Glacial Response to Heat Waves as Shown in Suspended Sediment Concentration of White River, WA

Greta Schwartz[1] and Claire Todd[2]

1- Department of Geosciences, Pacific Lutheran University, Tacoma, WA, 98447, schwartzg@plu.edu

2- Geological Sciences, California State San Bernardino, San Bernardino, CA, 92407

Abstract

Suspended sediment is a key resource for ecosystems in the Pacific Northwest, with the potential to both contribute to and detract from watershed health. Glaciers are a large source for much of the sediment production and are greatly affected by increasing temperature as a result of climate change. Understanding how heat waves affect glacial suspended sediment production is vital to understanding how sediment sources will be affected as heat waves increase in frequency and severity. Suspended sediment samples taken from the glacially derived White River in Washington State from before and after the heat wave spanning June 26 to July 2, 2021 aim to help gain that understanding. Suspended sediment concentration (SSC) in mg/L was compared with temperature (ºF) to try and gain an understanding of how heat waves affect glacial suspended sediment production.

Introduction

Mount Rainier is a volcano in the Washington State section of the Cascade Range with the highest concentration of glacial ice in the conterminous United States (Sisson at al., 2011). The largest glacier on Mount Rainier is Emmons Glacier, which is the source for the White River. The White River begins on Mount Rainier and joins with the Puyallup River before draining into Puget Sound (Czuba et al, 2021). As it makes this journey, the White River carries suspended sediment sourced from Emmons Glacier. Suspended sediment is vital to the health of many ecosystems, but too much of it can be damaging, both to wildlife habitats and to human infrastructure (Czuba et al. 2021). Given how much glaciers are changing due to increasingly extreme weather such as heat waves, it is logical to assume that suspended sediment sourced from those glaciers is changing as well. As extreme heat waves become more frequent, it becomes increasingly important to understand how glaciers and their processes react to record breaking heat waves (Perkins-Kirkpatrick and Lewis, 2020). Looking specifically at the heat wave that hit the Pacific Northwest in the Summer of 2021, this study aims to predict how extreme heat waves affect glacial sediment production.

