Trends in Precipitation and Surface Discharge in the Clackamas and Nehalem Rivers

Nadison Kannan

Department of Geology, Portland State University

G410: Python for the Natural Sciences

Professor David Percy

March 21, 2025

Abstract

Plastic waste accumulation in the ocean occurs in five major zones in the Earth's oceans. The largest of the five is the Great Pacific Garbage Patch (GPGP). These plastic waste zones are primarily fed by rivers as they transport plastic waste from inland into the ocean. Therefore, if climate change were to change the regional precipitation patterns and subsequent discharge of affected rivers, it could also impact the rate of plastic transport from inland to ocean garbage zones. The research question explores the possibility of changing trends of precipitation and river discharge in the Columbia River Gorge: How have precipitation patterns in Northwestern Oregon changed and what impact does this have on nearby surface runoff?

The datasets are downloaded from the United State Geological Study (USGS) and include two stations, 1) the "USGS 14210000 CLACKAMAS RIVER AT ESTACADA, OR" and 2) "USGS 14299800 NEHALEM RIVER NEAR VERNONIA, OR". Both datasets are analyzed in Jupyter Notebooks using pandas for the analysis and manipulation of data and matplotlib.pyplot for visualizing trends. The main challenge was determining what to do with NaN values in the data, there was 18.25% rows with NaN values in the Clackamas River dataset and 16.37% NaN values in the Nehalem River dataset. These rows were removed so that both datasets had a discharge and precipitation value to compare for each date without any missing data.

Graphs of the data showed a cyclical pattern for both discharge and precipitation over the course of fifteen years. However, there was no clear trends of increasing precipitation. Recent years showed lower values for precipitation than prior years and thus lower rates of discharge for both rivers. Thus, there is a clear relationship between precipitation and discharge for both rivers, however no notable increase in either in the last fifteen years. Future research might benefit from a dataset with a longer timeframe to see more long-term trends.

Introduction

The Great Pacific Garbage Patch (GPGP) is a massive aggregation of ocean plastic waste in the Pacific Ocean between Hawaii and California. There are five plastic accumulation zones in the ocean and the GPGP is the largest of the five. It is estimated that one to two billion tons of plastic is transported from land to the ocean through rivers each year (The Ocean Cleanup). Plastic pollution in the ocean poses a great risk for the diversity of wildlife that inhabits the ocean as well as for human populations that rely on the ocean for food. Marine animals of all shapes and sizes mistake colorful plastics for food and will ingest them. Microplastics and other toxins will then bioaccumulate in the marine animals and bio-magnify all the way up the food chain until it reaches humans. Thus, the plastic waste that is discarded inevitably returns to the human populations that created it and potentially cause health risks.

Rivers are the primary conduit for transporting inland plastic into the ocean where it will end up in one of the five plastic accumulation zones. To precent more ocean plastic accumulation, stopping inland plastic waste transportation from river drainage is the most effective way to ensure that the oceans remain plastic free. However, the solution is far more complex, as every river in the world has a variety of different factors that determine how plastic is accumulated and transported by them (The Ocean Cleanup). The Ocean Cleanup, a non-profit dedicated to cleaning the ocean and stopping plastic pollution, lists the variables that must be considered for each river as river width, depth, flow, speed, debris composition, seasonality, and tides. Thus, to effectively address plastic waste transport via rivers, river dynamics and patterns must be understood.

River patters are typically cyclical, but this depends on the type of river and location. However, because the Earth's climate is slowly changing due to natural solar variability, as well as increasing concentrations of greenhouse gases and aerosols, the water cycle might also be affected. Because the water cycle is driven by heat in the atmosphere, change in climate could affect atmospheric water vapor concentrations, clouds, precipitation patterns, and runoff and stream flow patterns (NASA Earth Observatory). Thus, when trying to understand plastic waste transport via rivers to the ocean, climate change and its impact in river variability and change is an important consideration when thinking about the long-term prevention of plastic waste entering rivers in the first place. Additionally, changes in the precipitation and stream flow patterns may expedite plastic transportation to the ocean.

The research question being addressed in this project is as follows: How have precipitation patterns in Northwestern Oregon changed and what impact does this have on nearby surface runoff? This question focuses on changes in water cycle and thus river behavior due to climate change. The goal is to determine whether these changes exist and if so, how they might contribute or complicate the prevention of plastic waste entering rivers and draining into the ocean.

