Temporal Changes in Proglacial Stream Temperatures in White River, WA

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Abstract

Water temperature is a crucial component of water quality. Glaciers and snow in glaciated watersheds supply low temperature water during the summer melt season, which can help to counteract warming stream temperatures due to rising air temperatures and urbanization. Emmons Glacier located on Mount Rainier, WA supplies low temperature water to the Puyallup watershed via the White River. We measured stream temperature in White River at four sites located ~ 0.1 to 4 km from Emmons Glacier terminus. Data was collected using probes that were submerged in the river for 24 - 48 hour periods in June and July, 2016 - 2021. Meltwater temperatures within 0.2 km of the terminus are less than two degrees Celsius. Preliminary results show that meltwater temperature cycles diurnally, with peak temperatures occurring in the afternoon, and minimum temperatures occurring late at night or in the early morning; diurnal meltwater temperature fluctuations near the terminus are within one degree Celsius. These findings suggest that air temperature is the dominant influence on glacial meltwater temperature. At a site 4 km from the terminus, the water is one to five degrees Celsius warmer, and the diurnal temperature shift is larger, up to two degrees Celsius. The consistency of meltwater temperatures at the glacier terminus throughout our findings suggests that glacial melt may mitigate rising stream temperatures downstream.

Research Question

How do daily changes in the temperature of Emmons Glacier meltwater relate to changes in water depth and air temperature?

Mount Rainier and the Puyallup Watershed

Emmons Glacier is located on the northeast flank of Mount Rainier in Washington State (Figure 1). Meltwater from the Emmons Glacier terminus forms the White River, a tributary of the Puyallup Watershed which flows into Puget Sound (Figure 2). The Puyallup Watershed is home to several species of salmon and trout (Staubitz et al., 1997; Pierce County, 2021).

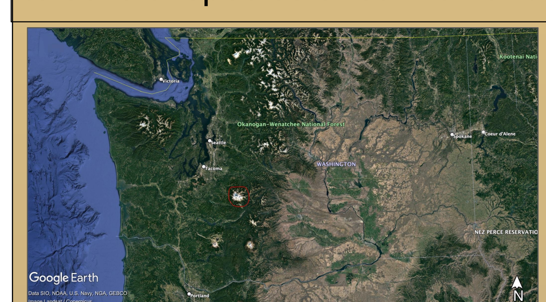


Figure 1 (above): Washington State; Mount Rainier is marked with a **red circle**.

