Hurricane Trends Along the East Coast

https://github.com/elise-227/BoosBrantleyHusted_ENV872_EDA_FinalProject.git

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Rationale and Research Questions

Hurricanes are a serious natural disaster that affects millions each year along the East Coast of the United States. Furthermore, hurricanes create severe flooding, dangerous storm surges, and high winds that have long-lasting and devastating consequences on many communities (Schmeltz et al. 2013). Understanding how climate change influences the trends of hurricanes will be informative for strategic planning to protect both property and lives in the future (Mudd et al. 2014). For this analysis we chose to look at discharge data in the vicinity of major rivers in states spanning the East Coast of the US. The objective of the analysis is to gain valuable insight on how locality and intensity of these hurricanes may be changing over the past three decades.

Discharge data in Florida, North Carolina, and New York will be used to gain a better understanding of how hurricane regimes change across the entire span of the coast through time. Furthermore, the comparative study will reveal if hurricanes are shifting poleward. Our central research questions revolve around investigating any increasing trends in discharge during the hurricane season (June-October) and where these increasing trends are more intense.

Research Questions

Question 1: Has there been an overall increase in mean daily discharge during the Atlantic hurricane season from 1990 - 2021?

Question 2: Has one portion of the East Coast of the US experienced a disproportionate increase in hurricane activity, and its associated discharge, compared to other portions commonly affected by these hurricanes?

Question 3: Are the general locations of hurricanes shifting towards the poles in the northern and/or southern hemisphere?

Dataset Information

All datasets used in this analysis were downloaded from the United States Geological Survey (USGS) website, specifically from historical records of discharge data recorded by field dataloggers. The data was obtained from three states varying in latitude along the East Coast (i.e., Florida, North Carolina, and New York). Stream gage locations were selected based on proximity to major river basins and vulnerable counties susceptible to hurricane impacts. Additionally, gage locations were specifically chosen with sufficient data, going back to at least the 1990s. Similar timeline ranges for the datatsets ensures a time series analysis that is comparable among all three sites. Discharge data was the data type used in this analysis with all datasets having at minimum daily recordings but some having recordings as often as every 30 minutes. The basic data structure is outlined below (Table @ref(tab:table1)).

Table 1: Table summarizing the dataset structure

Column Name	Description
Agency	USGS
SiteNumber	USGS gage number
MeanDischarge	Mean daily discharge (cfs)
Date	Date of collection
Month	Month of collection

Data Wrangling

Downloaded datasets included date/time and mean discharge (cfs) columns. After the date column was properly classified as a date, unnecessary columns were removed from the data frame. Next, the date column was separated out to filter for years 1990-2021 and to filter for hurricane months (June-October). The dataset was then saved into the processed folder for each of the research locations. Missing data values were then filled using a linear interpolation and then daily averages of discharge were created in a new, clean column of daily means. After all fo these steps were taken the data was considered to be wrangled and was then ready for initial visualizations.

Exploratory Analysis

The exploratory analysis of the data involved creating a map of the USGS gage locations along the East Coast of the U.S. to orient individuals towards the locality of the research. Also, the initial visualizations of the discharge data for each research location-during hurricane seasons-was included in the exploratory analysis from ~1990-2021. After the initial graphs displayed poorly visualized data, a log scale was applied to the y-axis in order to better present any noticeable trend that may be occurring. Comparing differences between the intensity, frequency, and shifts in these variables over time, permitted researchers to formulate predictions on possible changes in each research location as well as any changes over time. However, to fully understand these shifting trends, the following time series analysis was conducted.

Below is a map of where each USGS gage site is located along the Atlantic coast of the US.

```
#{r map of locations, warning=FALSE,echo=FALSE} #site_locations <- read.csv("../Data/Ra
stringsAsFactors = T) #site_locations.sf <- site_locations %>% #st_as_sf(coords
= c('Long','Lat'), #        crs=4269) #mapview(site_locations.sf[1,], zcol
= "Site.Name", col.regions = "deeppink1") + #mapview(site_locations.sf[2,],
zcol = "Site.Name", col.regions = "turquoise4") + #mapview(site_locations.sf[3,],
zcol = "Site.Name", col.regions = "forestgreen") #
```

Figure @ref(fig:ex-an-FL) is an initial plot of discharge within hurricane months at the Florida location and shows a potential decrease in discharge over time.

The following plot (Figure @ref(fig:ex-an-NC)) for the North Carolina daily discharge dataset displays a potential increasing trend over time.

The following Figure @ref(fig:ex-NY) for the New York daily discharge dataset displays a potential increasing trend over time.

