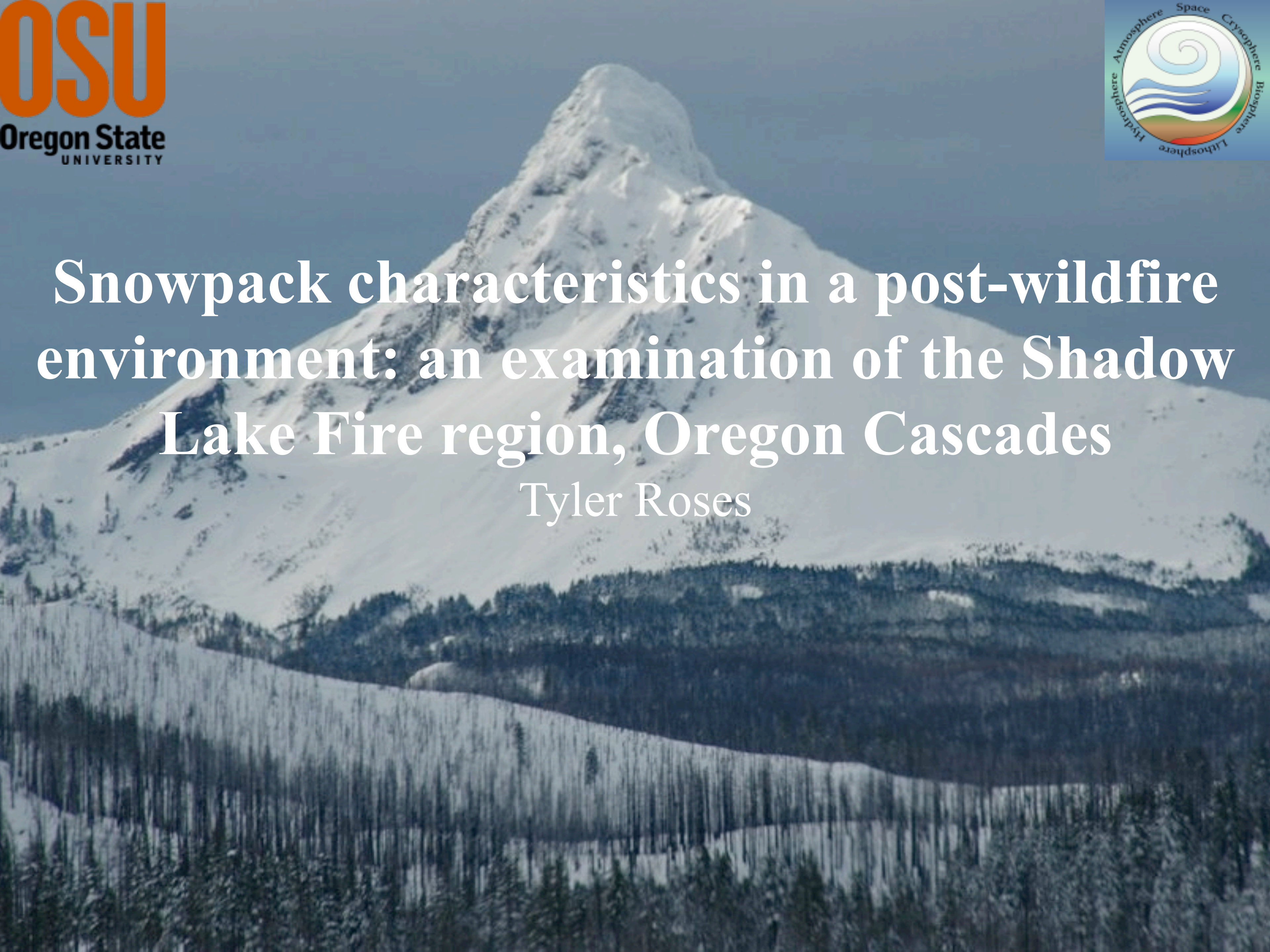
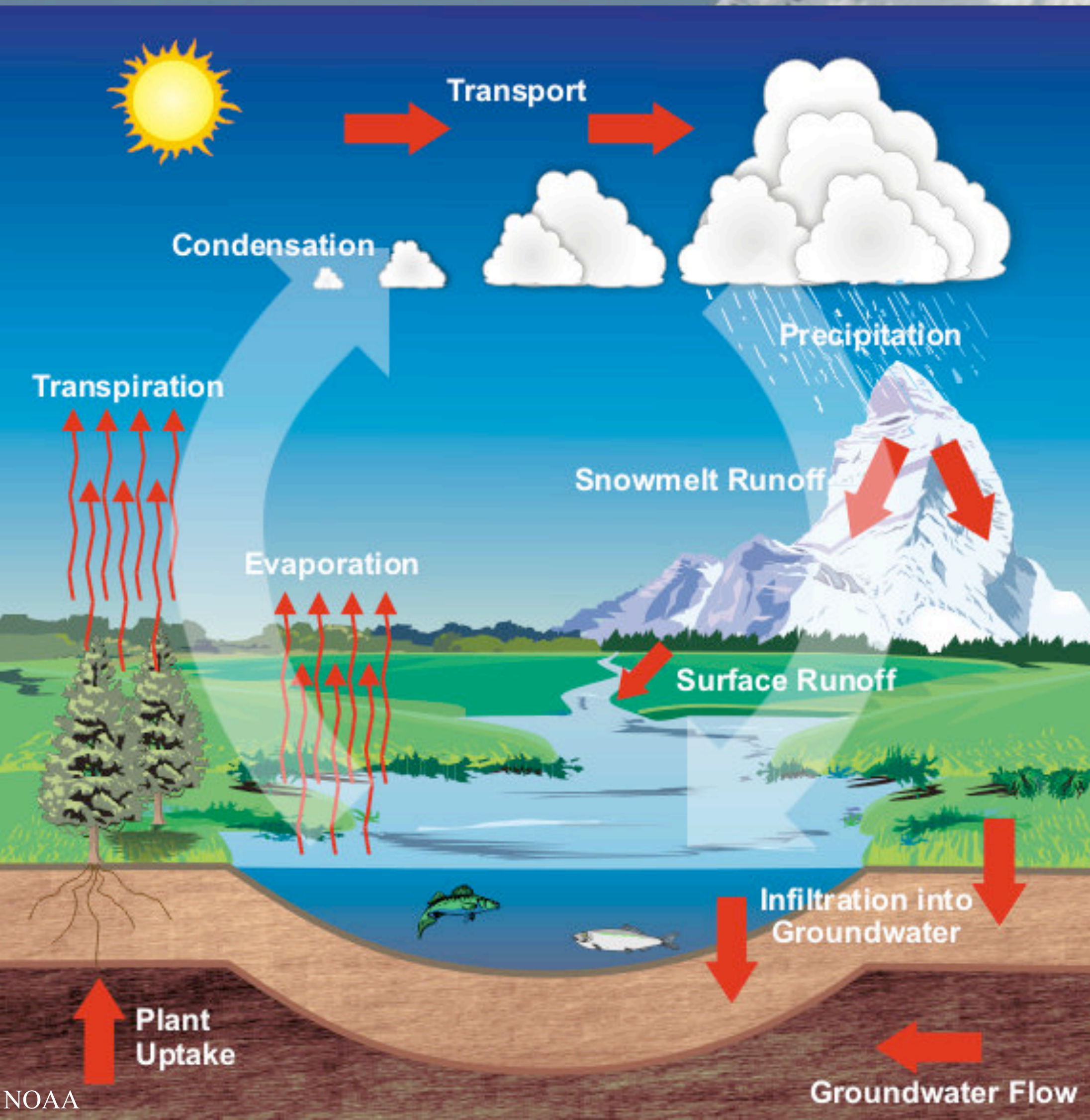


