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Elevated Levels of Black Carbon on Mount Rainier in Correlation to Wildfires

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Background

The effects of climate change on the Puget Sound are in already effect. Increased wildfire frequency/severity, ocean acidification, and rising sea levels are commonly known products.[1] An additional effect is water scarcity.

At higher elevations, warmer winters lead to early season snow melt and more variable precipitation resulting in less melt water available during the summer months. Water scarcity means reduced viability of agriculture, hydroelectric power, and recreation throughout the state. Mount Rainier, Washington's highest peak, is the origin of nine Puget-Sound-draining watersheds, each likely facing a future of water scarcity.[2]

Water scarcity is additionally compounded by heightened levels of black carbon (BC) in Rainier's snowpack. BC (Figure 1) is the product of the incomplete combustion of anthropogenic source (fossil fuels and biomass) or wildfires.

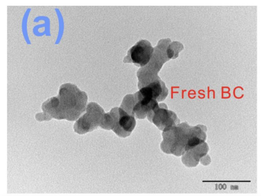

Figure 1. Black Carbon (BC).[3]

Albedo refers to the ability of certain surfaces, such as snow or ice, to reflect sunlight and heat (Figure 2). BC lowers the albedo of the surface snow resulting in a faster melt rate and exacerbation the aforementioned climate change effects.

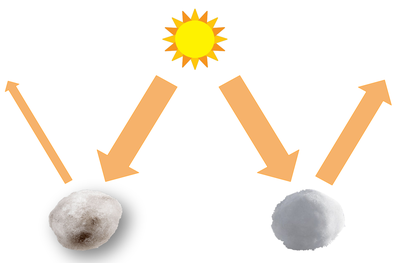

Figure 2. Reflectivity of dirty snow and clean snow.

Research Objectives

The surge in climate change driven wildfires throughout the Pacific Northwest have raised notable concerns about $PM_{2.5}$ (black carbon) and its implication on snow quality.

Research objectives included:

- Estimating the BC loading on Mount Rainier through continuous sampling and monitoring.
- Tracking and integrating wildfire/snowfall activity using diverse softwares.
- Analyzing snow contaminants using the Light Absorption Heating Method (LAHM, Figure 2) and Scanning Electron Microscope (SEM).

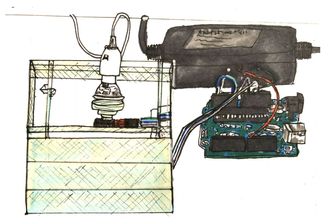

Figure 3. An illustration of the Light Absorbing Heating Method instrument.[4]

Methods

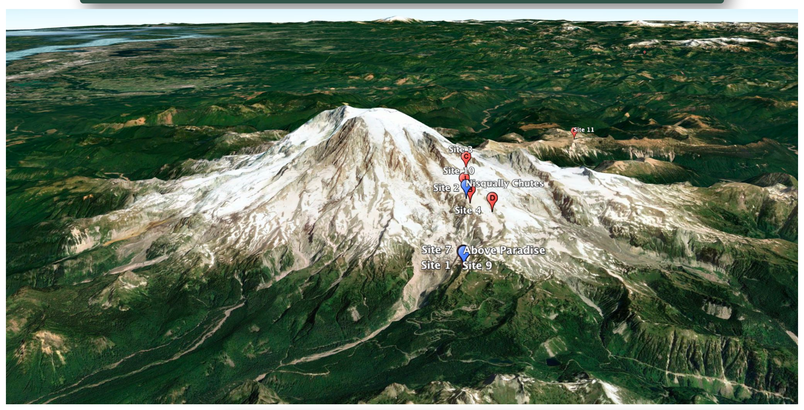

Figure 4. Mount Rainier (*Tahoma*) labeled with 11 sampling sites and above Paradise and Nisqually Chutes locations.

Field Work:

1) On site (Figure 4) metadata was recorded: coordinates, altitude, time, temperature, aspect, direction-facing, and snow information.
2) Using a trowel, shovel, and avalanche probe, the snow is extracted as a column in intervals every 5 to 10 cm (Figure 5).

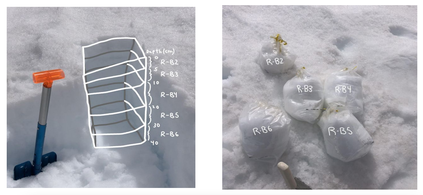

Figure 5. A sampling column from site 3.

