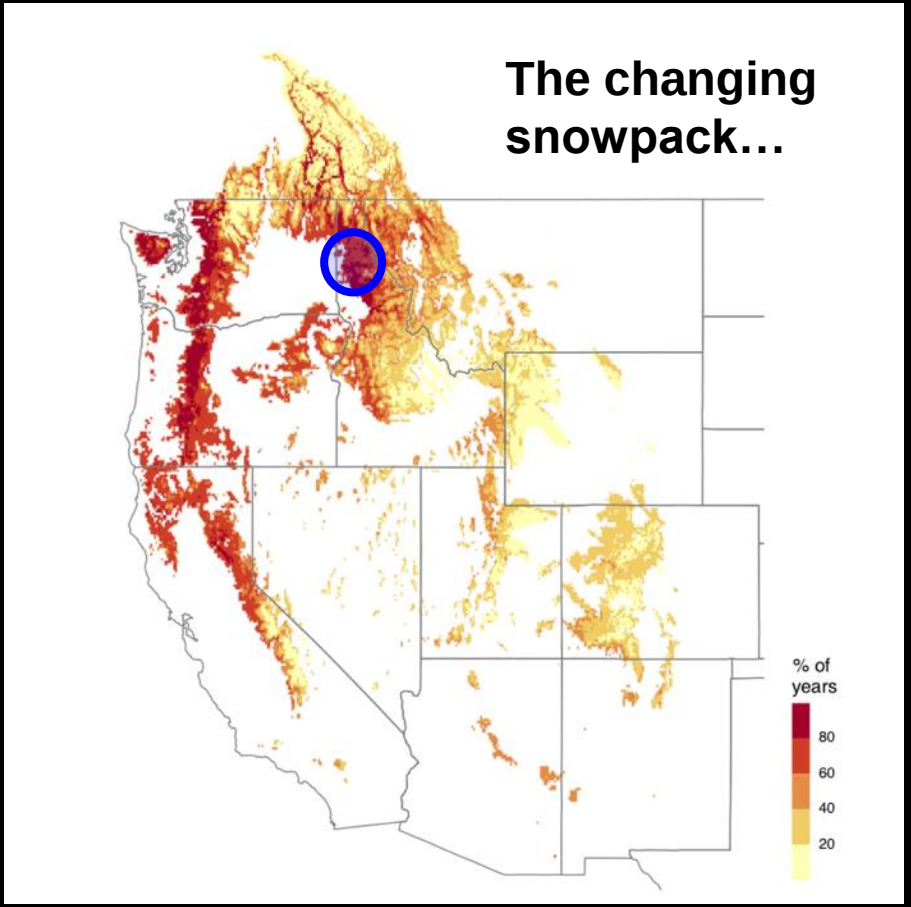
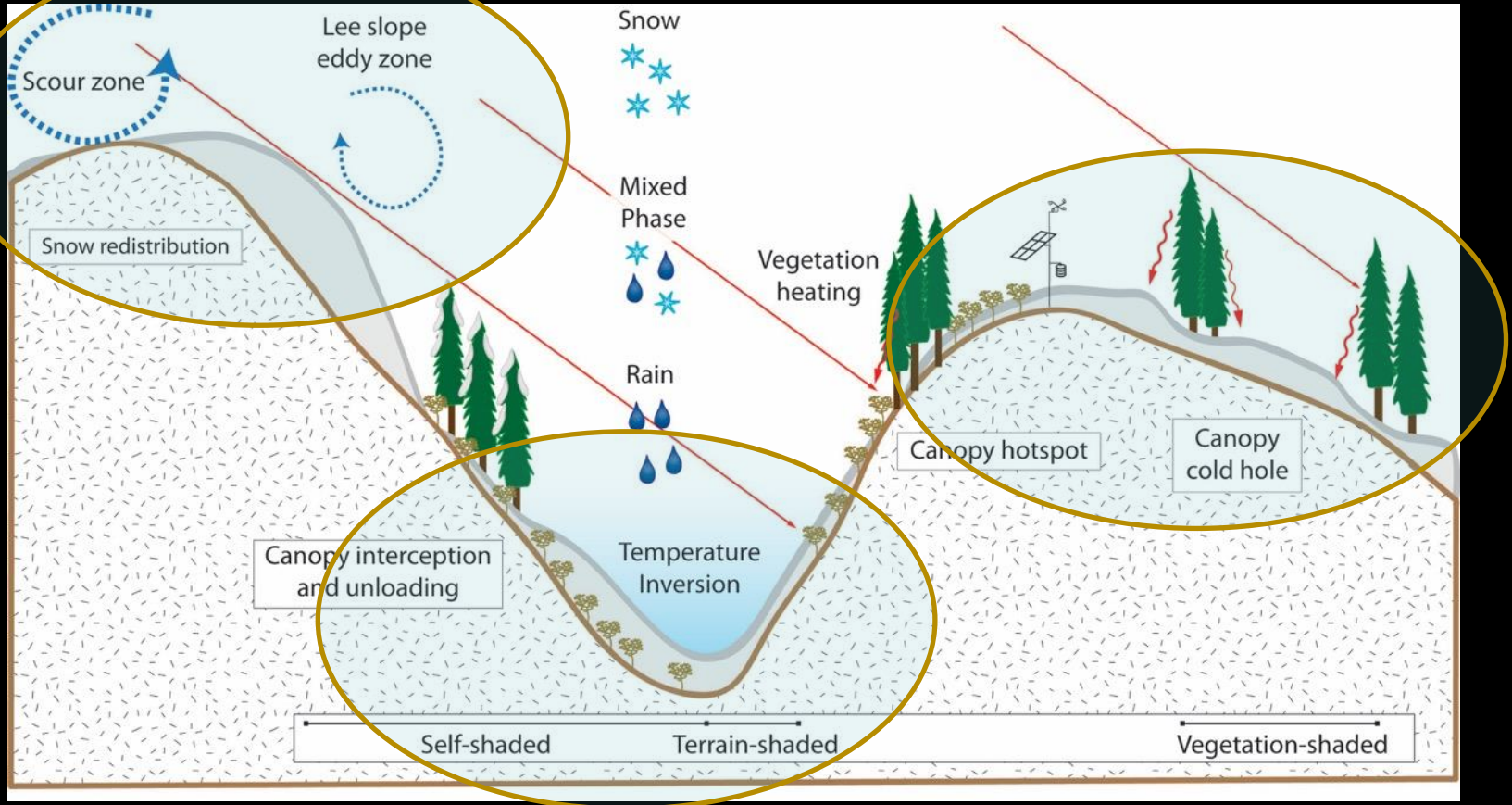
The Context:
Projected Snow in the Western U.S.

- Snow metric patterns are all similar:
  - Rain:snow ratio
  - Peak snow depth
  - Melt timing
  - Successive snow droughts
- Declining low flows…



Marshall, A. M.*, J. T. Abatzoglou, T. E. Link, and C. Tennant. 2019. Projected changes in interannual variability of peak snowpack amount and timing in the western United States. Geophysical Research Letters, 46(15), 8882-8892. https://doi.org/10.1029/2019GL083770.