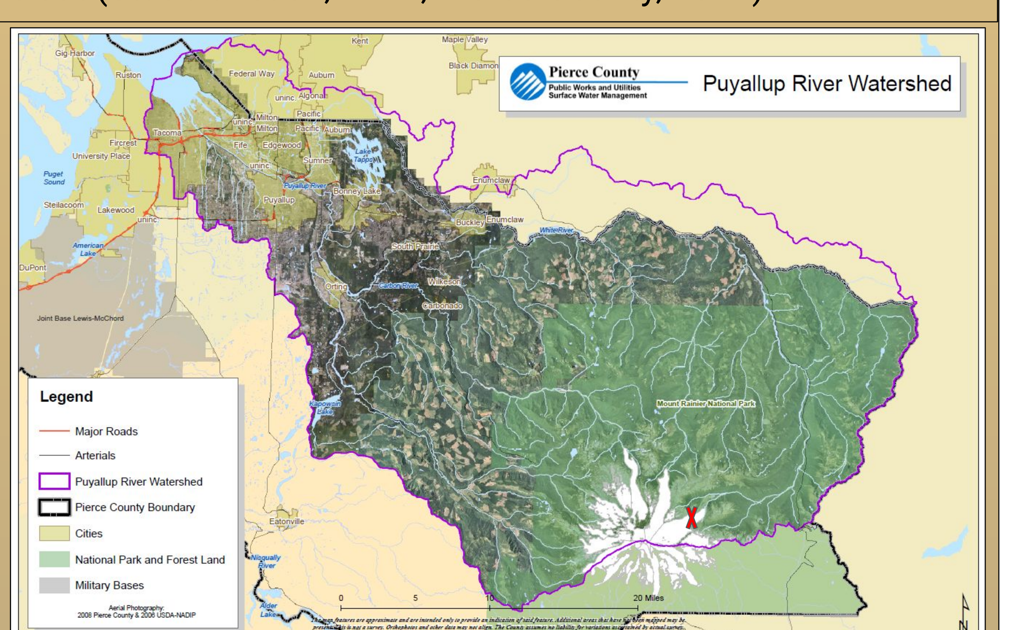


Figure 2 (right): Puyallup River Watershed; Emmons Glacier is marked with a **red X**.

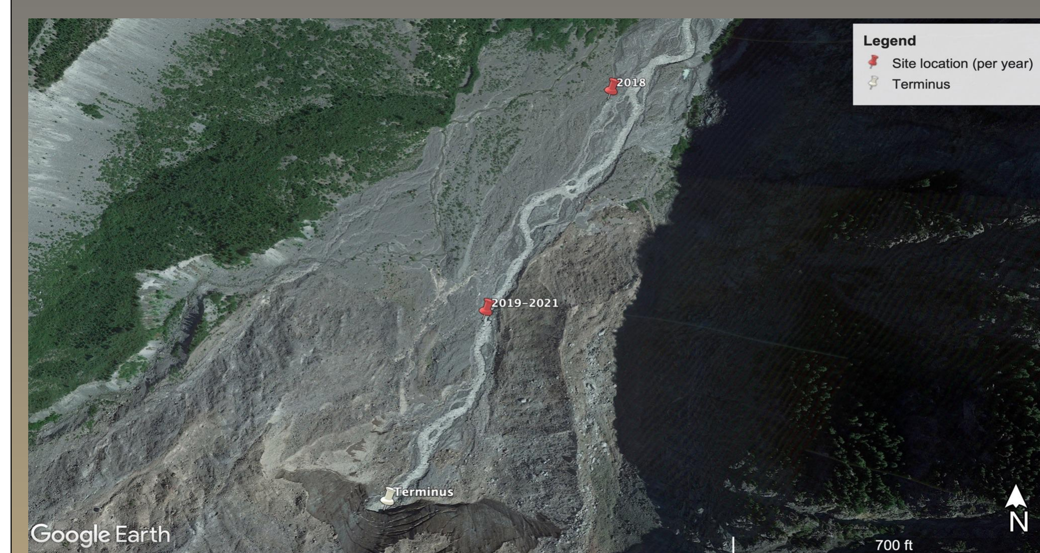
The Importance of Stream Temperature

Rising stream and air temperatures in the Pacific Northwest threaten habitats for cold-water fish species (Fellman et al., 2015). Glaciers play an important role in regulating stream water temperature because they supply cold meltwater during summer months (Grah and Beaulieu, 2013; Fellman et al., 2014) which is when we can expect most activity from native aquatic species. The Puyallup Watershed experiences high discharge during summer due to snow and ice melt from Mount Rainier; this water transports glacial flour and flows through contaminant sources concentrated in lowland areas (Takesue et al., 2017). Glaciers on Mount Rainier are losing volume (Sisson et al., 2011), which will impact streamflow. A decrease in the supply of glacial meltwater may reduce the amount of cold meltwater in comparison to warmer groundwater (Milner et al., 2009). Understanding glacial meltwater temperatures is important for predicting the impacts of glacial change on watershed health.

Methods

- Data collection sites were selected to be as close as possible to the glacier terminus; energetic and turbulent stream conditions limited possible data collection locations.
- Water temperature and depth were measured continuously with a Hanna Multiparameter Probe and a Solinst pressure transducer. These instruments were temporarily suspended in the stream and anchored to a large rock on the bank. We calibrated pressure transducer measurements using periodic measurements of depth with a meter stick.
- Pressure transducer data was collected at 1 minute and 15 minute intervals. We used a 30-minute moving average to eliminate the effects of turbulent stream conditions Air temperature data was downloaded from the Northwest Avalanche Center. We used archived data from the Sunrise Base station which is located at 6,410 feet above sea level, approximately 1,500 feet above the terminus of Emmons Glacier.