3) The samples were then placed into labeled two-layer bags and transported back to campus in a cooler for analysis. The bags remained frozen until processing.

Lab Work:

1) The snow was melted and then pushed through a 60 mL filter-mounted syringe.
2) The filtered water measured in a graduated cylinder.
3) The filters were dried for 24 hours before analyzing.

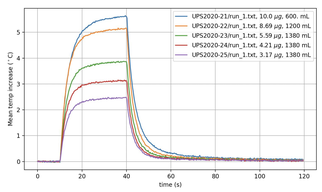

Figure 6. A Python analysis of LAHM data from site 3.

Analysis:

1) The filters were placed in the LAHM and the Arduino ran to obtain a data list. The data list was analyzed using Python (Figure 6) for filter load, BC equivalent (BCE) concentrations, and the limit of the temperature curve (t0).
2) Sections of each filter were cut for investigation by SEM.

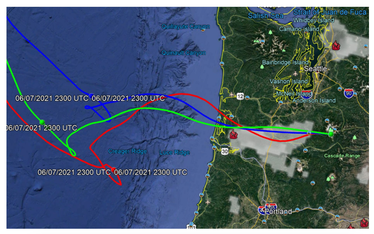

Figure 7. HYSPLIT and BlueSkies modeling for 6/7/2021 and site 8.

3) Metadata was used to track snow and wildfire events to observe patterns in BC concentration using the Hybrid Single Particle Integrated Trajectory Model (HYSPLIT) and BlueSkies (Figure 7).

Results

Figure 7 demonstrates the increase in BC concentrations on Mount Rainier between 2020 and 2021 at correlating locations and depths.

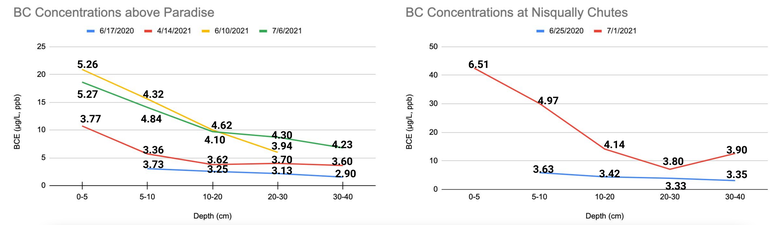

Figure 8. BC concentrations along with annotated t0 values separate sites and the locations of above Paradise and Nisqually Chutes.

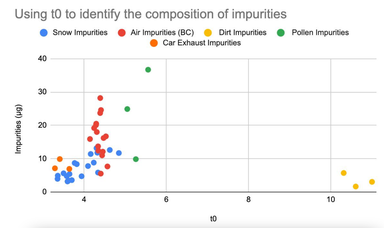

Figure 9. A scatter plot of t0 values from various contaminants.

HYSPLIT and BlueSkies integration (Figure 7) allowed BC measured and the smoke dispersion from wildfires to be correlated. On four occasions, higher than expected BC was linked to wildfire smoke passing above Mount Rainier.

Through use of Python analysis for t0 (Figure 9) and the SEM (Figure 10), BC was certified as the main heating component in snow samples. The analysis of other particulates by SEM and t0 helped to compare the sampled BC to filters containing pure BC air impurities, local pollen, local soil, and vehicle exhaust.

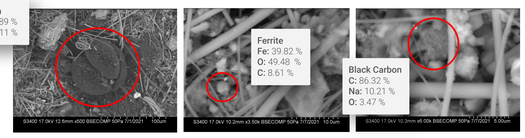

Figure 10. SEM images of particulates from above Paradise.

Conclusion/What Now?

1) Mount Rainier's snow is directly impacted by BC.
2) Elevated BC is correlated with wildfire activity.

To establish causation:

- Must narrow down timing for BC deposition and positive measurement.
- Better chemical analysis of BC.

References

1) Dunagan, C. New Report Describes Anticipated Climate-Change Effects in Washington State. *Puget Sound Institute*, 2020.
2) Ashford, M. A. 55210 238th A. E.; Us, W. 98304 P.-2211 C. Fishing and Boating - Mount Rainier National Park (U.S. National Park Service)
3) Variability in individual particle structure and mixing states between the glacier–snowpack and atmosphere in the northeastern Tibetan Plateau - Scientific Figure on ResearchGate.
4) http://www.naturalsystemsresearch.com/LAHM_Manual.html

Acknowledgments

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