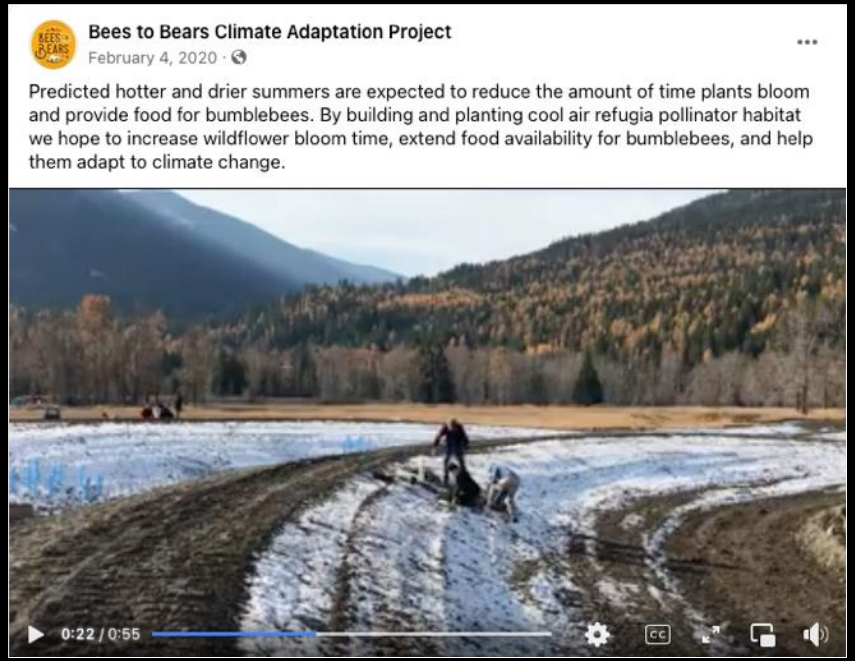
Snow Patterns and Processes in Complex Terrain



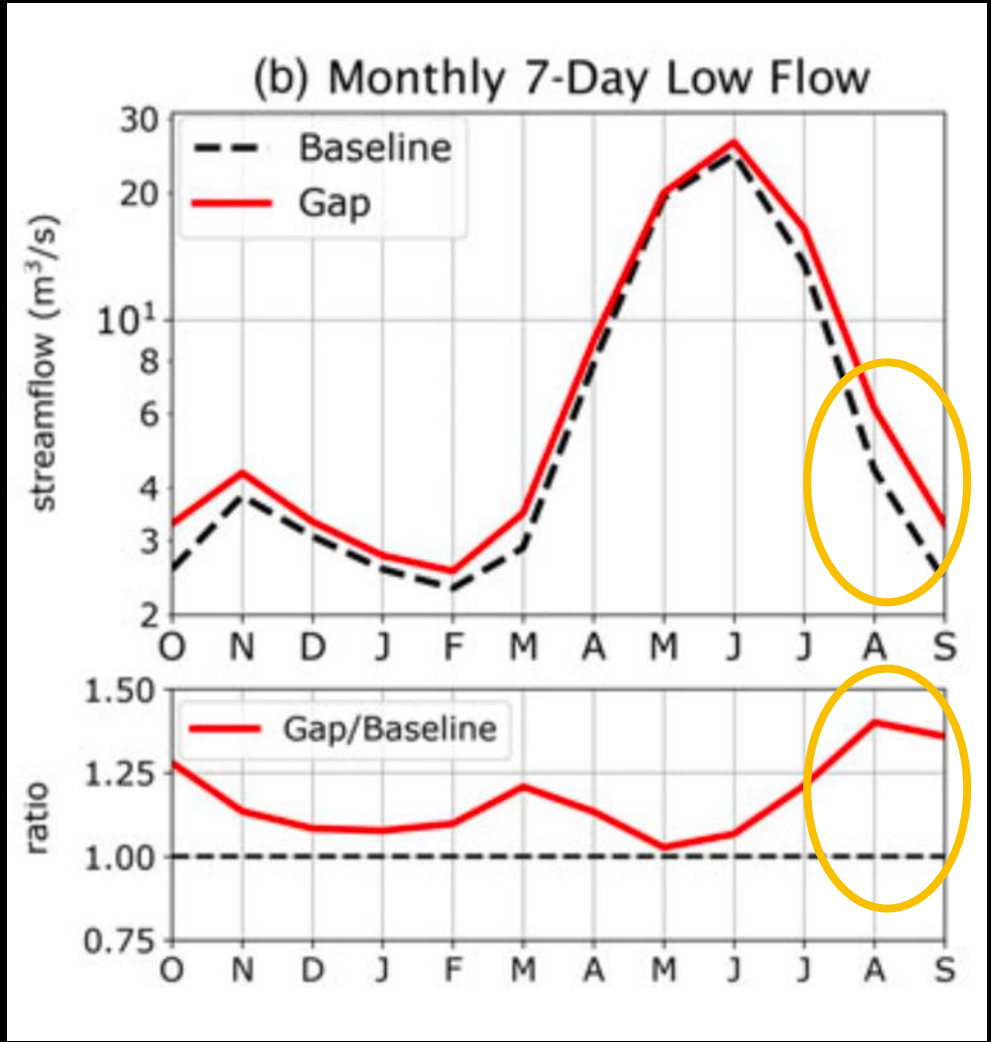
Importance of Snow Refugia

Across Scales…

- Biodiversity hotspots
- Wildlife
- Fire hazard risk reduction
- Hydrograph recession
- Climate change adaptation



Snow Refugia - Forest Gaps - and Low Flows



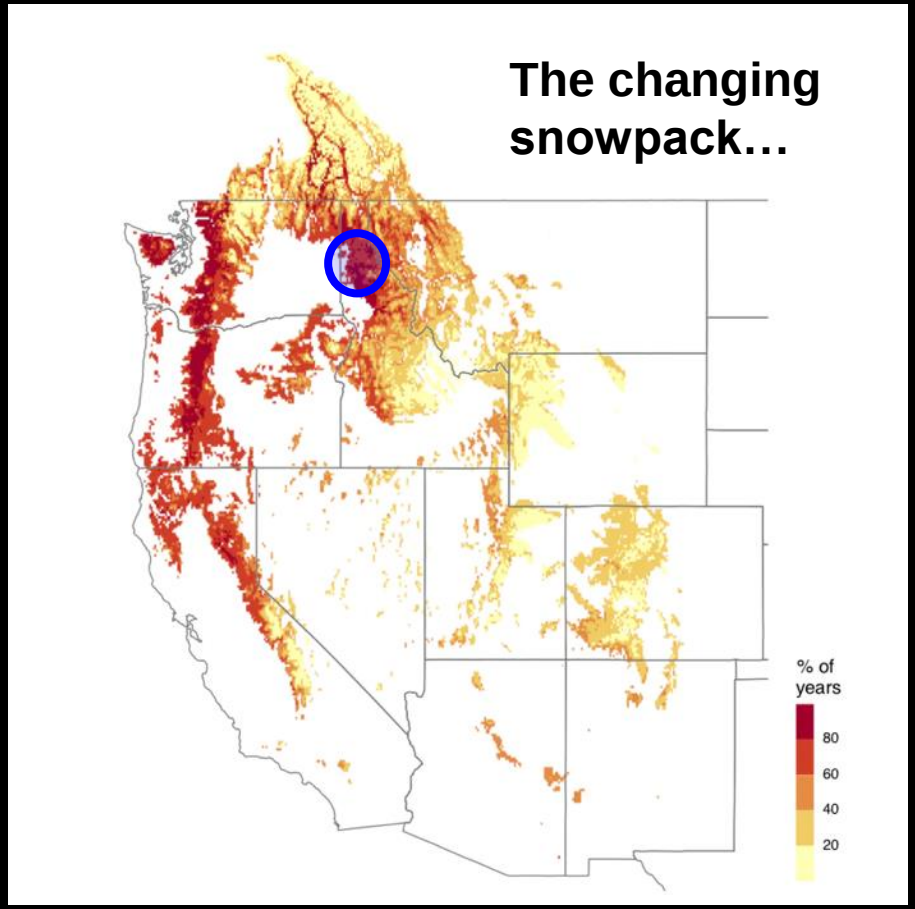
Sun, N., Wigmosta, M., Zhou, T., Lundquist, J., Dickerson-Lange, S., and Cristea, N., 2018. Evaluating the functionality and streamflow impacts of explicitly modelling forest-snow interactions and canopy gaps in a distributed hydrologic model. Hydrological Processes 32(13) 2128–2140.

