The Impact of Water Column Mixing in a Salt-Wedge Estuary

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Abstract

The Puget Sound is a complex estuarine system within the Salish Sea, fed by both high salinity water from the Pacific Ocean and freshwater from a number of rivers. The Snohomish River is one of the largest of these freshwater inputs, transporting freshwater from the Skykomish and Snoqualmie rivers to Port Gardner Bay off the coast of Everett. At its mouth, the higher density salt water from the Puget Sound intrudes into the freshwater, forming a salt wedge that causes a highly stratified water column which rapidly changes with the tidal cycle. In this stratified water column, little mixing occurs between the different layers of the water, resulting in a lack of nutrients near the surface. This study aims to quantify the amount of mixing occurring at this location in relation to tidal patterns and season and analyze the effect varying levels of mixing have on related chemical properties. This research is being conducted at the Ocean Research College Academy (ORCA), a dual enrollment program through Everett Community College. In cooperation with Gravity Marine Consulting and the Port of Everett, ORCA has permanently moored a SeaBird CTD 3 meters below the surface in the mouth of the Snohomish River. The CTD captures temperature, salinity, chlorophyll, turbidity, and dissolved oxygen measurements at 30-minute intervals. Velocities in 3-dimensions are recorded by a Nortek Aquadopp. This study will define the characteristics of the salt wedge in relation to temperature and salinity and then look at its influence on chlorophyll and turbidity levels.

The Impact of Water Column Mixing in a Salt-Wedge Estuary

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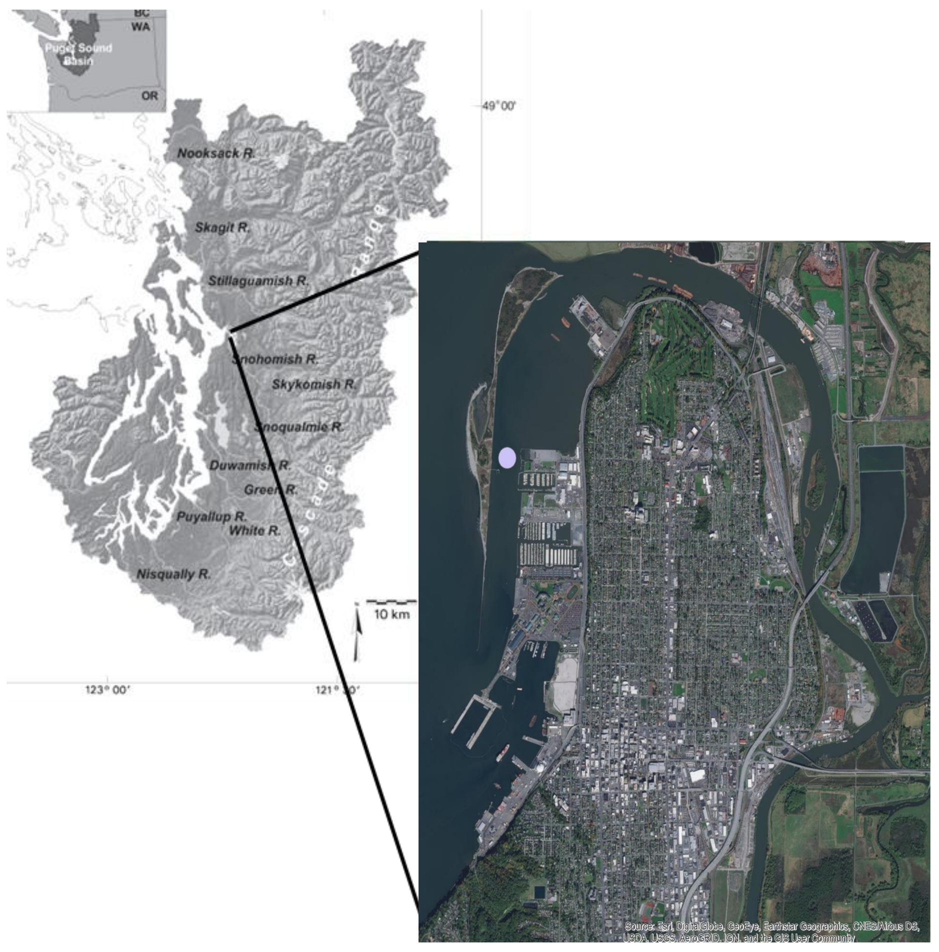
Introduction