Study Area



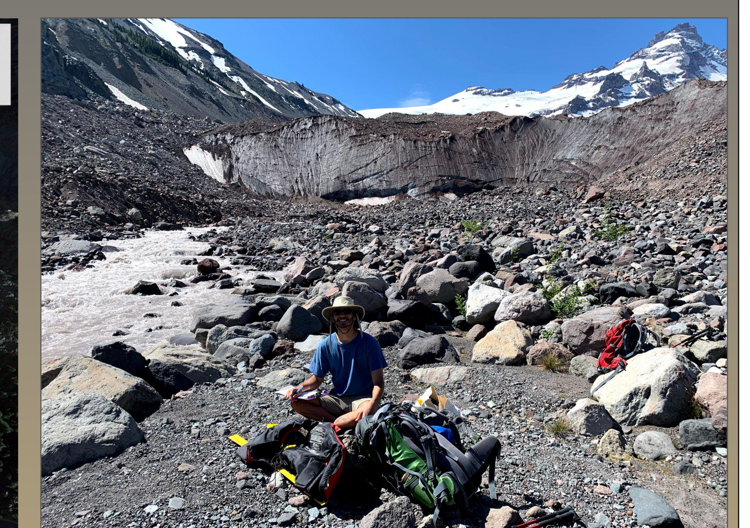


Figure 3 (above left): White River data collection sites. 2019-2021 data were collected in the same place. The terminus is 0.23 km from these sites and 0.31km from the 2018 sample collection point.
Figure 4 (above right): Emmons Glacier terminus as seen from the 2019-2021 data collection site.
Figure 5 (left): Turbulent conditions in White River during the 2021 field season. Ice chunks have been purged from the glacier during high flow.