Objectives

- Snow Refugia Characteristics
  - Rain-Snow Transition Zone
  - Where Do They occur?
  - Sensitivity to Biophysical Characteristics
- Snow Mass and Energy Balance of a Snow Refugia
  - Compare & Contrast: Open, Forest, Snow Refugia

The Field Laboratory

- U.S. Interior Pacific Northwest
- Northern Rockies Ecoregion
- Rain-Snow Transition Zone



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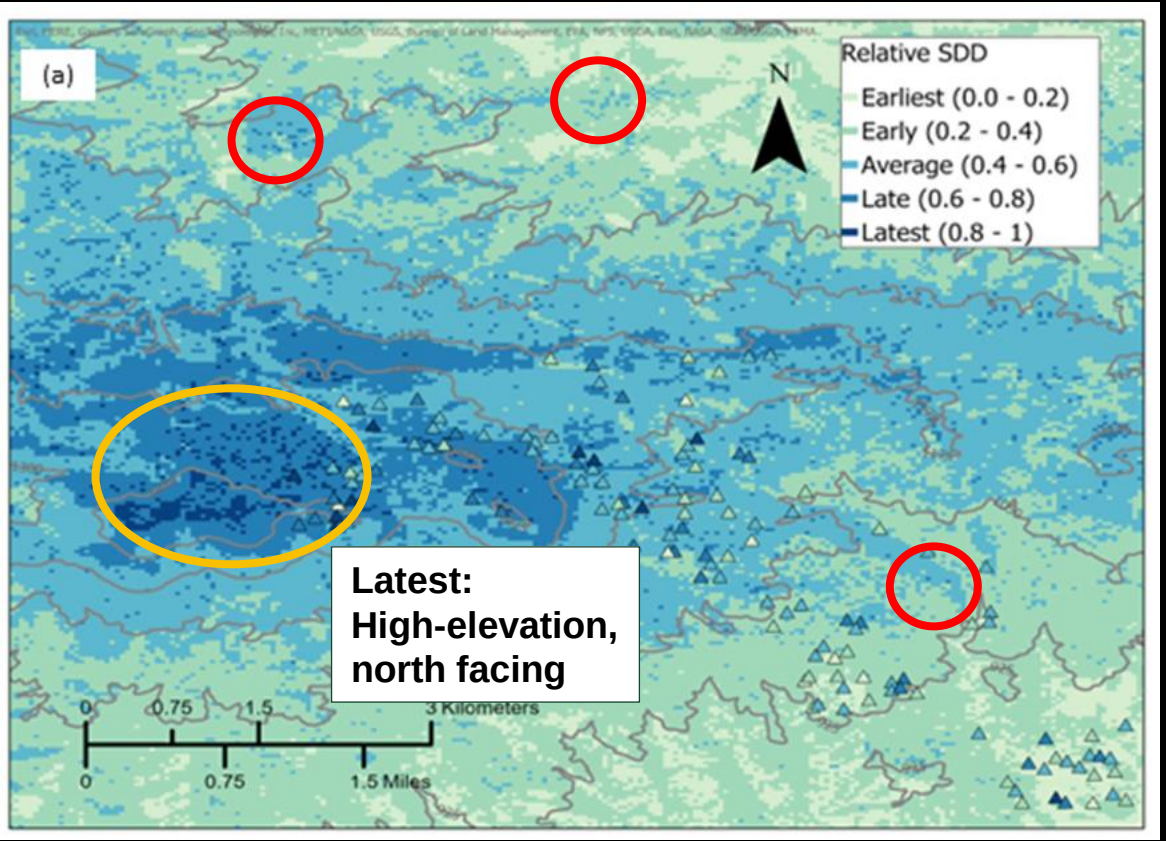
The Field Laboratory
Moscow Mountain, Idaho

Methods:

Stratified Network of Automated Cameras

134 total

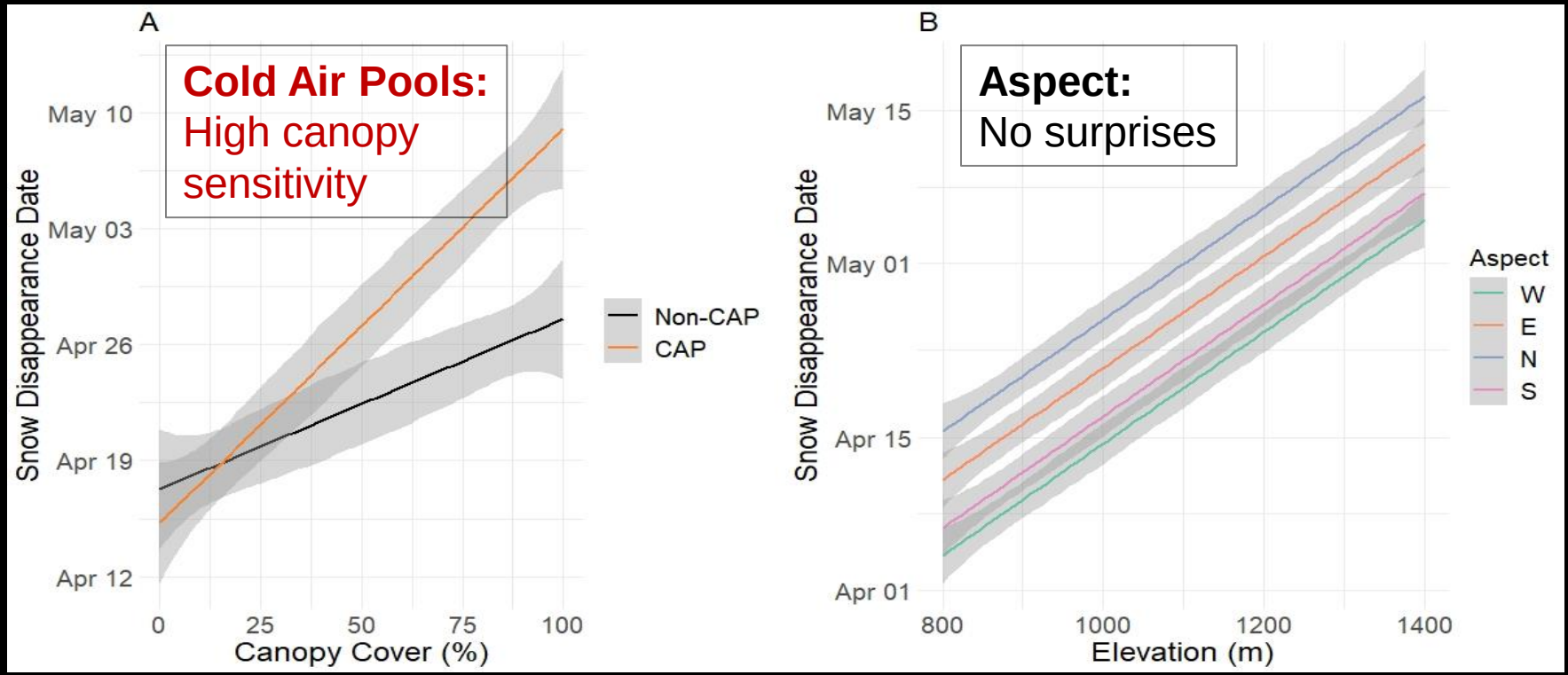
Results: Snow Refugia in the Rain-Snow Zone



Strickfaden, K.M., Marshall, A.M., Svancara, L.K., Ausband, D.E., and Link, T.E., 2023. Understanding the spatiotemporal distribution of snow refugia in the rain-snow transition zone of north-central Idaho. Environmental Research Letters 18(4) 044014.