Methods

This project will utilize publicly accessible data through the United States Geological Survey (USGS) website that has water data with up-to-date readings for various stations across the United States. From this database, there are various stations around the Columbia River in Western Oregon that must be parsed through to find stations that have a long-established record of both river discharge and precipitation. As it turns out, most of the stations in this area did not have a large enough record of precipitation, however both the “USGS 14210000 CLACKAMAS RIVER AT ESTACADA, OR” and “USGS 14299800 NEHALEM RIVER NEAR VERNONIA, OR” stations had continuous daily data for the last 15 years. These rivers are in geographically similar areas and so their data would be useful to compare to determine if there are any overarching trends or lack thereof.

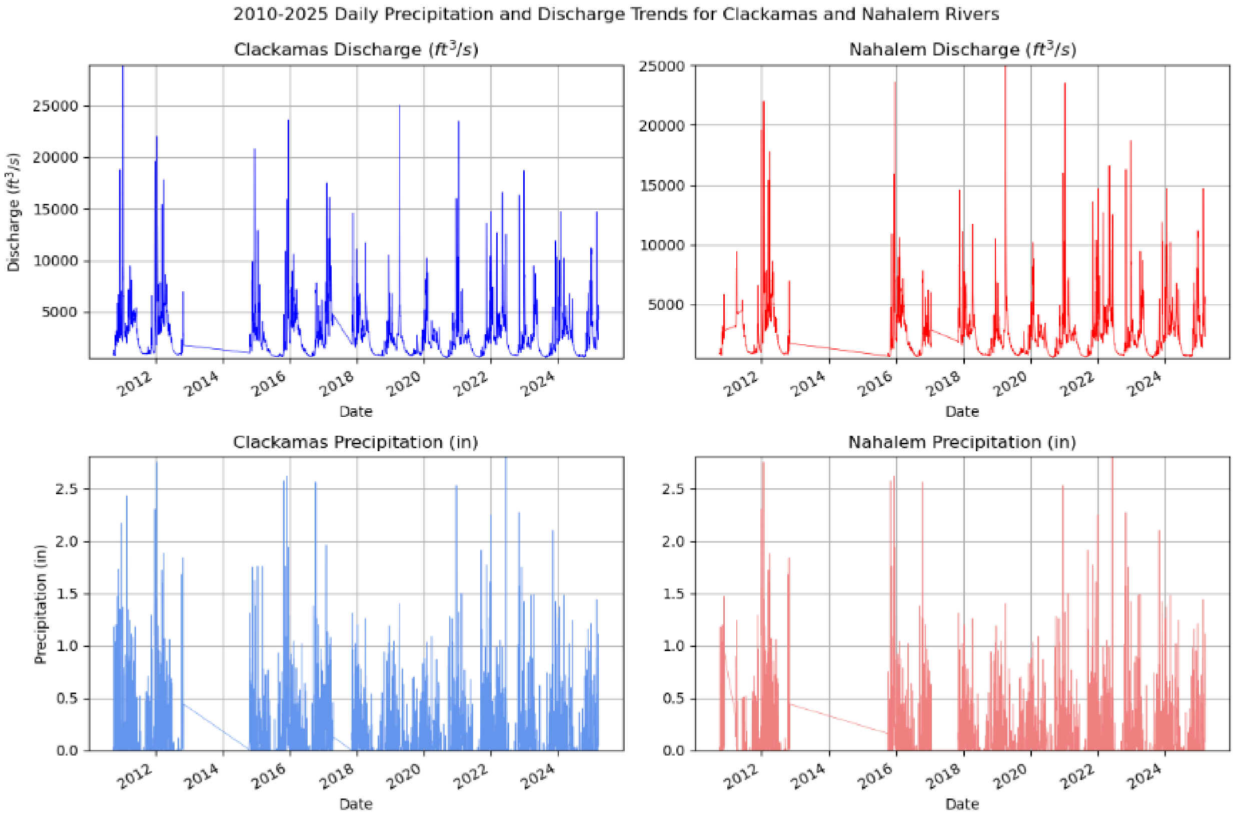
Next, the datasets were downloaded for both stations for the entirety of the available precipitation timeframe- the data for discharge went much farther back. The time frame of the data that was chosen was between the dates of October 1, 2010, and March 18, 2025, 14 years, 5 months and 18 days' worth of daily continuous data. To analyze, manipulate, and visualize the data, the files were uploaded into Jupyter Notebooks using pandas for python. The files were downloaded as tab-delimited text files and needed to be read in to account for this format. This included converting all numerical columns to numbers and converting dates to python's 'datetime' format. The last step in uploading the data was to select only the columns of data that were needed and to rename the columns for easier reference. The columns that remained were the date, discharge, and precipitation columns. The date column contained the date of observation (YYYY-MM-DD format), the discharge column contained the volume of water flowing per second at a specific point in a river, measured in cubic feet per second, and the precipitation column contained the amount of rainfall recorded on that day, measured in inches. The Clackamas River and Nehalem River data were contained in two separate data frames