Snowpack characteristics in a post-wildfire environment: an examination of the Shadow Lake Fire region, Oregon Cascades

Tyler Roses

Why are snow studies important?

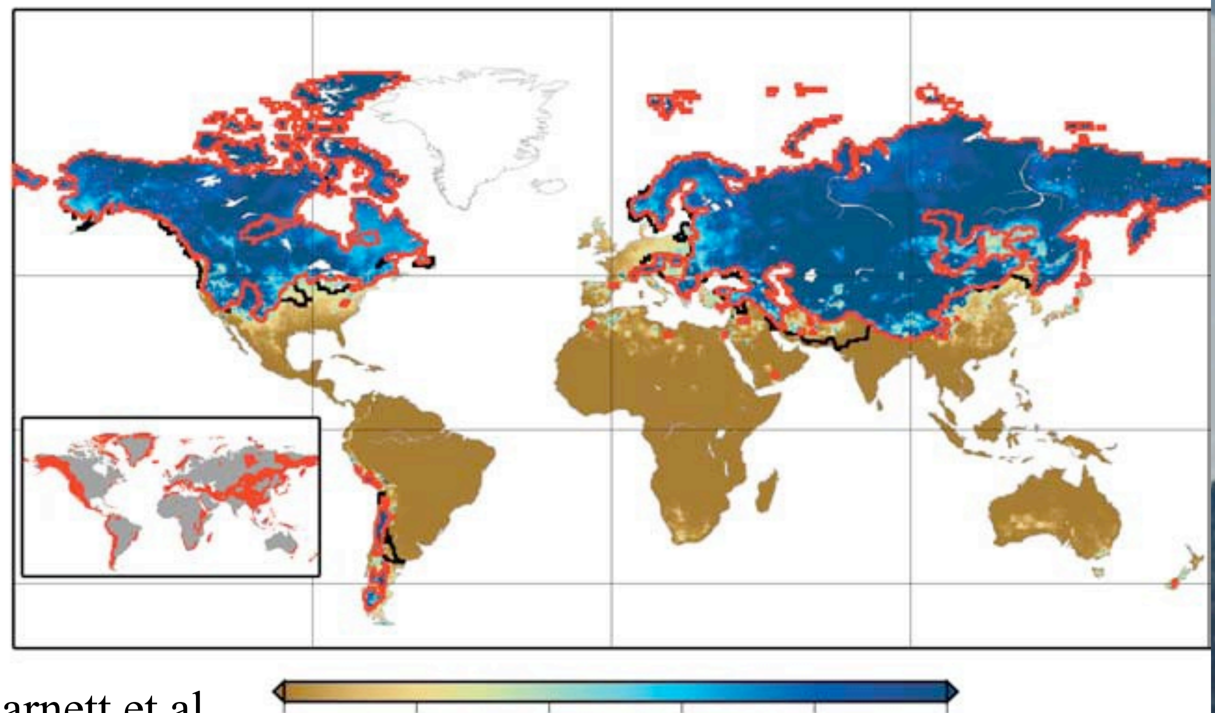
The Water Cycle



NOAA

- Snow is an important part of the hydrological cycle
- In regions like the Pacific Northwest more than 50% of annual precipitation in mountainous regions comes in the form of snow
- Snowmelt runoff is later used for recreation, hydropower, agriculture, drinking water, and municipal purposes
- Slow melting snow is the most effective way of recharging the groundwater supply