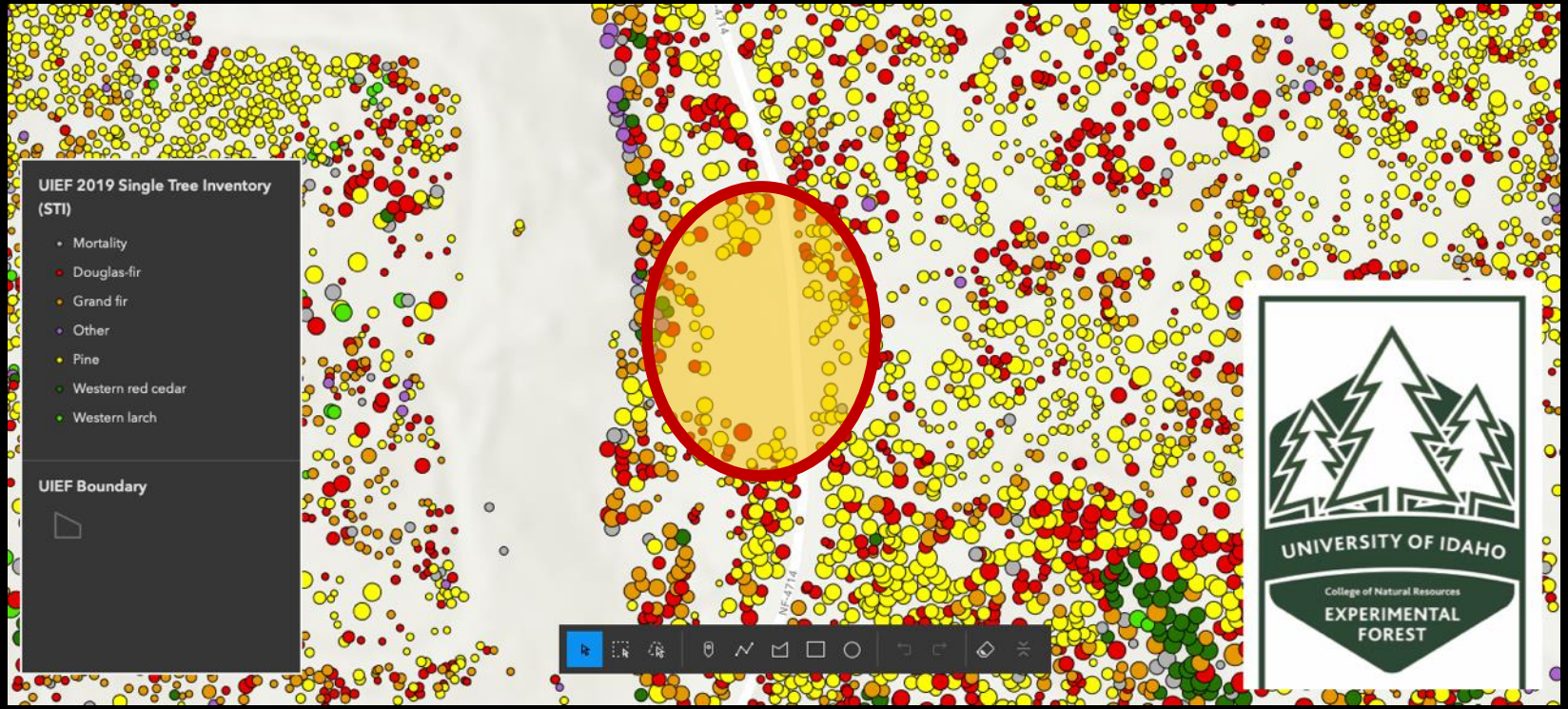
Lots of late snow: Low elevations

Results: Snow Refugia Sensitivity



Mass and Energy Balance Simulation of a Snow Refugium

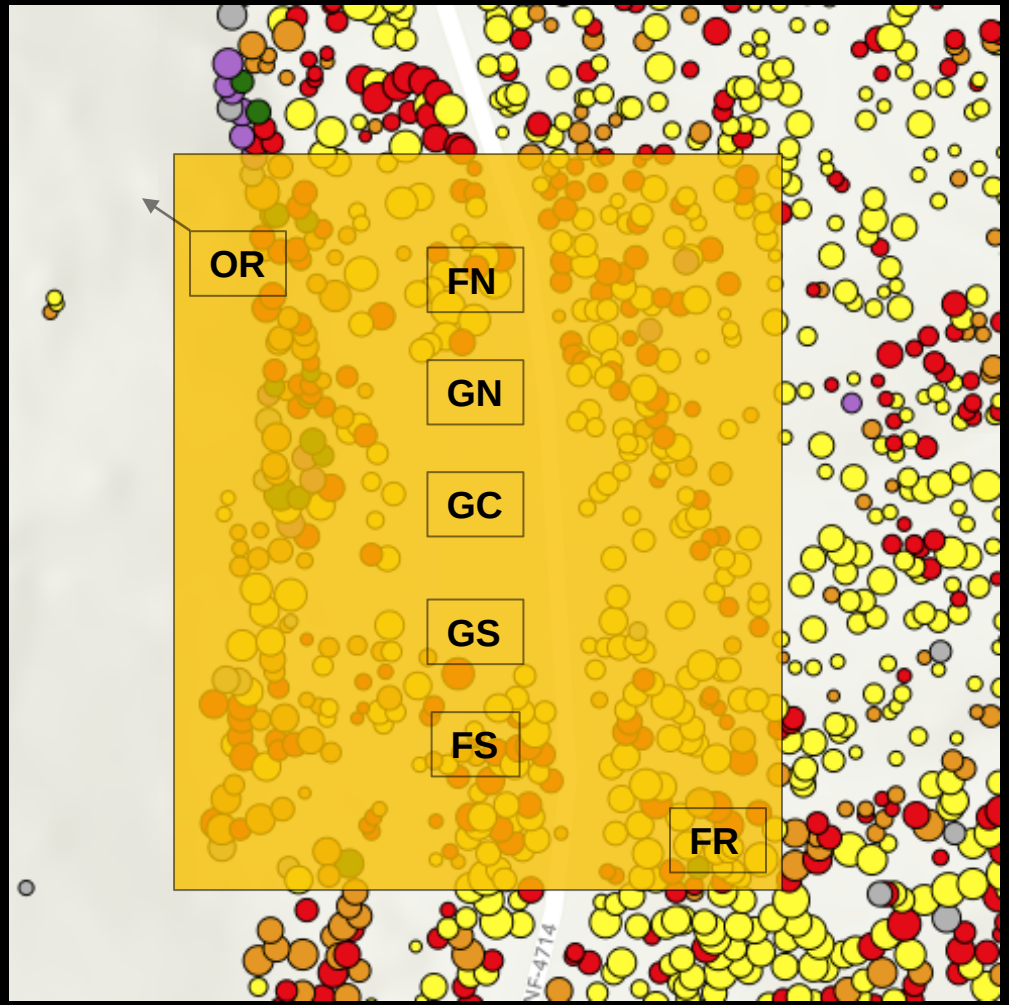
Cold Air Pool, Forest Gap



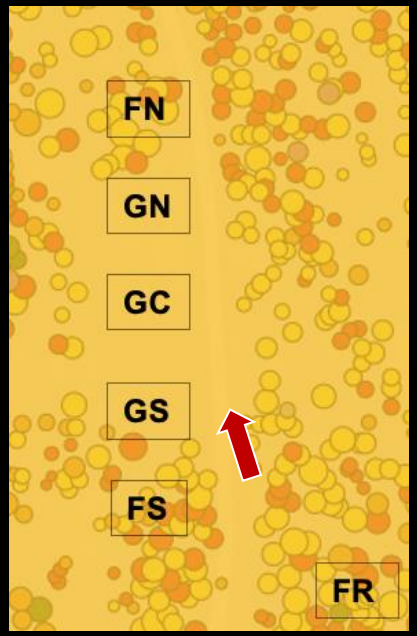
Methods:

Meteorological Observations

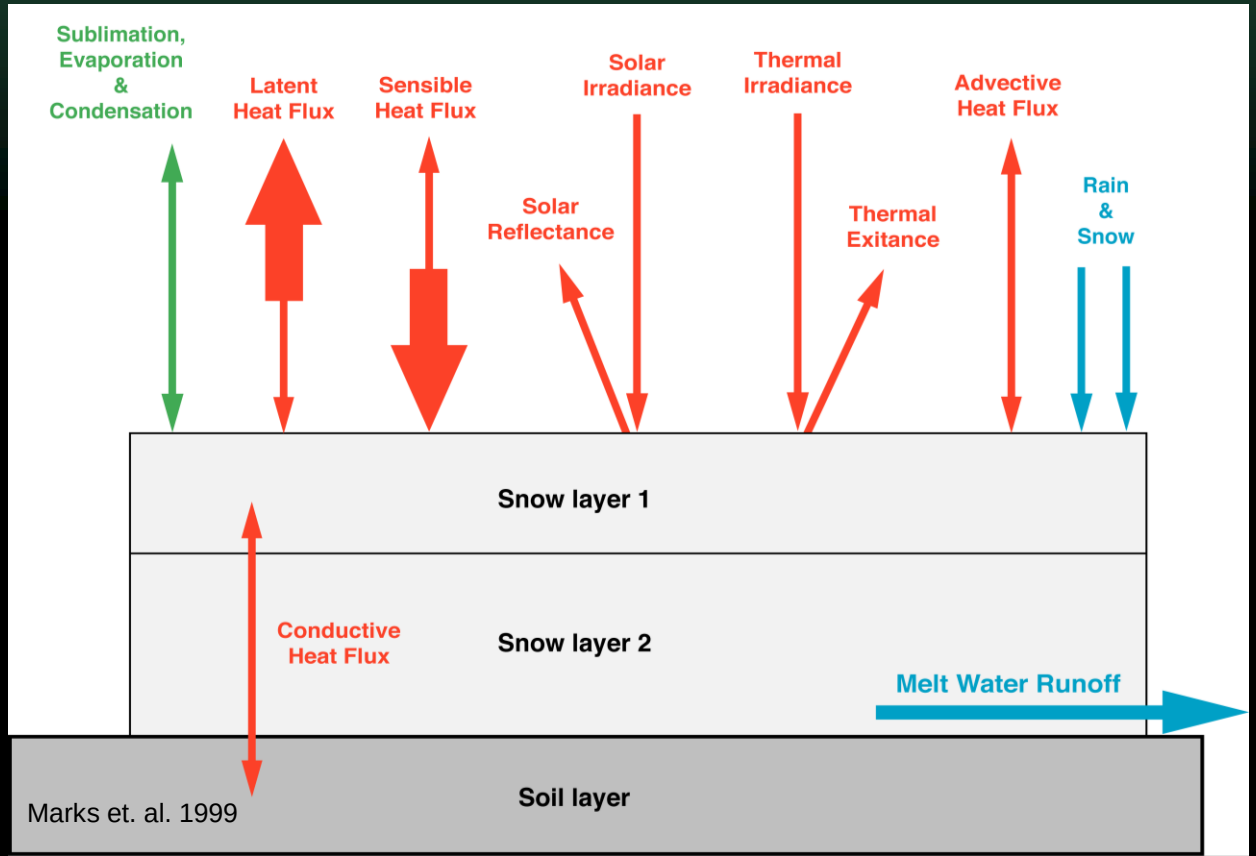
- Shortwave radiation
- Air temperature
- Humidity
- Wind Speed
- Canopy temperature
- Soil temperature



Methods: 7 Meteorological Stations

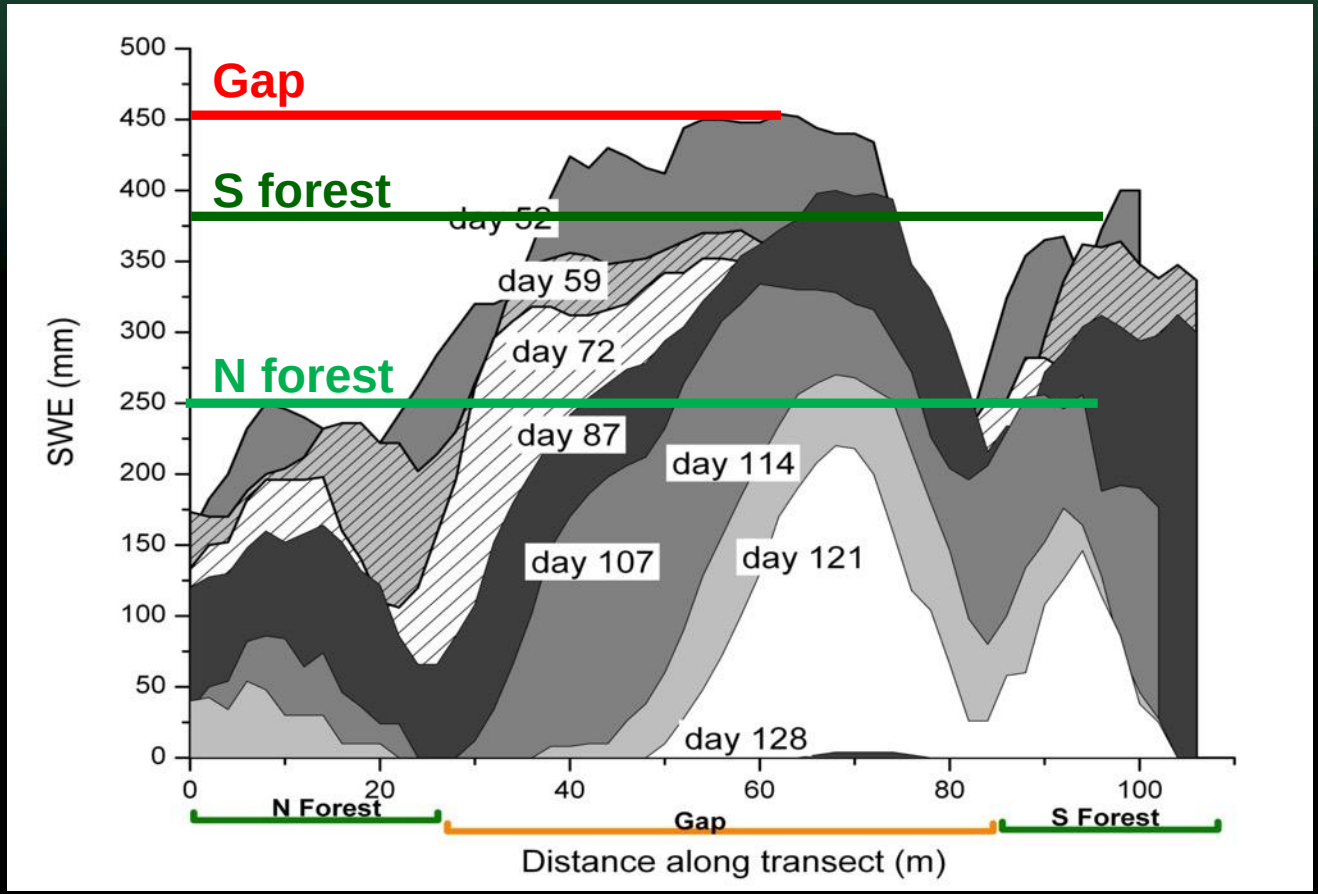


Methods: Mass and Energy Balance Snow Model (snobal)