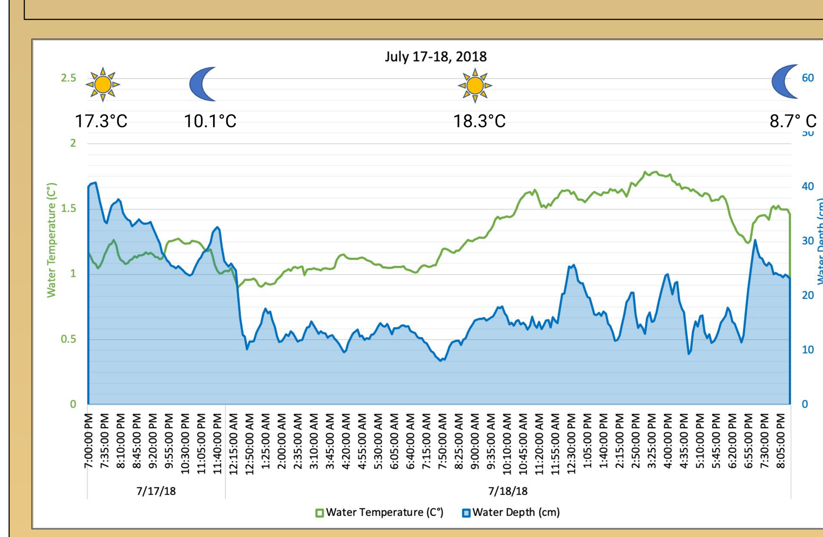
Results

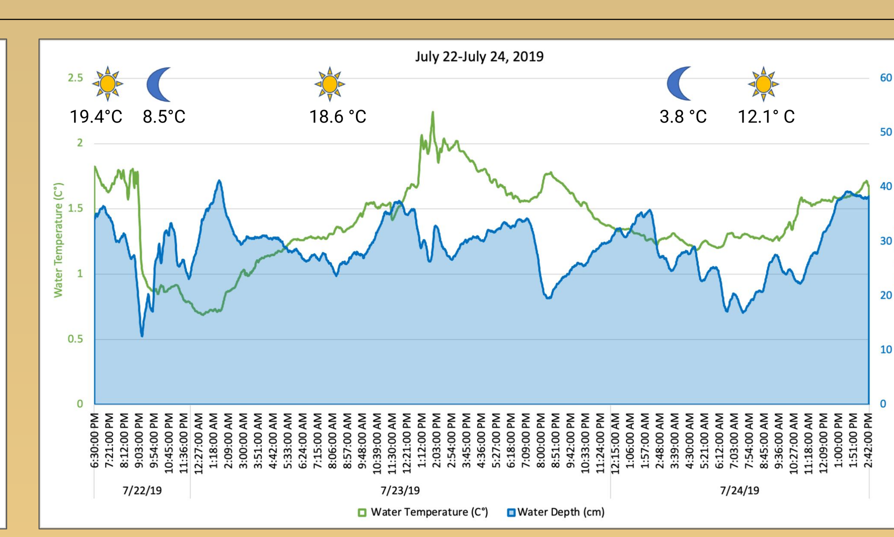
We documented meltwater temperatures ranging from 0.3 to 2.3 +/- 0.2 degrees Celsius (Figures 6 - 8). The highest meltwater temperatures occur early to mid afternoon, and the lowest meltwater temperatures occur in the early morning. This timing corresponds with the typical timing of high and low diurnal air temperatures.

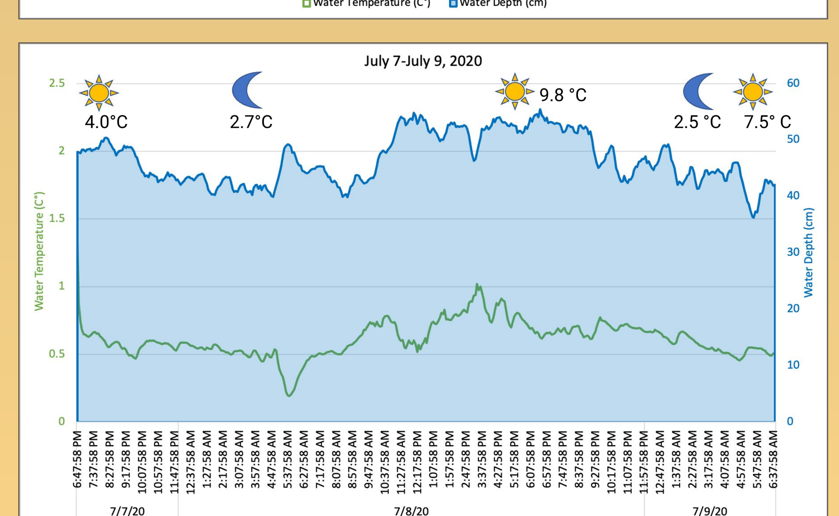
Meltwater temperatures typically change 0.75 degrees Celsius over 12 hours, but our 2019 dataset captured a larger change over a similar timeframe; meltwater temperatures increased from 0.75 degrees Celsius at 12:30 AM to 2.25 degrees Celsius at 2:00 PM.

Our 2018 and 2019 data collection occurred during diurnal air temperature changes of ~ 10 degrees Celsius, but in 2020 air temperatures during our data collection period were lower with smaller diurnal changes.

Meltwater depths ranged from less than 10 cm to more than half a meter, with the lowest meltwater water depths documented in 2018 when data was collected farther downstream than in other years. Meltwater temperature does not have a consistent relationship with meltwater depth, although in some instances abrupt changes in water depth and meltwater temperature coincide. We address the challenges of measuring and interpreting water depth in the discussion section.