Global Distribution of Snowmelt Dominated Streamflow



Barnett,et.al

Figure 1 | Accumulated annual snowfall divided by annual runoff over the global land regions. The value of this dimensionless ratio lies between 0 and 1 and is given by the colour scale, *R*. The red lines indicate the regions where streamflow is snowmelt-dominated, and where there is not adequate reservoir storage capacity to buffer shifts in the seasonal hydrograph.

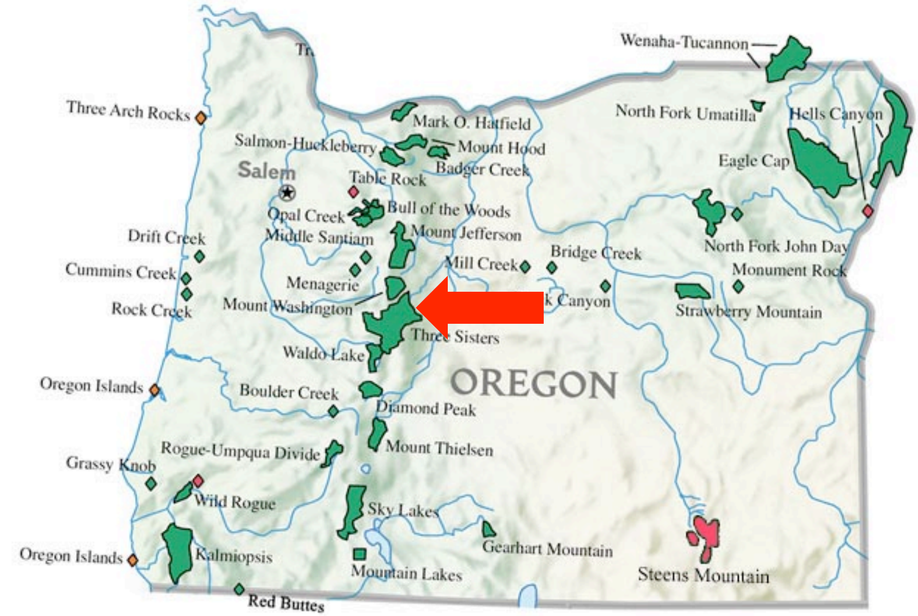
•Streamflow in blue regions is primarily snowmelt dominated

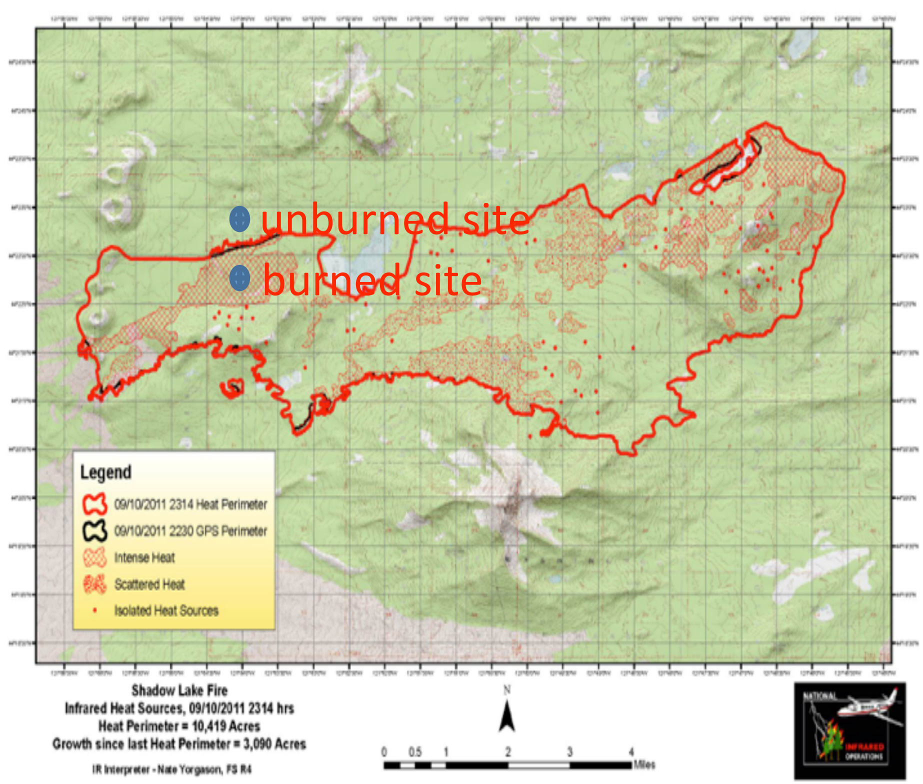
•Regions surrounded by red line lack the infrastructure to adjust to changes in seasonal melt

•As global warming continues the timing of peak spring runoff will shift to earlier in the year

•62% of the world will suffer from water scarcity by 2030

•Increased forest fire severity adds another complication to hydrological forecasting as greater areas are being burned