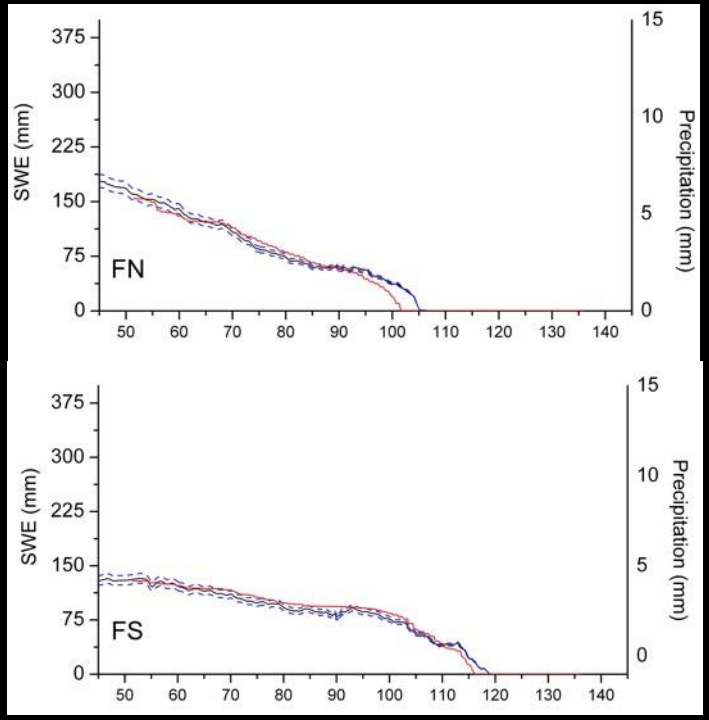


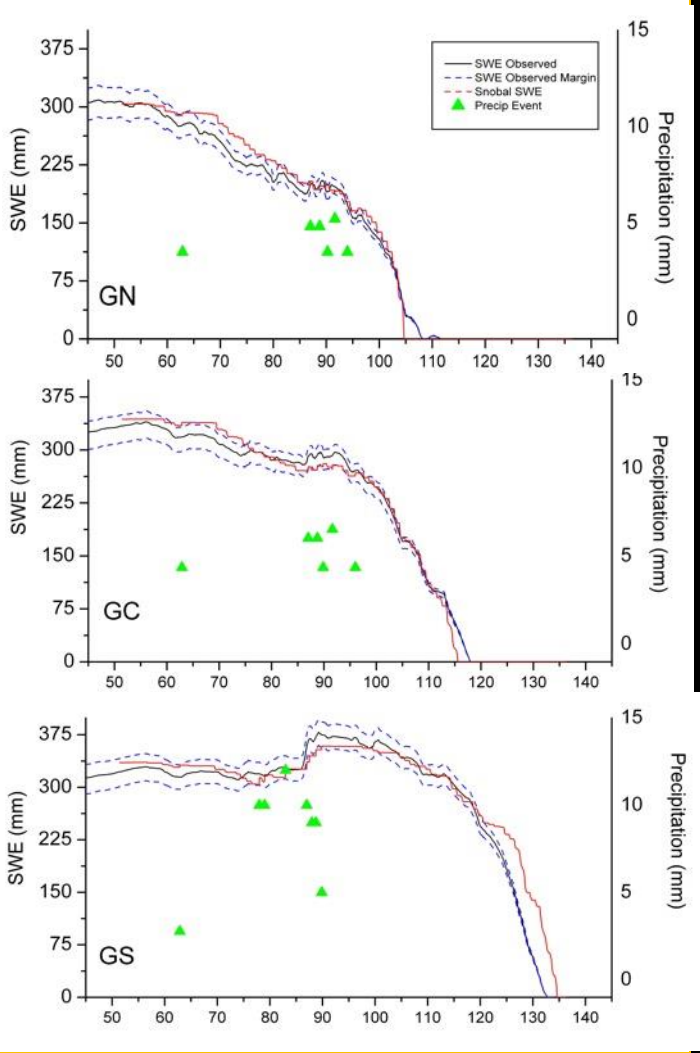
Marks, D., Domingo, J., Susong, D., Link, T., and Garen, D., 1999. A spatially distributed energy balance snowmelt model for application in mountain basins. Hydrological Processes 131935–1959.