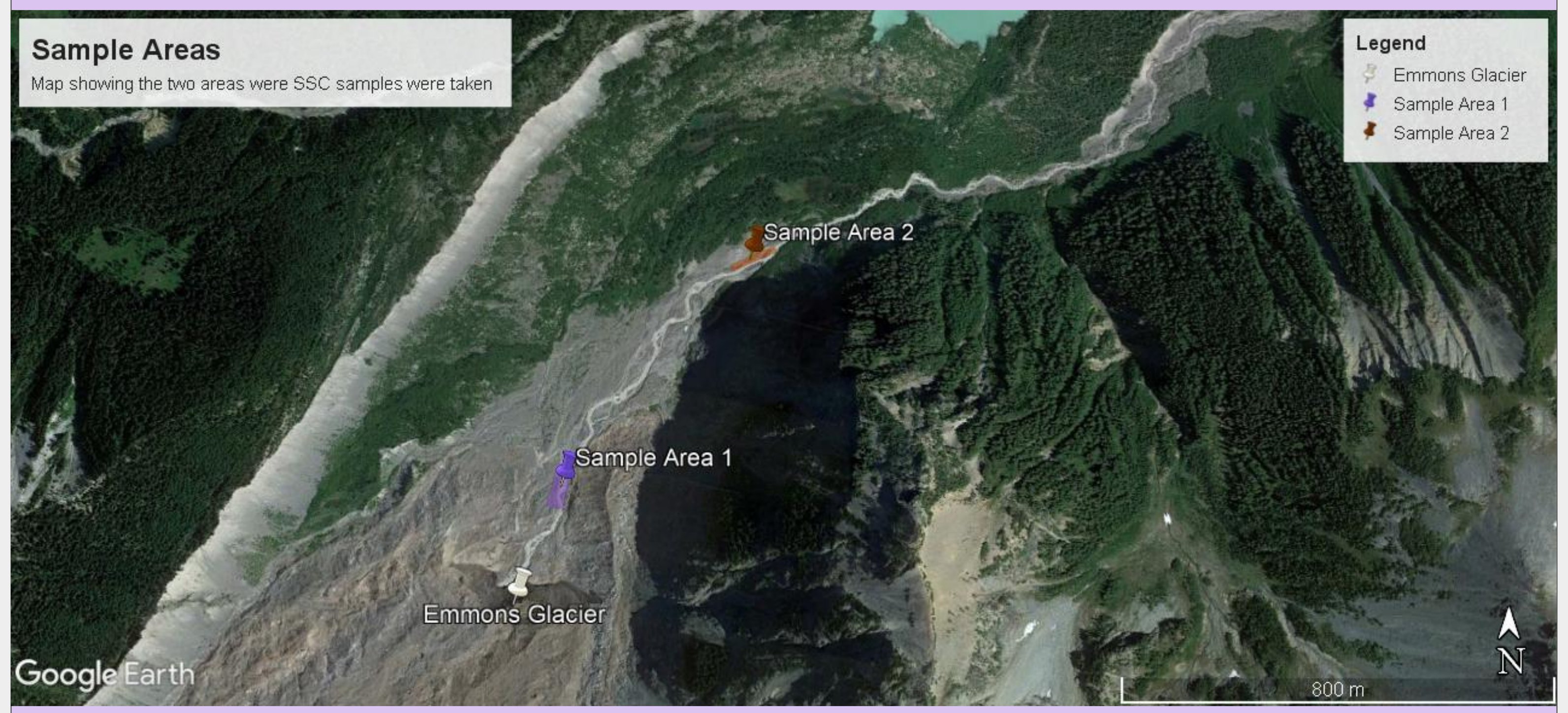

Figure 1: Map of White River on Mount Rainier showing the location of Emmons Glacier terminus, and the two areas where SSC samples were taken from White River

Figure 2: Image of the terrain of Area 1. Note the large boulders.

Figure 2: Image of the terrain of Area 2. Note the sediment deposits.

Methods

Four samples were taken from two locations on White River near the mouth of Emmons Glacier. Two samples were taken in the morning and two in the afternoon. Date, time, and GPS were recorded at each site. Sampling sites were chosen based on ideal channel characteristics.

Ideal sample sites were fairly straight in order to obtain as uniform a current as possible with a stable bank from which to take samples. These locations result in a more uniform water column.

Due to the changing nature of the Emmons Glacier terminus, sampling from the same location each time was not always possible. When this happened GPS was used to find a location that was as close to the original as possible. Sample sites are therefore labeled as Area 1 and Area 2 on the location map (Figure 1).

In the lab the suspended sediment was filtered out of the water onto filter paper using a vacuum filter. The weight of the filter paper was removed from the total weight of the filter paper and the suspended sediment was the resulting number. SSC was recorded in mg/L.

Temperature information was taken from the Sunrise Base with an elevation of 6410ft. This location was closest to the sampling areas, and was used because temperature was not recorded when sampling. The temperature and the SSC were graphed in a spreadsheet to determine how or if SSC was related to temperature. Temperature was taken every hour, and the temperature closest to the sample time was used. In the case of samples taken in the middle of the hour, the temperatures were averaged.