Study Region

- Shadow Lake Fire within the Mt .Washington Wilderness Area, Oregon Cascades burned ~42km^2 of forest in 2011
- Large contributor of groundwater recharge within the McKenzie River Basin which is the main tributary of Willamette River
- Elevations within McKenzie River Basin range from 10,358ft. (summit of South Sister) to 375ft.(convergence of McKenzie and Willamette Rivers)
- 2-3 °C increase in temperature causes winter precipitation to fall as rain instead of snow
- This watershed is dominated by low to mid-elevation snowpack making it vulnerable
- Paired sites are set up to study variables such as albedo, wind speed, temperature, snow accumulation and melt rates in both burned and unburned forests

Common Definitions in Snow Studies

Albedo-a materials ability to reflect light/shortwave radiation

- Albedo= Reflected light/Incoming light
- High albedo materials such as fresh white snow will reflect ~90% of incoming shortwave radiation
- Low albedo materials such as snow that is covered in soot or debris will absorb shortwave radiation

Snow Water Equivalent(SWE)- the amount of water contained in a snowpack if that snow were to be melted

- SWE=Density*Depth and is measured in kg/m^2
- One of the most important snow measurements; used to predict total potential runoff

Accumulation-period of active snow deposition

- Occurs throughout the winter months

Ablation-period of snowmelt

- Occurs in early spring through summer

Expected results based on previous research

Variable	Burned Forest	Unburned Forest
Snow Accumulation	High	Low
Temperature	High	Low
Density	High	Low
Snow Water Equivalent	High	Low
Debris Content	High, mostly soot and bark	Low, mostly sparse pine needles
Melt Rate	Rapid	Slow
Ice Lenses	Many	Few

Snow Pit Data Collection

Accumulation Period

Burned Forest

- A snow shovel is used to dig a snow pit all the way to the soil
- The face of the snow pit that has the sun behind it is scraped completely clean and level
- Total snow depth is measured using a folding ruler
- Dial stem thermometers are placed every 10cm to record temperature gradient

Ablation Period

Burned Forest

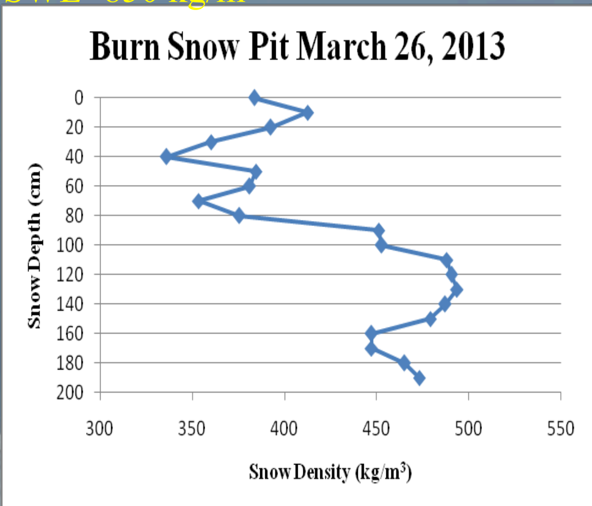
Unburned Forest

- Snow cutter is used to remove and weigh a known volume of snow every 10cm
- Snow samples from the cutter are put into a nalgene bottle and taken to a lab to be filtered for debris content
- Snowpack stratigraphy is reconstructed by recording grain size, shape, and thickness of each layer