Now that the data was uploaded and contained in separate pandas data frames, the next step was to verify the integrity of the data, that is, check for missing data and NaN values. It turns out that there was a significant number of NaN values in each of the datasets. A quick analysis revealed that the Clackamas River dataset was 18.25% NaN values, and the Nehalem River dataset was 16.37% NaN values. Additionally, these NaN values were preventing the program from converting the numerical columns into numerical data types. There were two options for dealing with this NaN data, replace it with 0's or random data, or remove all rows that had a NaN value in one of the columns. Since the project is mostly concerned with the relationship between discharge and precipitation, it was decided to remove all rows that have a NaN value, so that only rows that have a numerical value for both columns remained. That way, the main trends remain intact, and there would be a true value for discharge and precipitation to compare against each other. After dropping the NaN values, the Clackamas River dataset had 4319 rows, and the Nehalem River dataset had 3707 rows.

Now that the NaN values were filtered out, the data was now ready to be visualized. After graphing the raw data, the curves were a bit too noisy to see any clear trends, so two new columns with weekly mean discharge and precipitation were added to the data frame with the intention of reducing noise while also preserving any trends. However, due to the amount of data, graphing the weekly means did not reduce the noise by much. Finally, a distribution of the data values for both discharge and precipitation were created to see the distribution of data.

Results

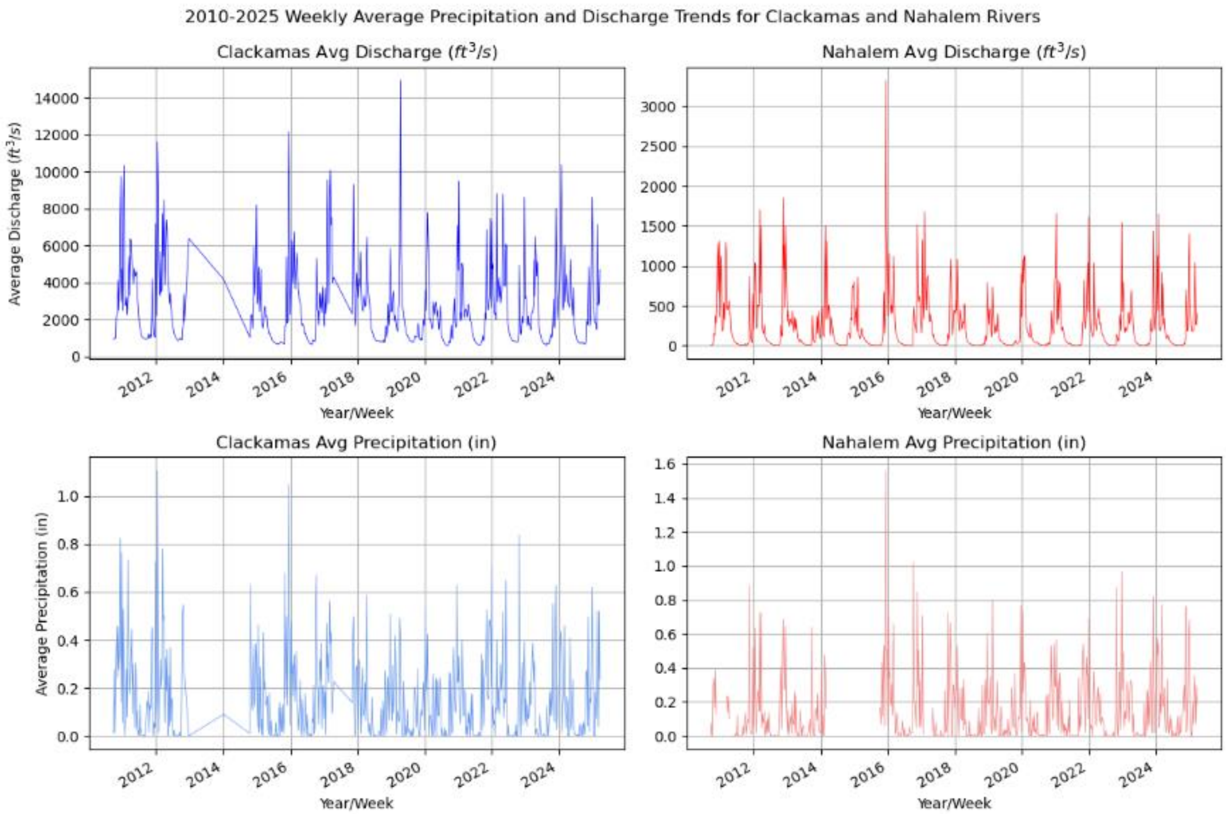
The graph of the daily discharge and precipitation is included below. From these subplots, there is a clear break in the data, likely where the NaN data that was cleaned out. It seems that most of this data that was missing was around 2013 and 2015. Despite this missing data, most of the rest of the data remains continuous and therefore fruitful for further analysis. A cyclical pattern can be observed in both the discharge and the precipitation, both of which seem to have peaks around the same times. This is to be expected since the water cycle is just that- cyclical. Just from looking at the graphs, it appears as though there are no overarching trends of increasing or decreasing overall discharge or precipitation. Additionally, the daily graphs are a bit too noisy to get a clear idea about overarching trends. To get a better idea of whether there are overarching trends, it might be beneficial to look at weekly averages.