Results: Accumulation and Ablation Trends



SNOBAL Model Performance

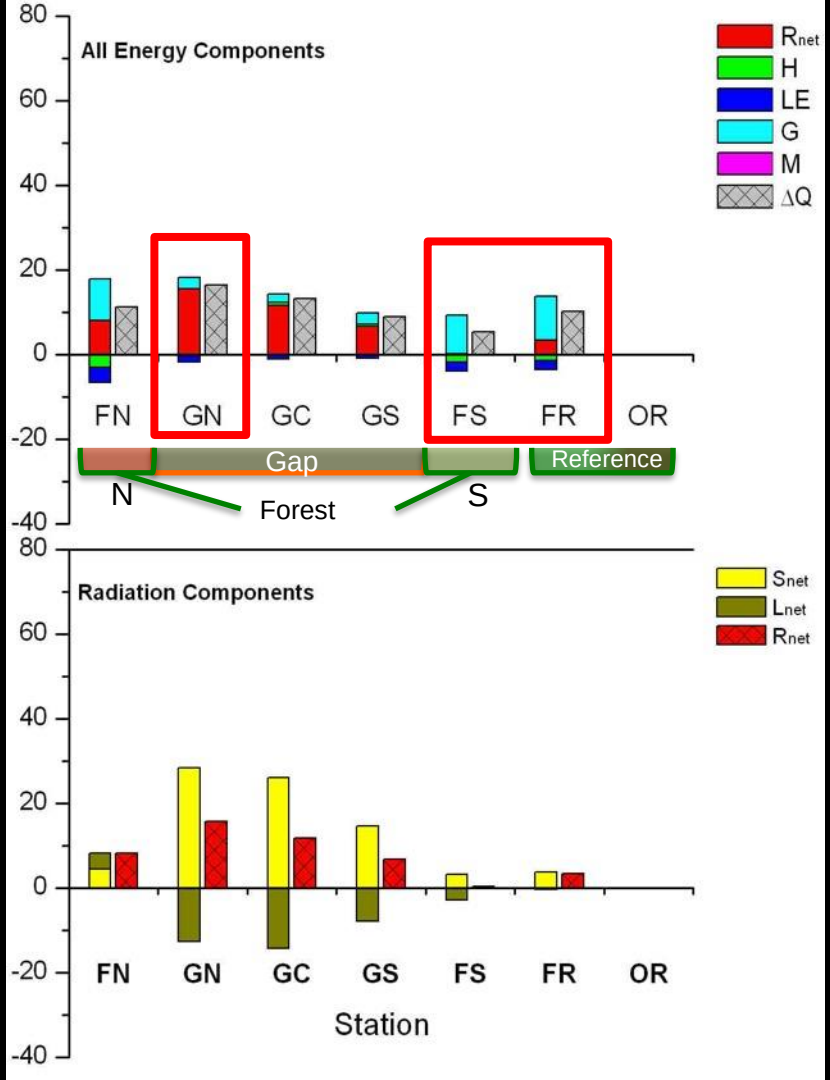




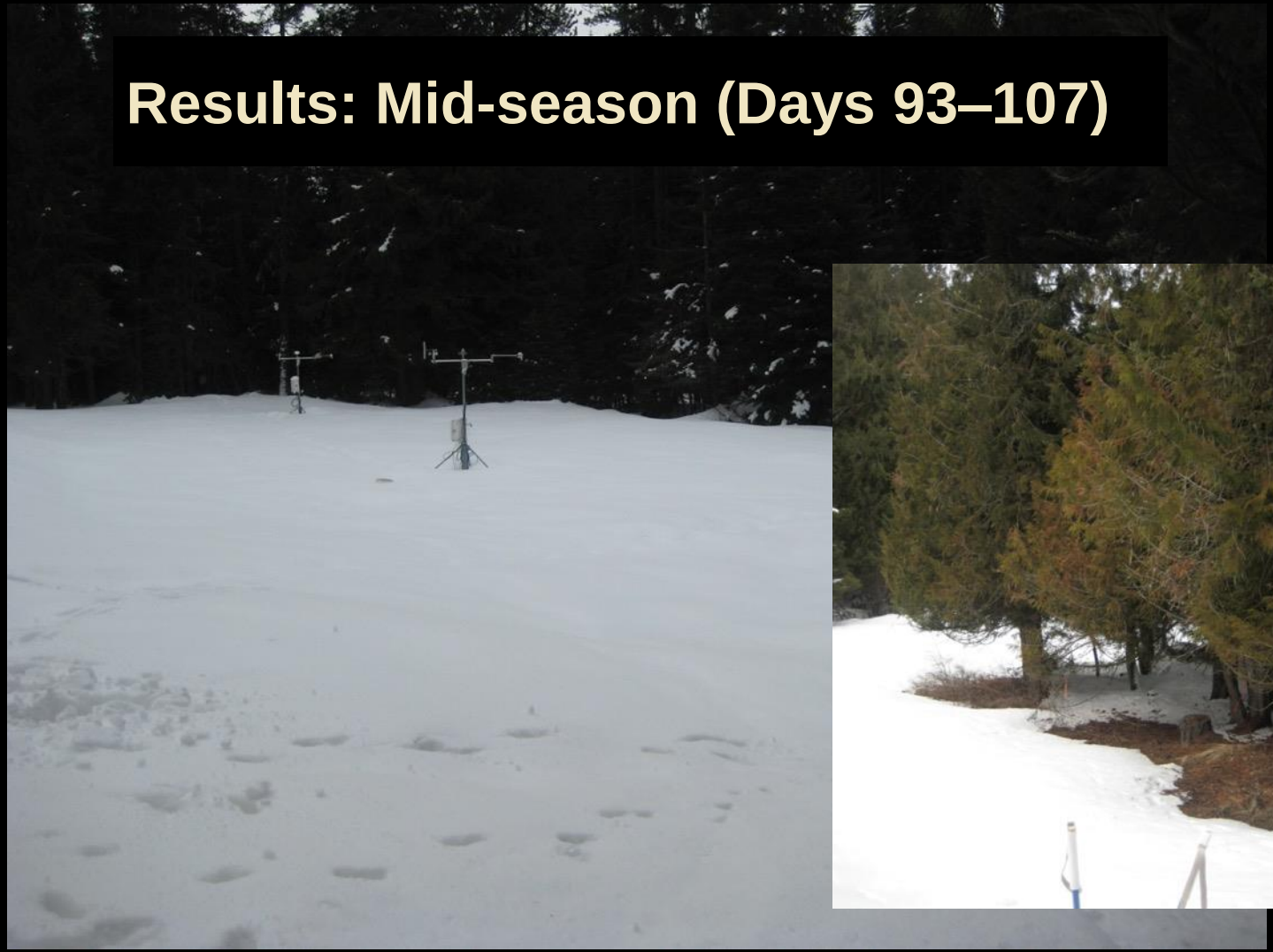
Results - Early season

Days 65–79

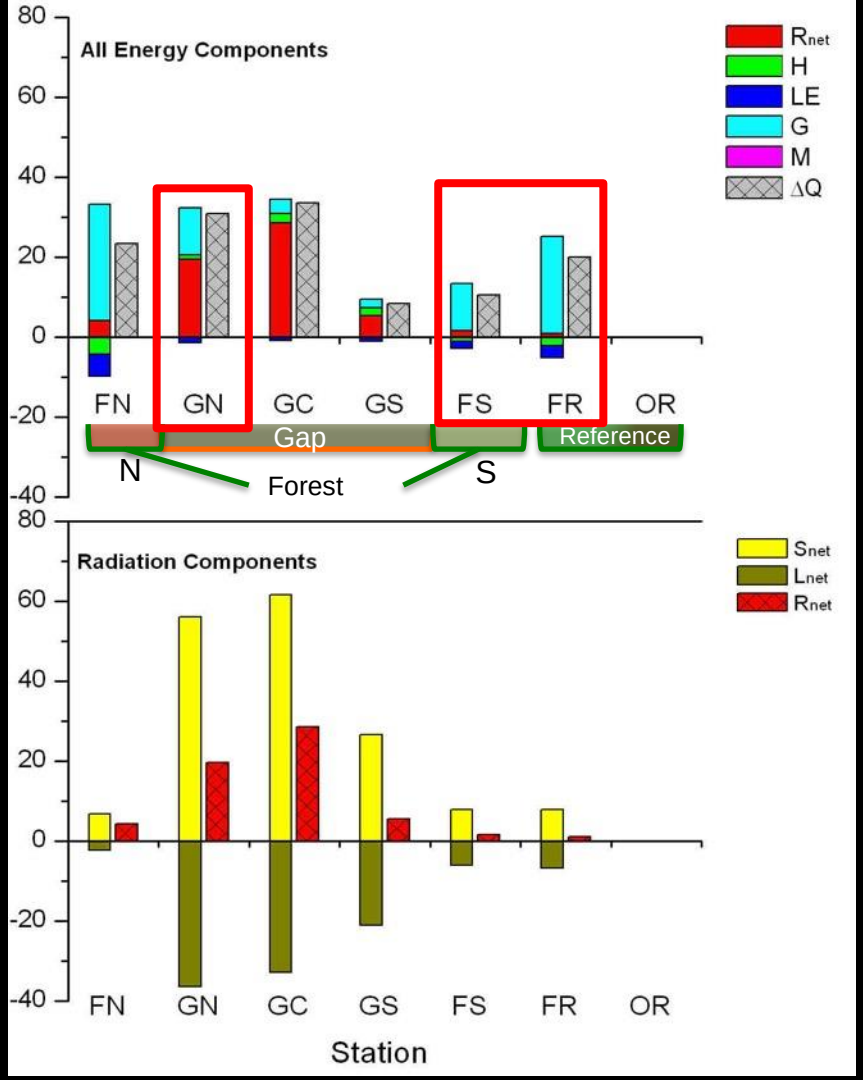
Results: Early Season (Days 65–79)



Results: Mid-season (Days 93–107)

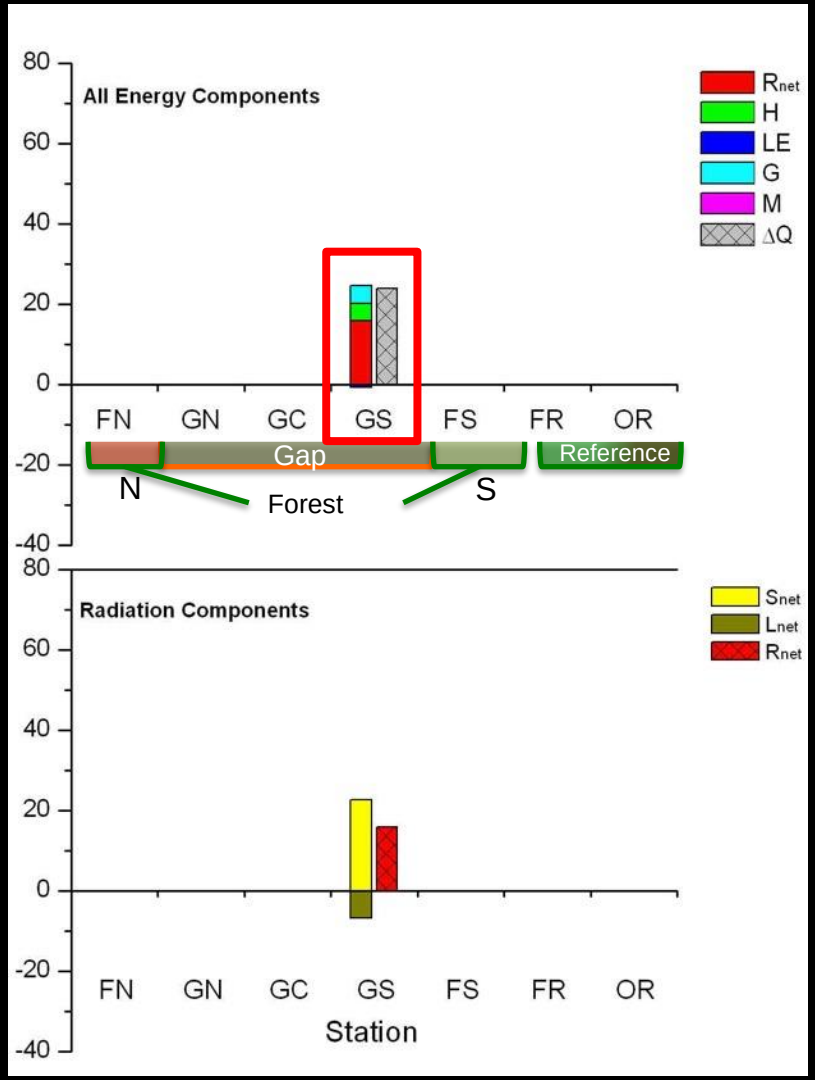


Results: Mid-Season (Days 93–107)