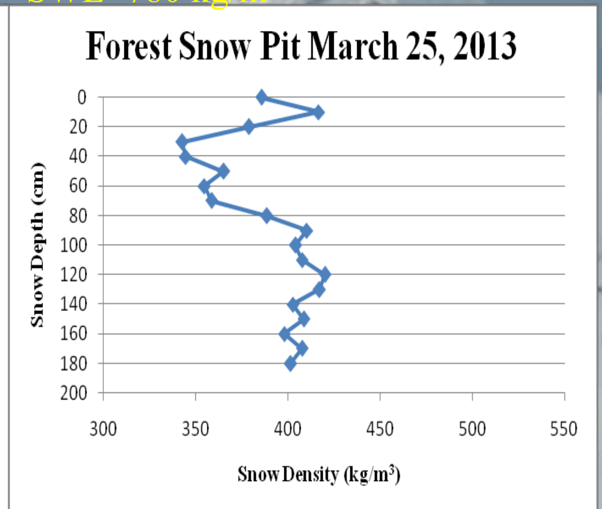
Snow Density Results

Accumulation Period

SWE=850 kg/m²

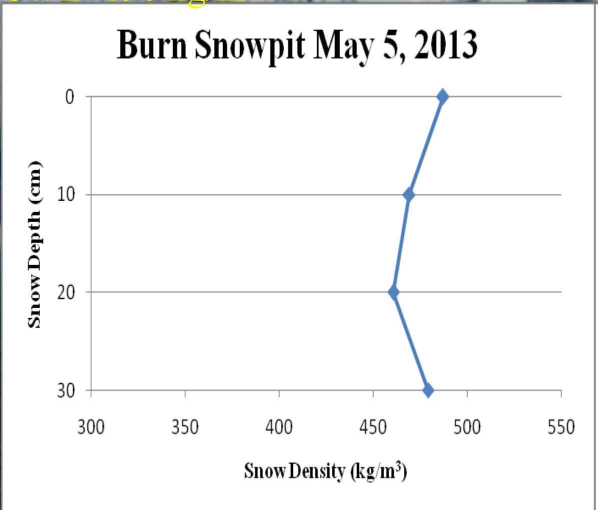


SWE=780 kg/m²

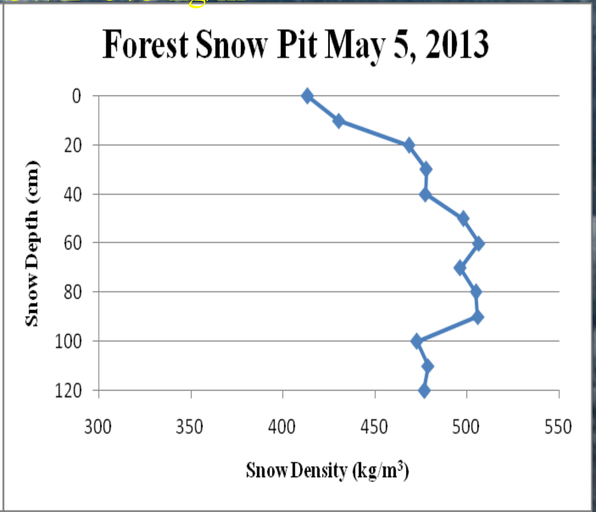


Ablation Period

SWE=190 kg/m²



SWE=573 kg/m²

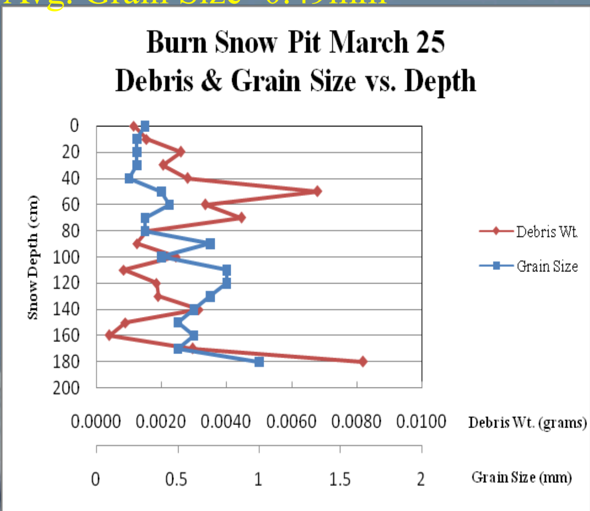


- Overall density increases with depth in all snow pits during all periods
- Density is greater in the burned forest during accumulation and is roughly equal during ablation
- Increased density results in increased SWE during accumulation with same depth
- Forest contains greater SWE in ablation due to greater depth