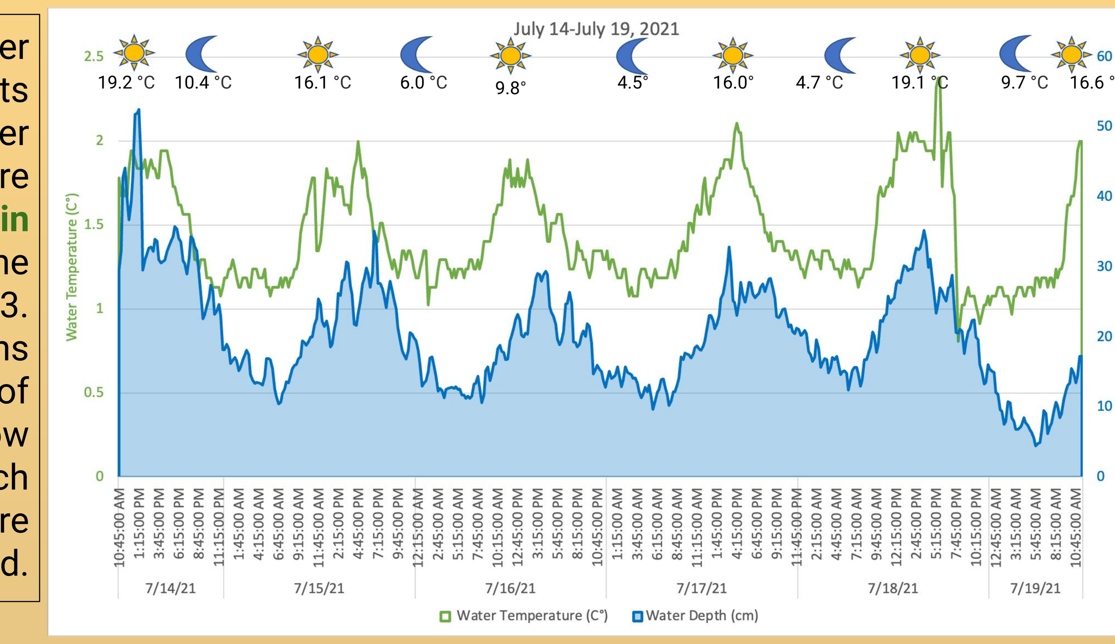






Figures 6 - 8 (clockwise from above left): Water depth measurements **(in blue)** and water temperature measurements **(in green)** collected at the sites shown in Figure 3. Sun and moon icons indicate the timing of high and low temperatures for each day data were collected. For dates when data collection occurred for only part of the day, these temperatures are the highest and lowest temperature during data collection. High and low temperatures are indicated below or next to the sun and moon icons.

Figure 9: 2021 water depth measurements **(in blue)** and water temperature measurements **(in green)** collected at the site shown in Figure 3. Sun and moon icons indicate the timing of high and low temperatures for each day data were collected.



Discussion

Our results suggest that air temperature has some influence on glacial meltwater temperatures, even a very short distance after meltwater emerges from the glacier terminus (Figure 4). This finding is consistent with weak relationships between air temperature and glacial runoff temperature found by Fellman et al. (2014).

Coincidental changes in meltwater depth and meltwater temperature suggest that surges of meltwater from the glacier terminus can cause a sharp but temporary decrease in meltwater temperatures.

Measuring meltwater depth and temperature in a proglacial stream is extremely challenging. High energy stream conditions (Figure 5) cause changes in channel shape which may affect measurements of water depth. We heard boulders moving along the stream bed frequently during our field work. We checked for changes in channel geometry at the data collection site using periodic measurements of water depth with a meter stick. High energy stream conditions also have the potential to move temperature sensors and pressure transducers, and in some cases perhaps lift them out of the water. Changes in stream channel geometry and water depth can also expose sensors or reduce water depth at a sample collection site. Figure 9 shows a five-day sample period in 2021 where water temperature and water depth change in tandem with diurnal air temperatures; a sharp contrast to data collected in earlier years (Figures 6-8). This close correlation suggests that our instruments moved after our initial installation and was in very shallow or ponding water or exposed to air directly. During this sample period we were unable to perform periodic checks on stream depth, and we suspect our initial calibration of water depth at the sample site was not effective after the sensors moved or the stream channel changed.

Given the impact of glacier change on downstream watersheds (e.g., Milner et al., 2017), we recommend further study of meltwater stream temperatures at Mount Rainier.

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