Subplots of the daily discharge and precipitation of the Clackamas and Nehalem rivers from 2010 to 2025.

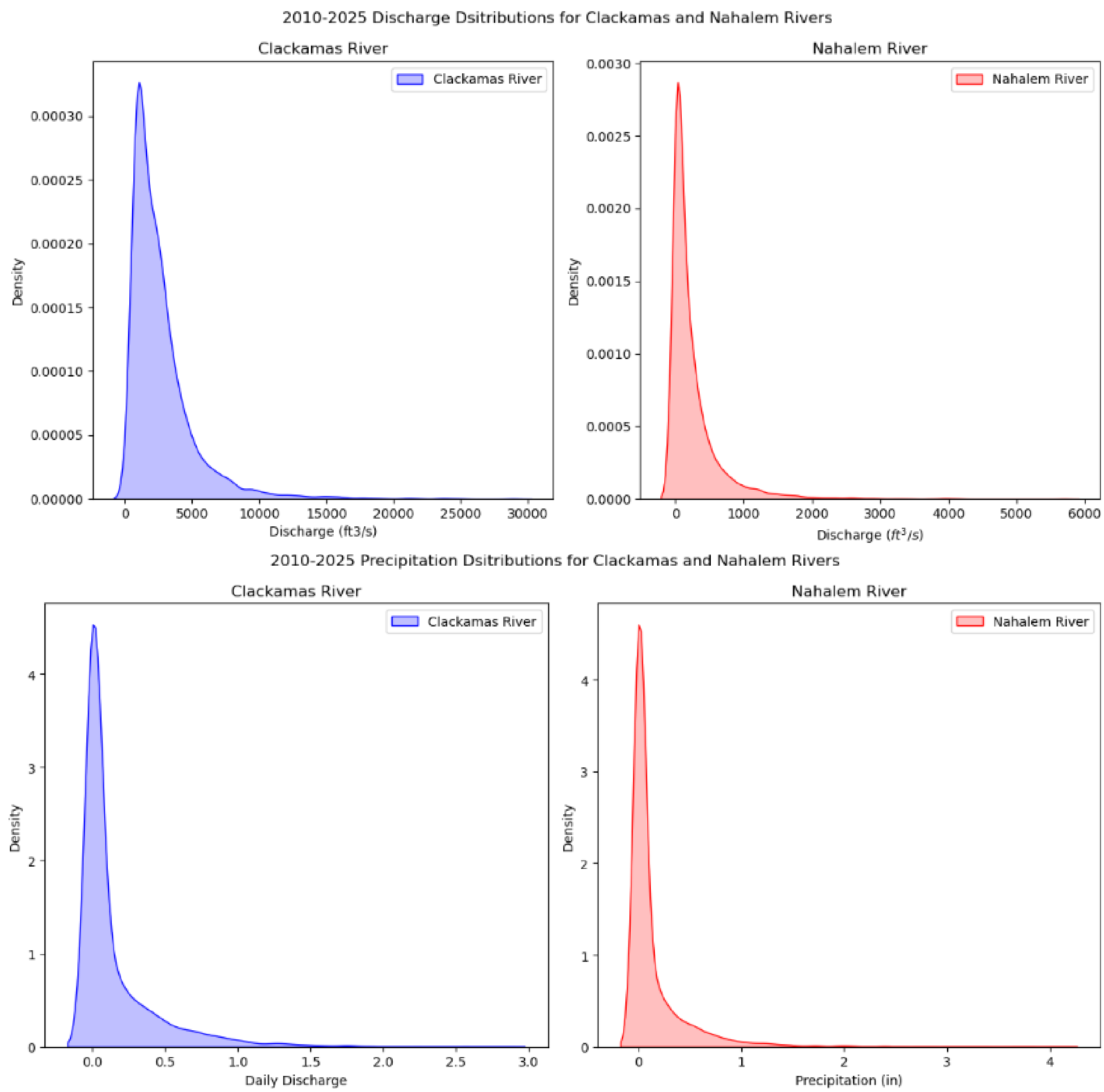
The graphs of average discharge per week in the figure below are slightly less noisy, however it is still unclear whether there is a larger overarching trend. Based on visual observation, the cyclic rise and fall are still preserved. There is clearly a relationship between both the discharge and precipitation graphs for both rivers in that when one rises, the other does too and vice versa. Just based on the water cycle, the precipitation is likely the causal driver for the rise in river discharge.