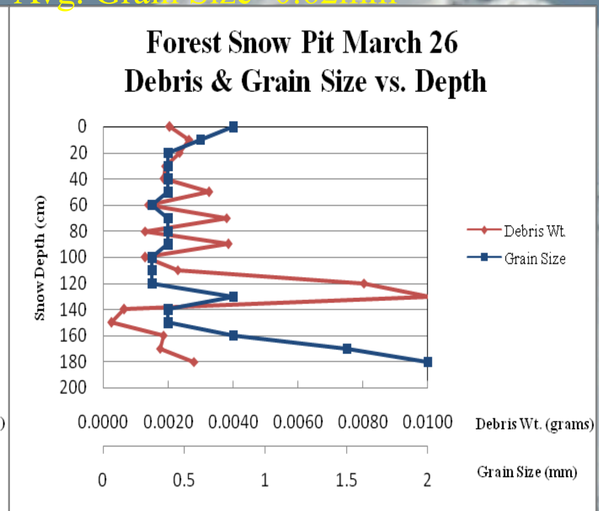
Debris Content & Grain Size

Accumulation Period

Total Debris= 0.1004g
Avg. Grain Size=0.49mm

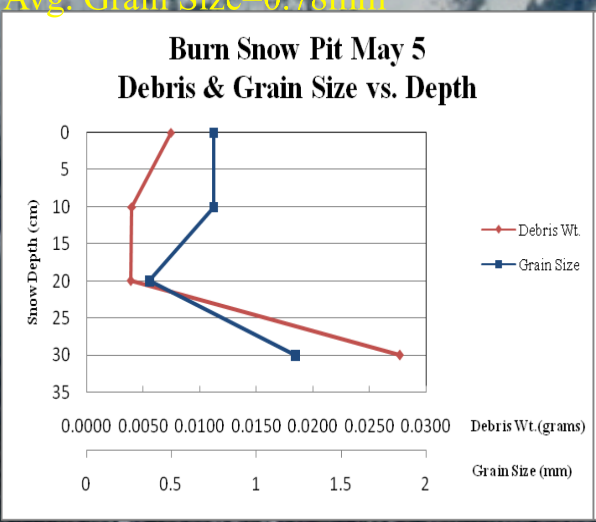


Total Debris= 0.1114g
Avg. Grain Size=0.62mm

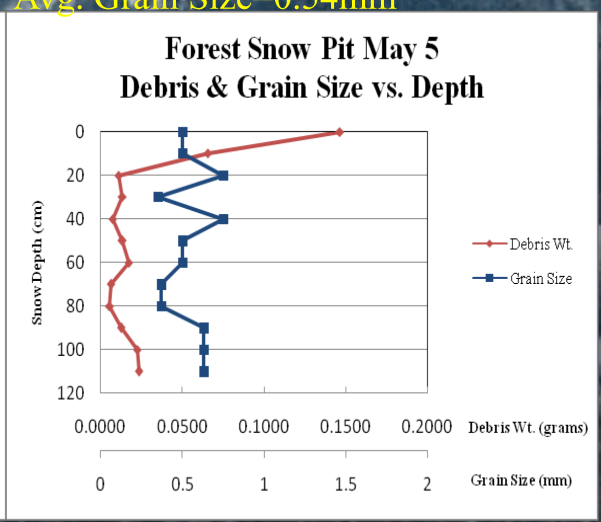


Ablation Period

Total Debris= 0.0861g
Avg. Grain Size=0.78mm



Total Debris= 0.6856g
Avg. Grain Size=0.54mm



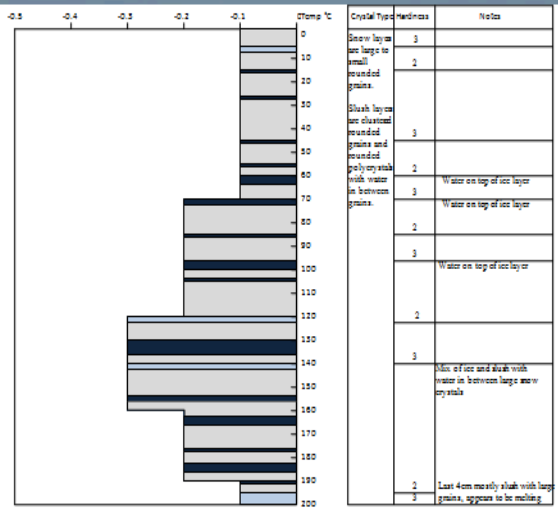
- Grain size increases with depth and are similar between burned and unburned forest
- Debris content varies with depth possibly indicating wind events that would deposit debris on top of the snowpack
- Total debris content during accumulation is nearly equal while total debris content during ablation is much greater in the forest (due to greater depth)
- Average grain size varies throughout