Results: Late- season (Days 121–135)

Results: Late Season (Days 121–135)



Conclusions:
Snow Refugium Characteristics

Peak SWE
~ +52% SWE

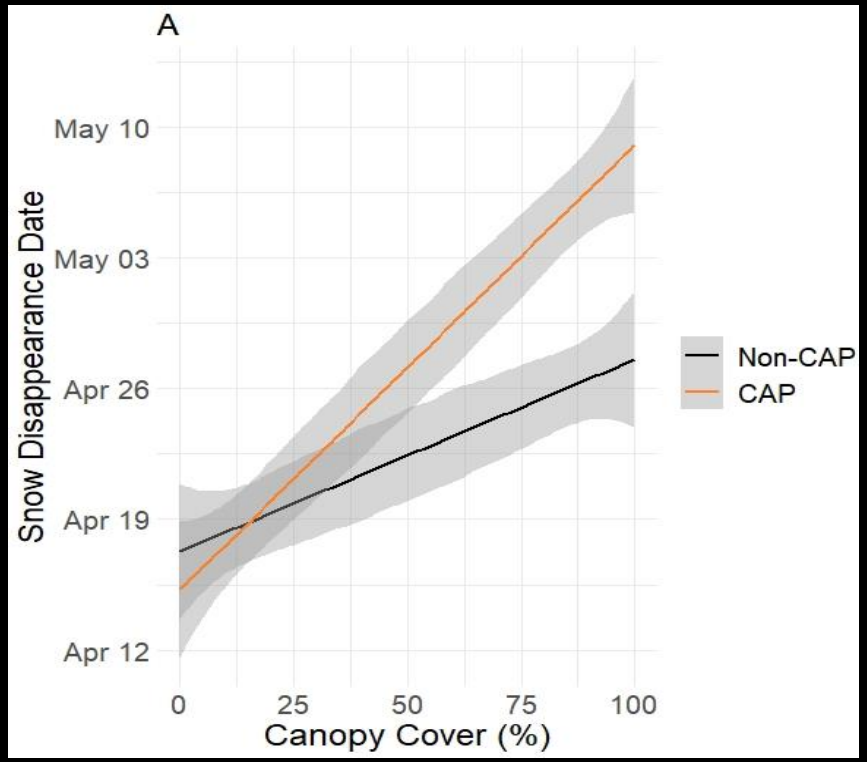
Snow Disappearance Date
~ 60 day melt delay vs. open
~ 20 day melt delay vs. forest

Canopy Gap Edge
- No interception
- High SWE
- Low longwave radiation
- Low shortwave radiation

Cold Air Pool
- Low wind
- Low turbulent fluxes
- Stable local atmosphere

Energy Fluxes
- Negative turbulent fluxes
- Radiation minimal
  - Until late season
- Large soil heat flux !?
  - Role of littler?
  - Tg: +0.5 to +1.0 ° C
  - Exfiltration ?

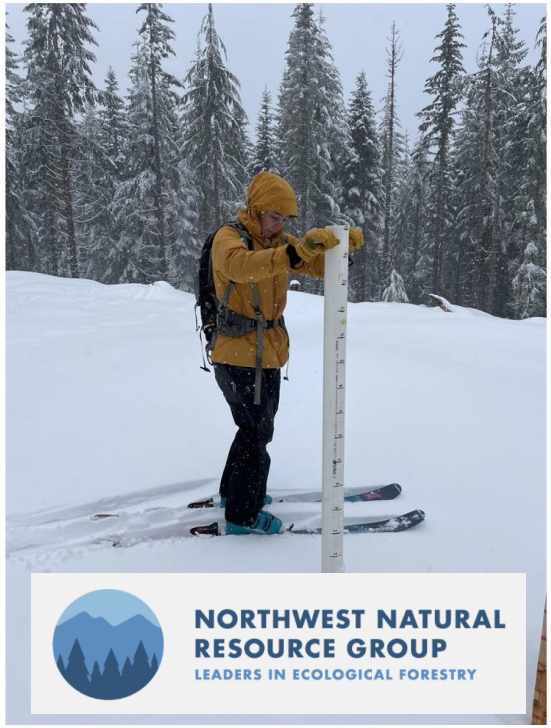
Conclusions: Snow Refugia Sensitivity



Cold Air Pools

- Limited turbulent flux
- Radiation dominates
- High canopy sensitivity

Refugia Creation – WA Cascades



An NNRG technician takes a snow core in the center of the gap cut.

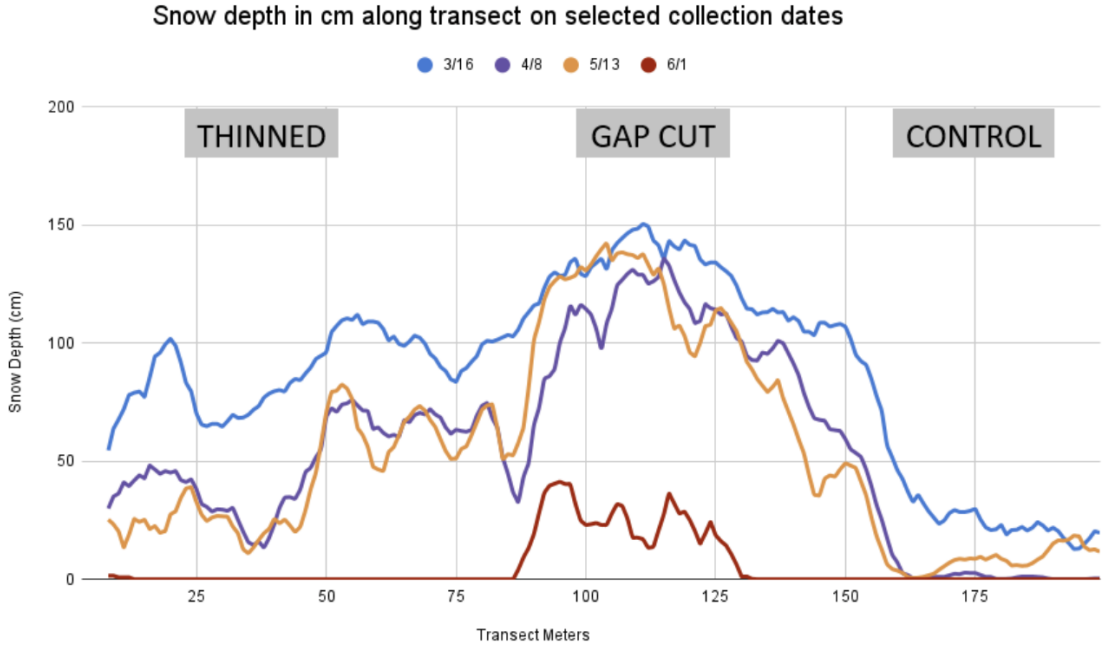


Figure 1: Snow depth in cm at each collection date by distance along a transect. The figure displays snow depth throughout the season, and is color-coded by date. The transect passed through, from left to right, the thinned area (meters 1–82), the gap cut (83–152) and the control area (153–200)


Thank You!
Questions?
NORTHWEST
Climate Adaptation
Science Center
University of Idaho
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RESEARCH
EXTENSION
CSREES
FOREST SERVICE
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