Unfortunately, the range of data that is available for both parameters are too small. To see if there is an increase or decrease of precipitation and thus river discharge over time, we would need data that goes back much longer than fifteen years. With such a small timeframe, it is difficult to determine whether there are any long-term increases in precipitation and even if there are, if they are attributed to normal weather patterns or longer scale patters line the La Niña and El Niño. One thing to note is that large precipitation values appear to be correlated with larger discharge values. This is to be expected, but these graphs confirm the relationship between precipitation and discharge.



Subplots of the daily average discharge and precipitation of the Clackamas and Nehalem rivers from 2010 to 2025.

Finally, plots of the distribution of values for discharge and precipitation were generated and included below to see if the data is skewed in any direction. Both figures for discharge and precipitation appear to be skewed right. This is because there are some higher value outliers that is pulling the distribution to the right. This could be explained as abnormally large precipitation or discharge values being recorded which might be indicative of climate change. The cause of these larger values is hard to determine from the data that was analyzed in this project, as these larger values could be from normal weather fluctuations.



Distributions of the discharge (top) and precipitation (bottom) values for both the Clackamas and Nahalem Rivers.

Because of the dataset having data from only the past fifteen years, the exploration done above is inconclusive and will need much more robust data sets to explore. At the very least, it can be said that according to analysis done above, that there are no notable changes in precipitation and thus discharge within the past 15 years. However, the graphs that were generated show a strong relationship with precipitation and river discharge. Thus, we can say that if climate change were to affect the water cycle by increasing rainfall, then this might contribute to faster discharge rates and thus more potential for more plastic waste to drain into the ocean.

Discussion

The results of the graphs and the overarching trends are difficult to extrapolate on. Earth's processes are on a geological time frame, so they unfold slowly over the course of thousands, sometimes millions of years. Even climate change which is a relatively rapid development might take hundreds of years of data to see clearly. Some effects of climate change might happen on a shorter time frame, but changes in precipitation, if there are any changes, will likely not appear on a time frame of fifteen years. To remedy this, much more robust datasets will need to be used, datasets with at least fifty years of continuous data might have more telling results.

This minimum timeframe for geological processes as they pertain to climate change raises an interesting implication, that data analysis insights are limited by the rigor of the datasets that are used. For instance, most of the stations that were considered for this project only had one or two years of precipitation data. This time scale is useful for looking at annual patterns, but research requiring long-term data will be inaccessible to an entire generation of researchers until decades more data are recorded. Surely there are alternative methods for researching these questions that do not rely on when a station was established, and these would be worth exploring in circumstances where a robust dataset is not available.

To further explore this question of climate change and its impact on precipitation driven plastic transport, a research question could focus on surface water velocity to see how it has changed over time. Observed trends might be more informative about how changes in runoff velocity could contribute to seasons of greater transport of plastics and other waste into the oceans thus contributing to a cyclical rate of increasing pollution entering the oceans from inland.

Plastic waste accumulation in the ocean is not a concern only because it impacts humans, it is a concern because it disrupted natural processes that have taken place in the ocean on a geological timespan (millions of years). Human populations have come to rely on predictable behaviors of these Earth systems for both survival and livelihood. Plastic waste accumulation in the ocean puts novel pressure on these otherwise stable environments and can cause unsightly consequences for both marine and human populations.

References

NASA Earth Observatory: The Water Cycle and Climate Change https://earthobservatory.nasa.gov/features/Water/page3.php

The Ocean Cleanup: The Great Pacific Garbage Patch https://theoceancleanup.com/great-pacific-garbage-patch/

The Ocean Cleanup: Halting Plastic Before It Reaches the Ocean – Tackling Trash Rivers https://theoceancleanup.com/rivers/

USGS National Water Information System https://waterdata.usgs.gov/nwis