Results

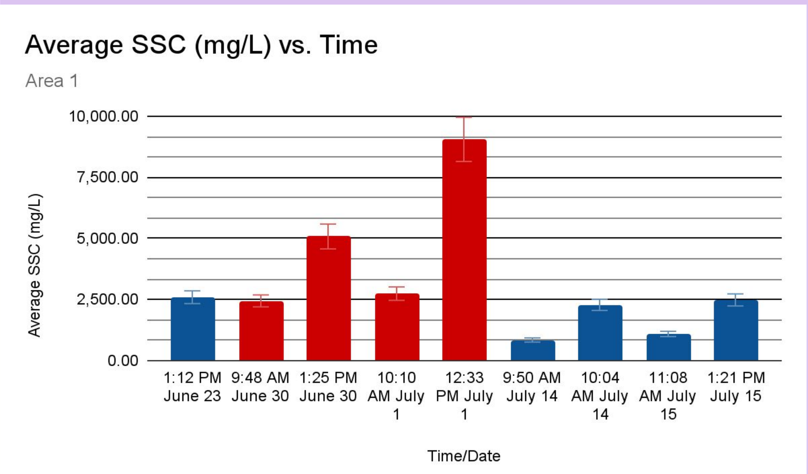

Figure 4: Average SSC (mg/L) vs. Time for Area 1

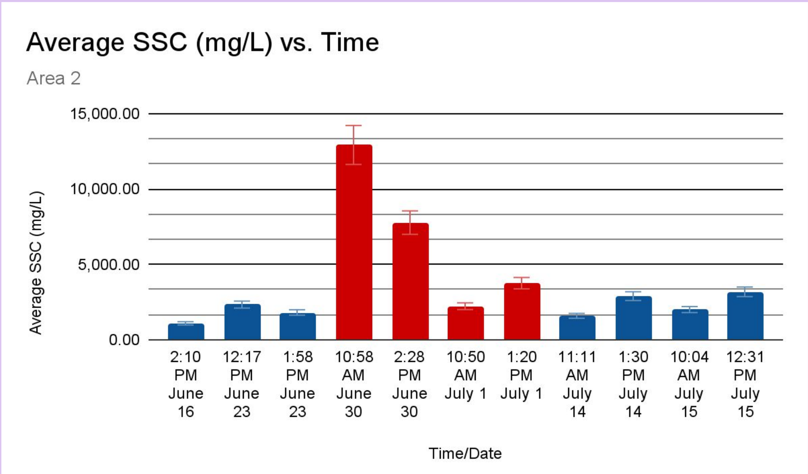

Figure 5: Average SSC (mg/L) vs. Time for Area 2

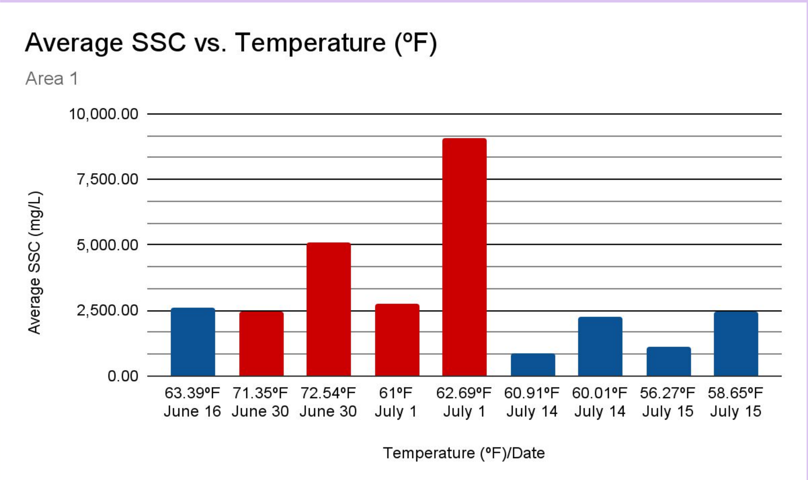

Figure 6: Average SSC (mg/L) vs. Temperature (ºF) for Area 1

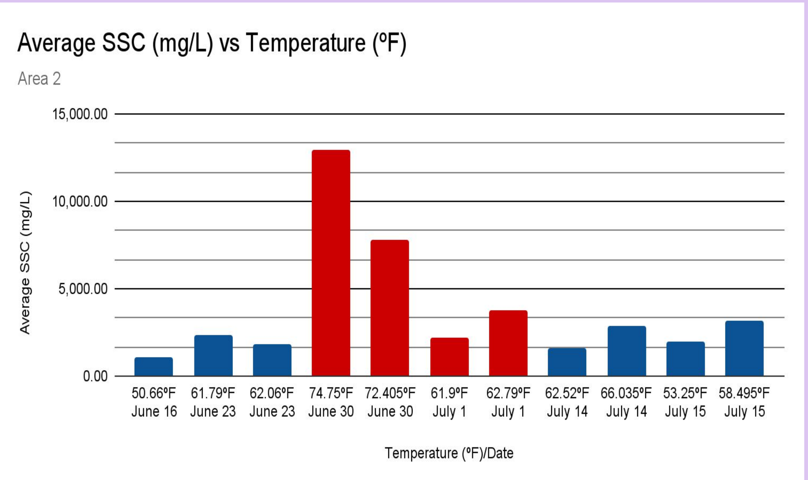

Figure 7: Average SSC (mg/L) vs. Temperature (ºF) for Area 2

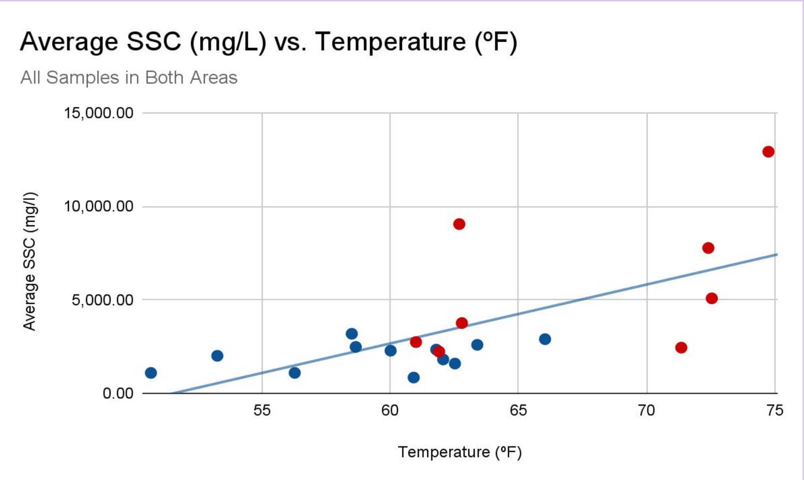

Figure 8: Average SSC (mg/L) vs. Temperature (ºF) for every sample

Legend

- Samples taken during the heat wave (red)
- Samples not taken during the heat wave (blue)

The highest average SSC was taken on June 30 at 10:58am at the second sample area with a value of 18318.31776 mg/L. Taken during the heat wave, the temperature when this sample was taken was 74.75ºF. The lowest average SSC was taken on July 14 at 9:50am at the first sample area with a value of 844 mg/L, this sample was taken after the heat wave ended with a temperature of 60.91ºF.