The Snohomish River flows into the North Whidbey Basin of the Possession Sound. Here, a salt-wedge type estuary is formed by density differences between the fresh water of the Snohomish River and the higher salinity water of the Possession Sound. This salt-wedge causes stratification in the form of a pycnocline and varies with both the tidal cycle and Snohomish River outflow. The amount of stratification occurring in the estuary can be quantified in terms of the vertical and East/West velocities present in the water column. Vertical and East/West velocities signify mixing occurring in the estuary because the Snohomish River runs in a purely North/South direction. For my hypothesis, I suggested that vertical velocities will decrease during large outflow events and ebbing tide, as the salt wedge shifts and the water column homogenizes. Subsequently, this decrease in mixing will result in lower turbidity values and, eventually, chlorophyll values. These biological products, turbidity and chlorophyll, have implications for the overall health of the estuary, making the amount of mixing in the estuary an important factor.

Study Site



Purple dot indicates location of the ADCP and CTD in the Snohomish River

Methods

This study utilized ADCP and CTD data collected from September 2017 to November 2017 at a centralized location near the mouth of the Snohomish River. Deployment of these instruments was achieved in cooperation with Gravity Marine Consulting. The ADCP data was recorded by a 1mhz Nortek Aquadopp deployed on the seafloor at 10 minute intervals. CTD data was collected by a Seabird CTD, on loan from the Department of Ecology, deployed on a 3-meter pivot off of a floating dock. Analysis was conducted using MATLAB. Snohomish River outflow data was obtained from the United States Geographical Survey.

ORCA

The Ocean Research College Academy is a dual enrollment program where high school juniors and seniors experience innovative, interdisciplinary, and student-centered learning. A longitudinal study of the local estuary forms the backbone of the first-year experience, and leads students to conduct independent research in their second year of the program. ORCA has received grants for a research lab and research vessel, funded by the National Science Foundation.

Acknowledgements

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Results

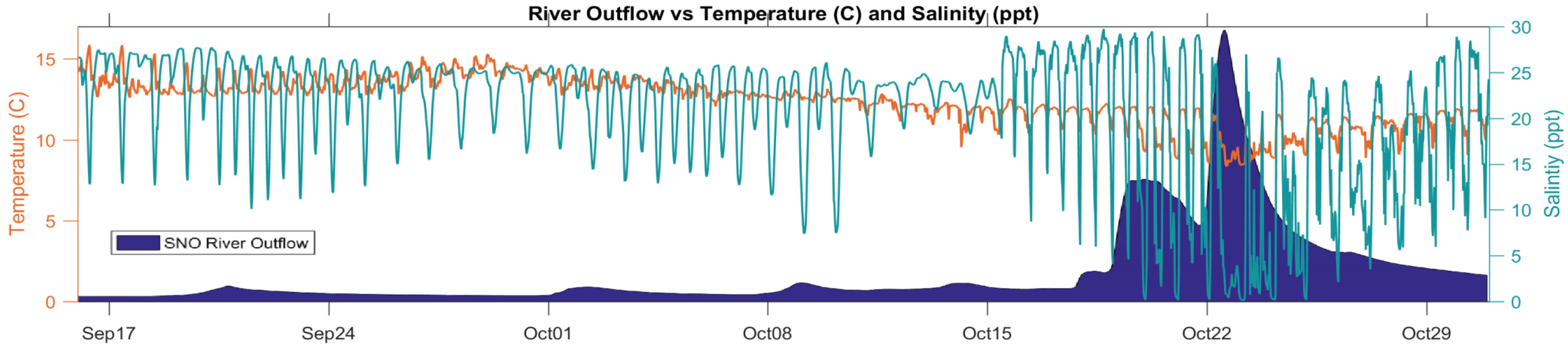

Figure 1: The Snohomish River outflow notably varied over the time period, with a large outflow event occurring in mid October. During this, the outflow of the Snohomish River peaked at 56,000 Cubic feet/second. As shown in the above graph, this input of fresh water disrupted the sinusoidal nature of the salinity and temperature cycles, causing shifts in density.