Snowpack Stratigraphy

Accumulation Period

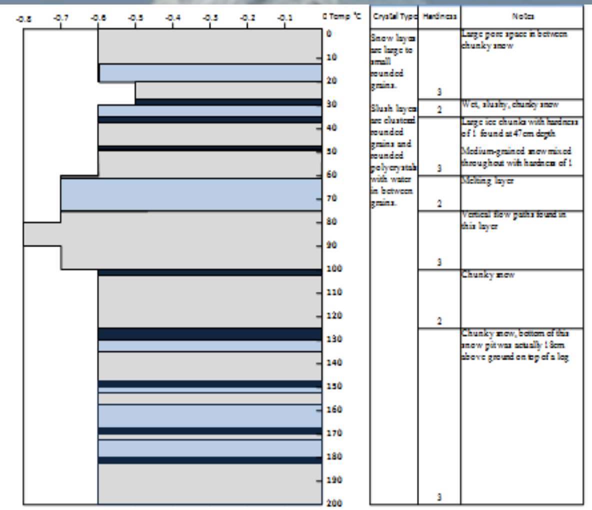
Burned Forest

Temp avg.=-0.2°C



Unburned Forest

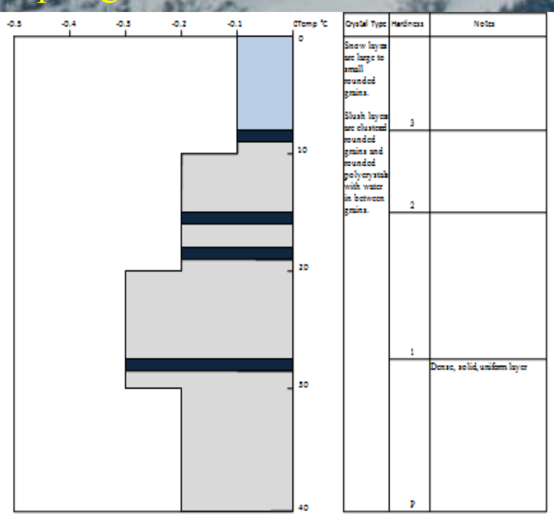
Temp avg.=-0.6°C



Ablation Period

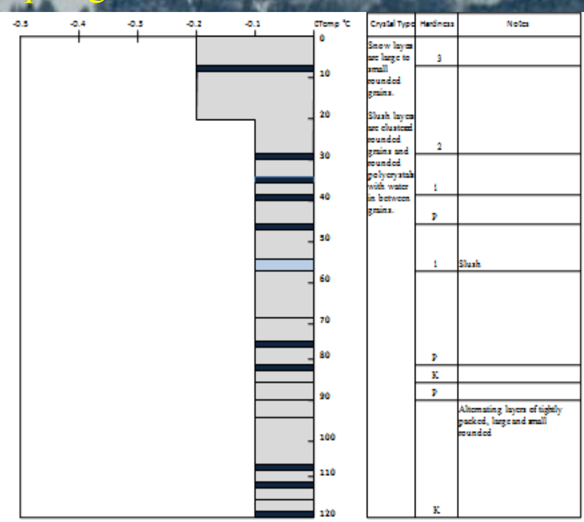
Burned Forest

Temp avg.=-0.2°C



Unburned Forest

Temp avg.=-0.1°C

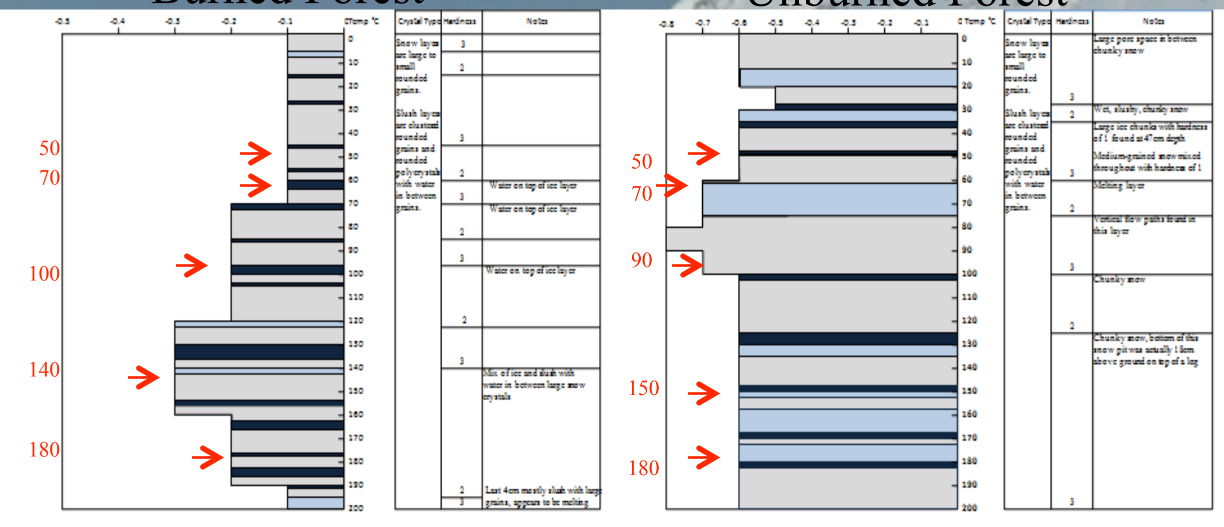


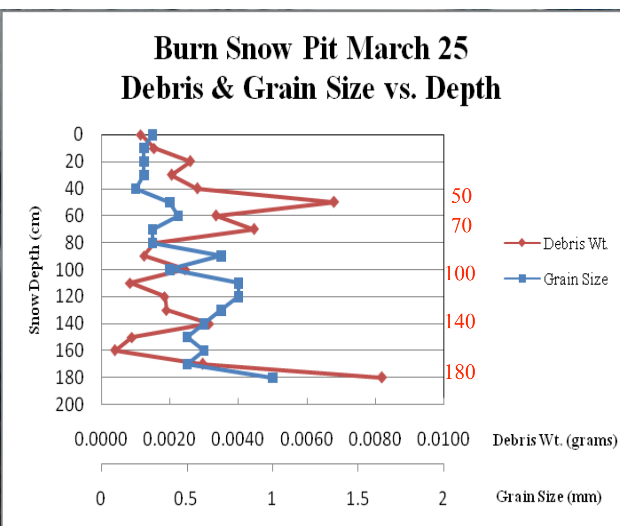
- Grain size and shape are fairly consistent throughout snowpack
- Maritime snowpacks consist of large rounded grains and large rounded polycrystals
- Hardness of snow and slush layers is 2-3 fingers, ice lenses are knife
- Temperature is higher in the burned forest during accumulation period but lower during ablation period
- Burned forest contains more ice lenses during accumulation period but fewer during ablation period
- Thicknesses of layers vary and have no obvious pattern but do record periods of snowfall and snowmelt

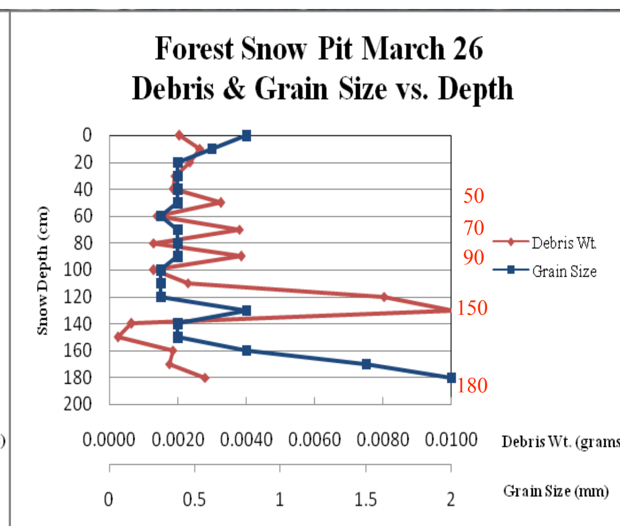
Can we correlate debris content with melting events?