Area 2 had a higher maximum SSC than Area 1, and saw SSC rebound to previous levels after the heat wave. Area 1 saw overall SSC levels drop after the heat wave and not return to previous levels.

Looking at Figure 8, there does appear to be a correlation between increase in temperature and an increase in SSC. High SSCs (>5,000 mg/L), occur predominantly with temperatures above 70ºF. SSC becomes more erratic as temperatures increase, this is best seen when comparing SSC taken at temperatures above 65ºF with the SSC cluster around 60ºF.

Discussion

The increase of SSC coinciding with the heat wave suggests that the increase of temperature had an effect on SSC. This could be due to an increase in discharge leading to more sediment leaving the glacier. The extreme heat also led to the freezing point on the mountain to be above much of the snow. This could have led to sediment that had long been frozen coming loose to flow out of the glacier.

It is possible that differences in the sampling areas could have led to inaccuracies. Bank erosion could have played a role in the high SSC at Area 2. Area 2 was located further away from the mouth of the glacier, and had more opportunity for bank erosion to occur, contributing to a more constant supply of sediment to supplement a waning glacial sediment source.

It is possible that the more mature sediment deposits at Area 2 could have contributed to SSC returning to pre-heat wave levels while Area 1, which did not have such established sediment deposits, did not.

As temperature increased the erraticy of SSC also increased. This could be due to instability caused by the heat wave. The increased discharge could have diluted SSC, while at the same time flushed out previously stable sediment stores within the glacier's bed.

There is also opportunity for error in regards to temperature. Temperature data was not taken directly from the sample areas, rather from the nearby Sunrise data location.

Conclusions

Temperature had an effect on SSC, but it is difficult to make a definitive conclusion about this study due to its limited scope. Further research is needed to be able to make definitive conclusions about how glacial sediment production is affected by heat waves.

Future studies focusing on one sample area closer to the mouth of the glacier would be beneficial. Being nearer to the source of the suspended sediment would help eliminate sediment input from past deposits to better isolate glacial sediment production.

Acknowledgements

I would like to thank the PLU Department of Natural Sciences and the PLU Geosciences Department for providing this research opportunity, the National Park Service for allowing this research to occur, Matthew Hacker for technical support, and Carol Hilder as well as John Mallinckrodt's Glacial Geology Research Fund for funding this research. A special thanks to my fellow researchers and Mike Turzewski for support along the way!

Works Cited

Czuba, J.A, Magirl, C.S., Czuba, C.R., Johnson, K.H., Olsen, T.D., Curran, C.A., Kimball, H.K., and Gish, C.C., 2012, Geomorphic analysis of the river response to sedimentation downstream of Mount Rainier, Washington: U.S. Geological Survey Open File Report 2012-1242, 134 p.

Frans C., Istanbulluoglu E., Lettenmaier D.P., Fountain A.G., and Riedel J.L., 2018, Glacier recession and the response of summer streamflow in the Pacific Northwest United States, 1960-2099: Water Resources Research, v. 54, p. 6202-6225.

Haritashya, U.K., Singh P., Kumar, N., and Gupta, R.P., 2006, Suspended sediment from the Gangotri Glacier: Quantification, variability, and associations with discharge and air temperature: Journal of Hydrology, v. 321, p. 116-130, doi: 10.1016/j.jhyrdol.2005.07.037.

Moore, R.D., Fleming, S.W., Menounos, B., Wheat, R., Fountain, A., Stahl, K., Holm, K., and Jakob, M., 2009, Glacier change in western North America: influences on hydrology, geomorphic hazards and water quality: Hydrological Processes, 23, p.42-61, doi: 10.1002/hyp.7162.

Nolin, A.W., Phillippe, J., Jefferson, A., and Lewis, S.L., 2010, Present-day and future contributions of glacier runoff to summertime flows in a Pacific Northwest watershed: Implications for water resources: Water Resources Research, v. 46, p. 1-14, doi: 10.1029/2009WR008969.

Perkins-Kirkpatrick, S.E., and Lewis, S.C., 2020, Increasing trends in regional heatwaves: Nature Communications, v. 11, doi: 10.1038/s41467-020-16970-7.

Sisson, T.W., Robinson, J.E., and Swinney, D.D., 2011, Whole-edifice ice volume change A.D. 1970 to 2007/2008 at Mount Rainier, Washington, based on LiDAR surveying: Geology, v. 39, no. 7, p. 639-642, doi:10.1130/G31902.1.

Stott, T., and Mount, N., 2006, Alpine proglacial suspended sediment dynamics in warm and cool ablation seasons: Implications for global warming: Journal of Hydrology, v. 332, p.256-270, doi: 10.1016/j.jhydrol.2006.07.001.