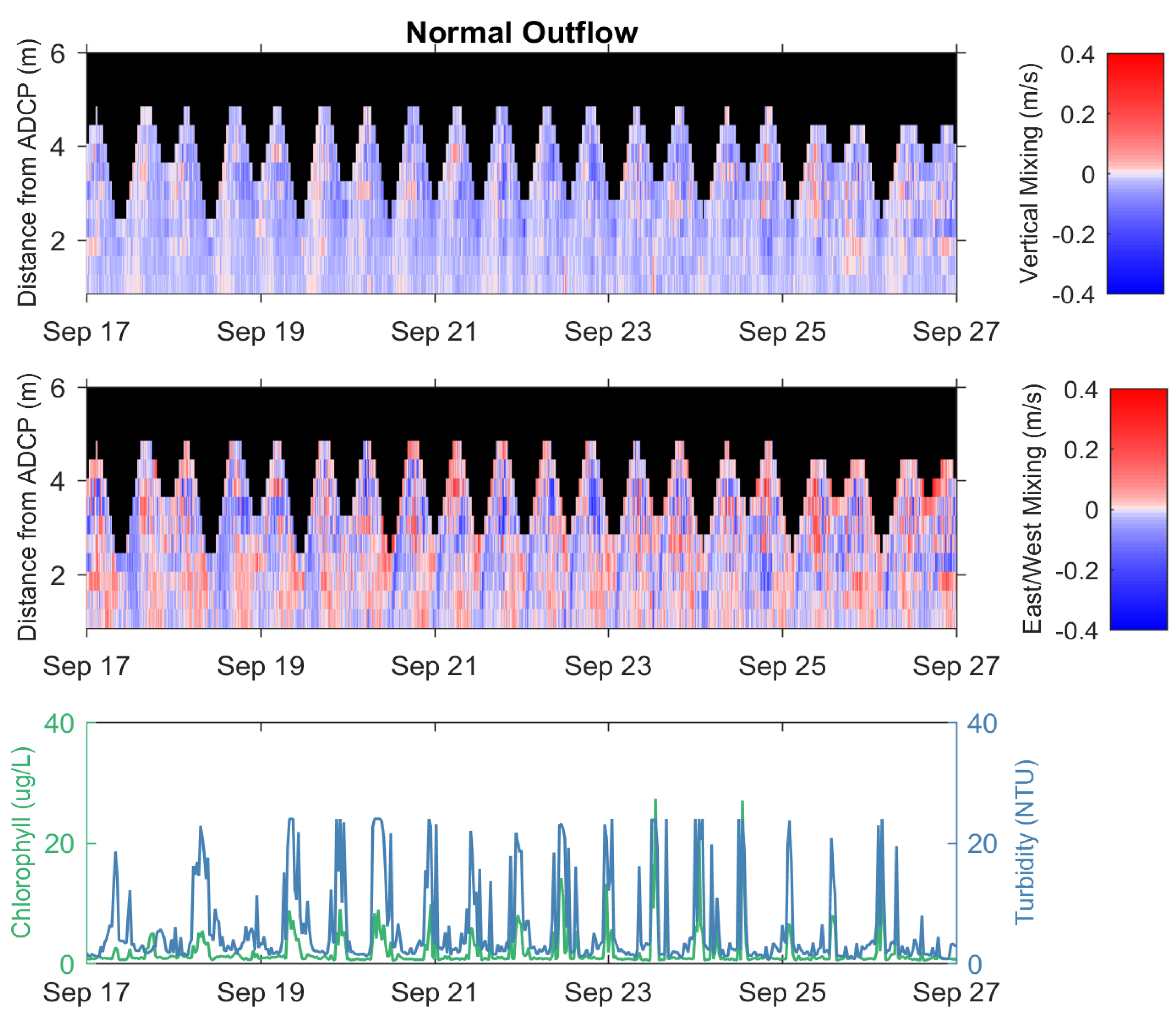

Figure 2: During normal outflow, velocities match tidal cycle. Turbidity and chlorophyll displayed a diurnal trend; peaks of 24 ug/L and 25 NTU