Accumulation Period

Burned Forest — Unburned Forest







- Using the debris content graph and snowpack stratigraphy it should be possible to find correlations between layers with high debris content and melting events

- Burned forest has debris content peaks at 50, 70, 100, 140, 180cm

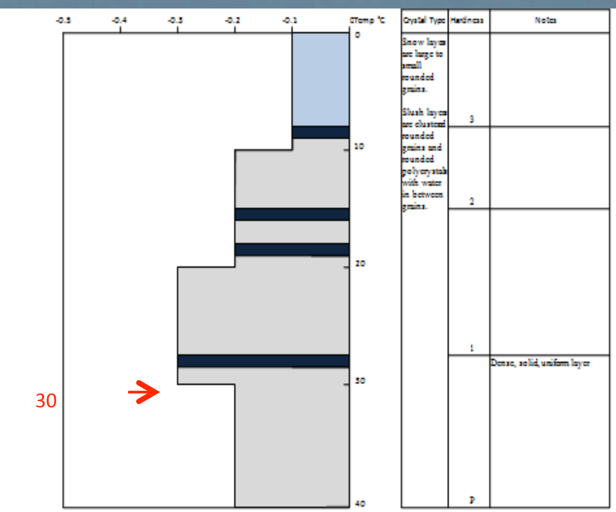
- Unburned forest has debris content peaks at 50, 70, 90, 150, 180cm

- Nearly all of the debris content peaks directly correlate with ice lenses or slush layers

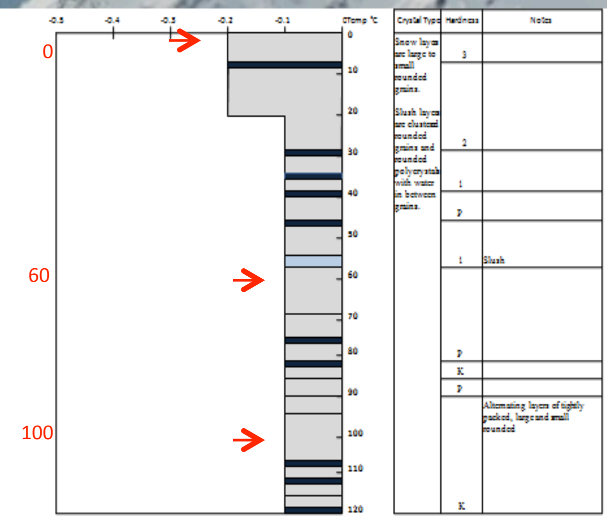
Can we correlate debris content with melting events?

Ablation Period

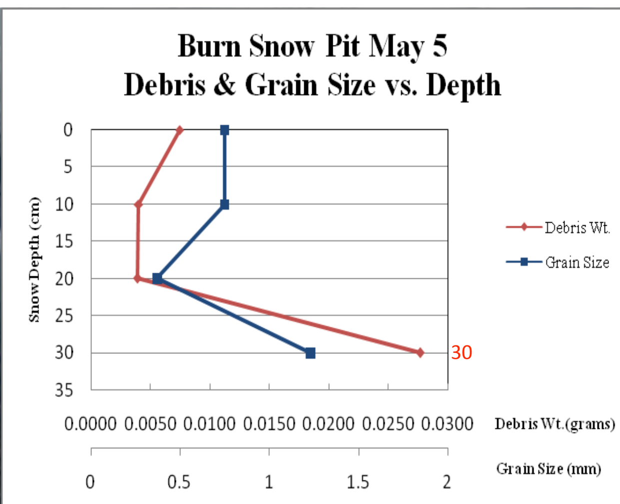
Burned Forest

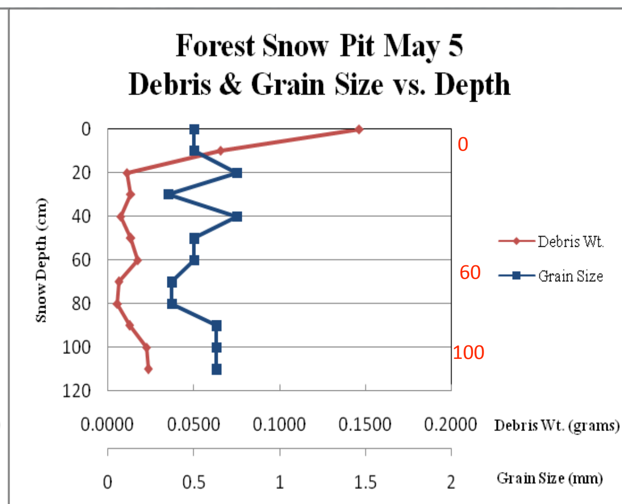


Unburned Forest



- Burned Forest has a debris content peak at 30cm
- Unburned forest has debris content peaks at 0, 60, and 100cm
- No correlation is evident during ablation period





Study Results Compared to Previous Studies

Variable	Burned Forest	Unburned Forest
Snow Accumulation	High ✓	Low
Temperature	High ✓	Low
Density	High ✓	Low
Snow Water Equivalent	High ✓	Low
Debris Content	High, mostly soot and bark ✗	Low, mostly sparse pine needles
Melt Rate	Rapid ✓	Slow
Ice Lenses	Many ✓	Few

Conclusions

•Results from this study are consistent with previous research

•Snow in a burned forest will experience greater accumulation,SWE, and faster melt rates than snow in an unburned forest. This lead to high magnitude streamflows during the melting season

•Small melting events during the accumulation season can be directly correlated with debris content

•There are some disparities that may possibly be accounted for due to spatial variability, mainly total debris content

•Further research next winter will include digging more pits in each of the burned and unburned forests during accumulation and ablation season

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- Dr. Anne Nolin, Associate Professor Oregon State University College of Earth, Ocean, and Atmospheric Sciences

- Kelly Gleason, PhD Candidate Oregon State University College of Earth, Ocean, and Atmospheric Sciences

- Matthew Cooper, Masters Degree Student Oregon State University College of Earth, Ocean, and Atmospheric Sciences

- Joe Cuellar, BS Geology Oregon State University

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