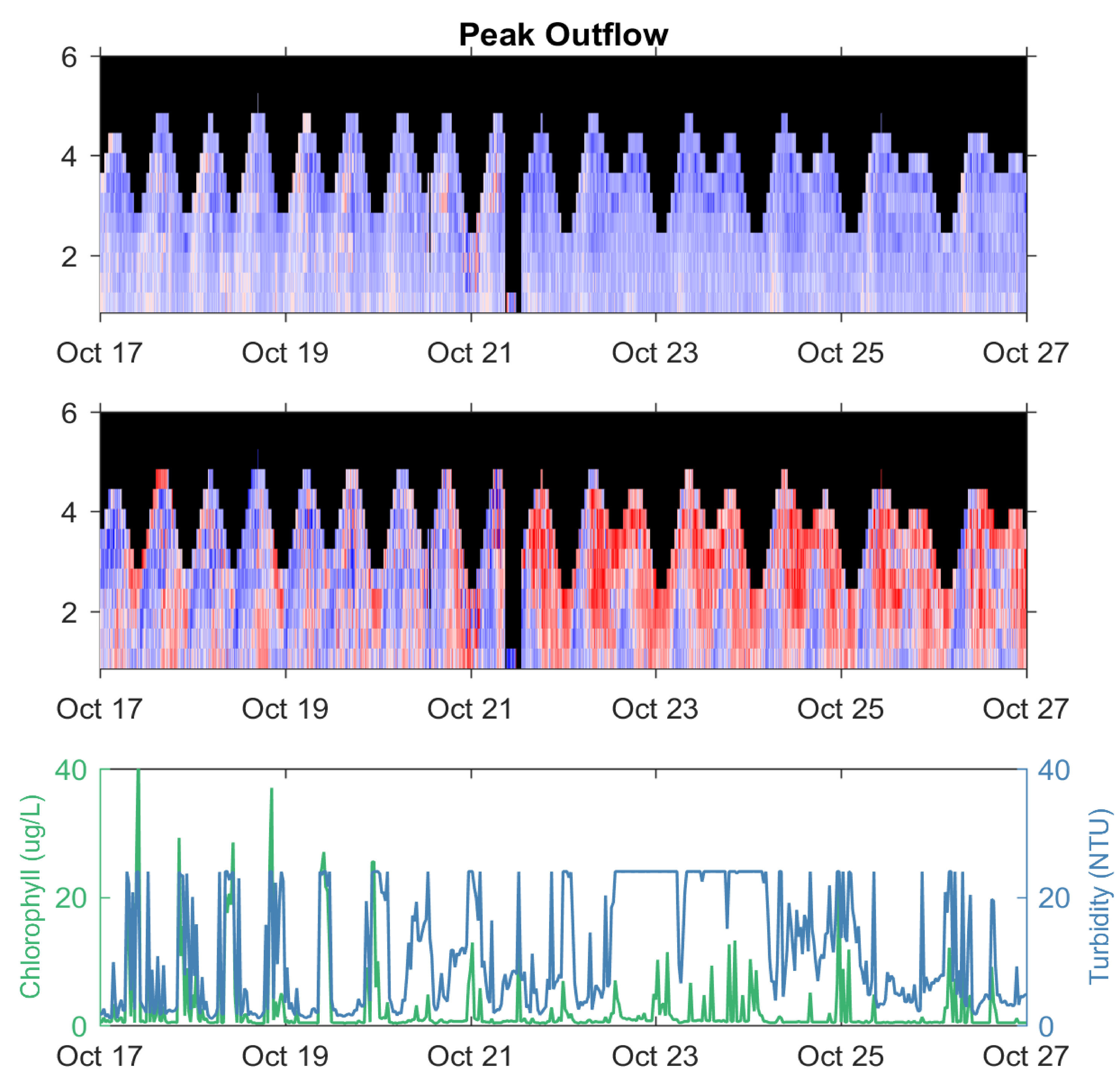

Figure 3: During peak outflow, downward velocities dominate due to river outflow. Turbidity and chlorophyll's trend was disrupted; peaks of 41 ug/L & sustained 25 NTU

Conclusions

Overall, this study was able to build a picture of how Snohomish river outflow, tidal cycle, velocities, and various biological factors interact over a month period. The initial hypothesis was partially supported. In terms of velocities, the time of peak outflow and ebb tide saw large negative vertical values, as predicted. This same trend was not as clear in the East/West velocities, but more mixing appeared to occur during peak outflow as indicated by higher overall velocity values. There did not appear to be any correlation with tidal cycle in these East/West velocities. In terms of biological products, the hypothesis was flawed. Instead of decreasing in turbidity and chlorophyll after a large outflow event, as predicted, turbidity and chlorophyll values saw higher peaks that were sustained for a longer period of time. This is likely because the Snohomish River outputs both nutrients and sediment into the water, affecting the two primary biological products of this study. Instead of looking at two isolated time spans, velocity values could be evaluated over a multi-month period to see how mixing affects these biological values outside of river influence. In addition, quantification of bottom shear stress, which correlates with sediment transport, and suspended sediment concentrations would provide a clearer picture of the interaction between velocity and turbidity.

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