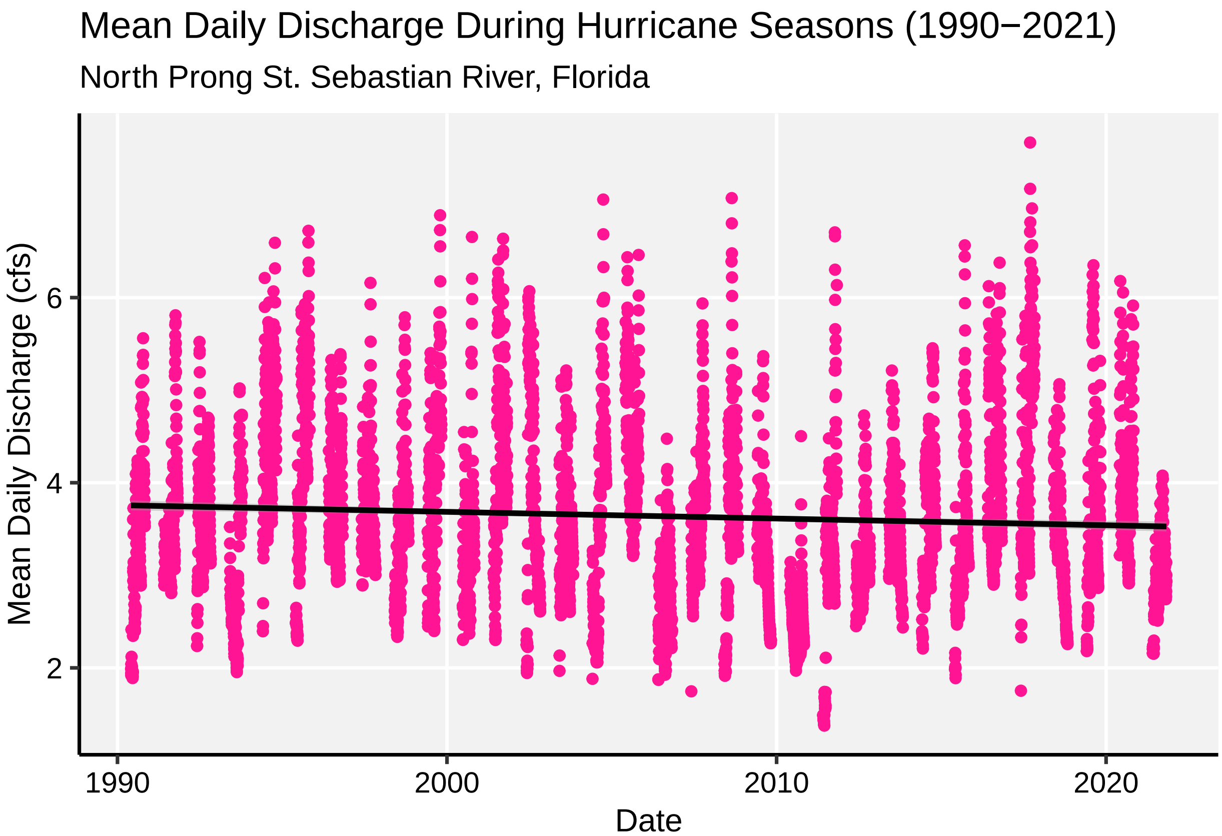

Figure 1: Florida Discharge (cfs) 1990-2021

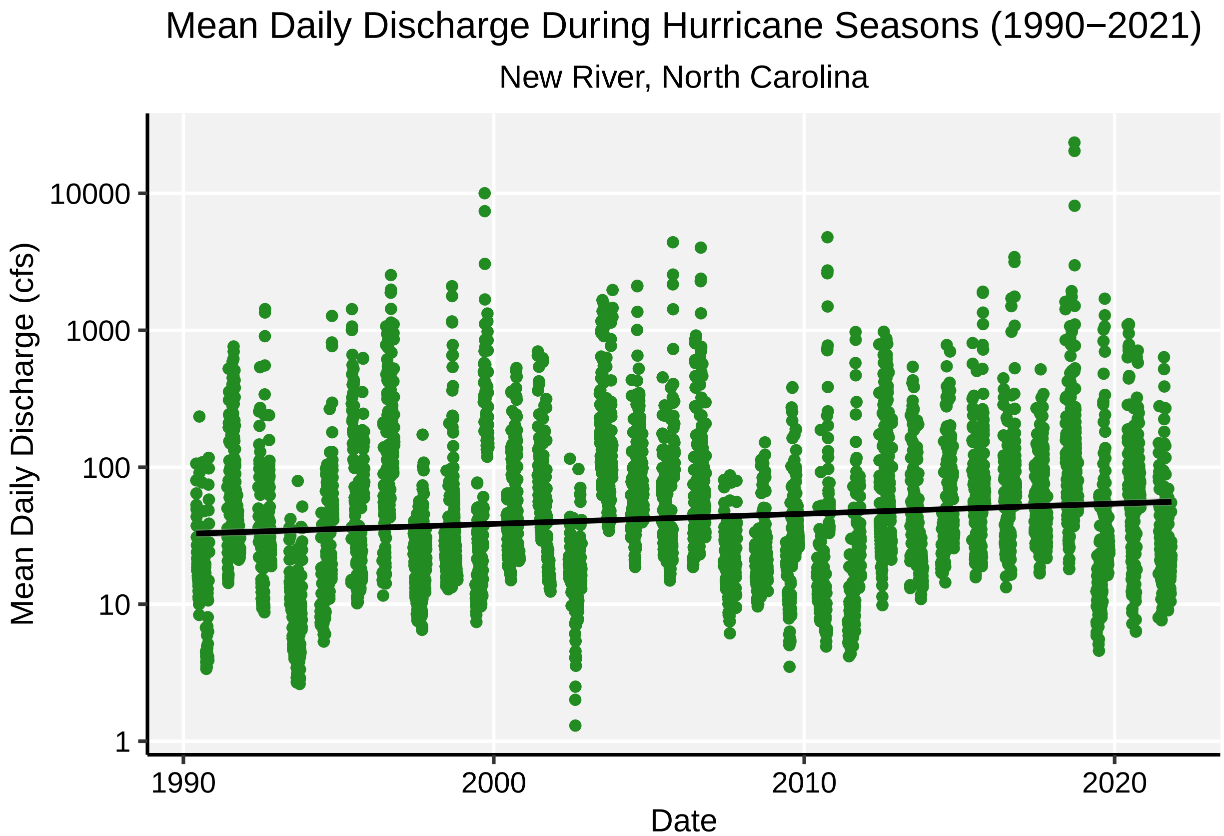

Figure 2: North Carolina Discharge (cfs) 1990-2021

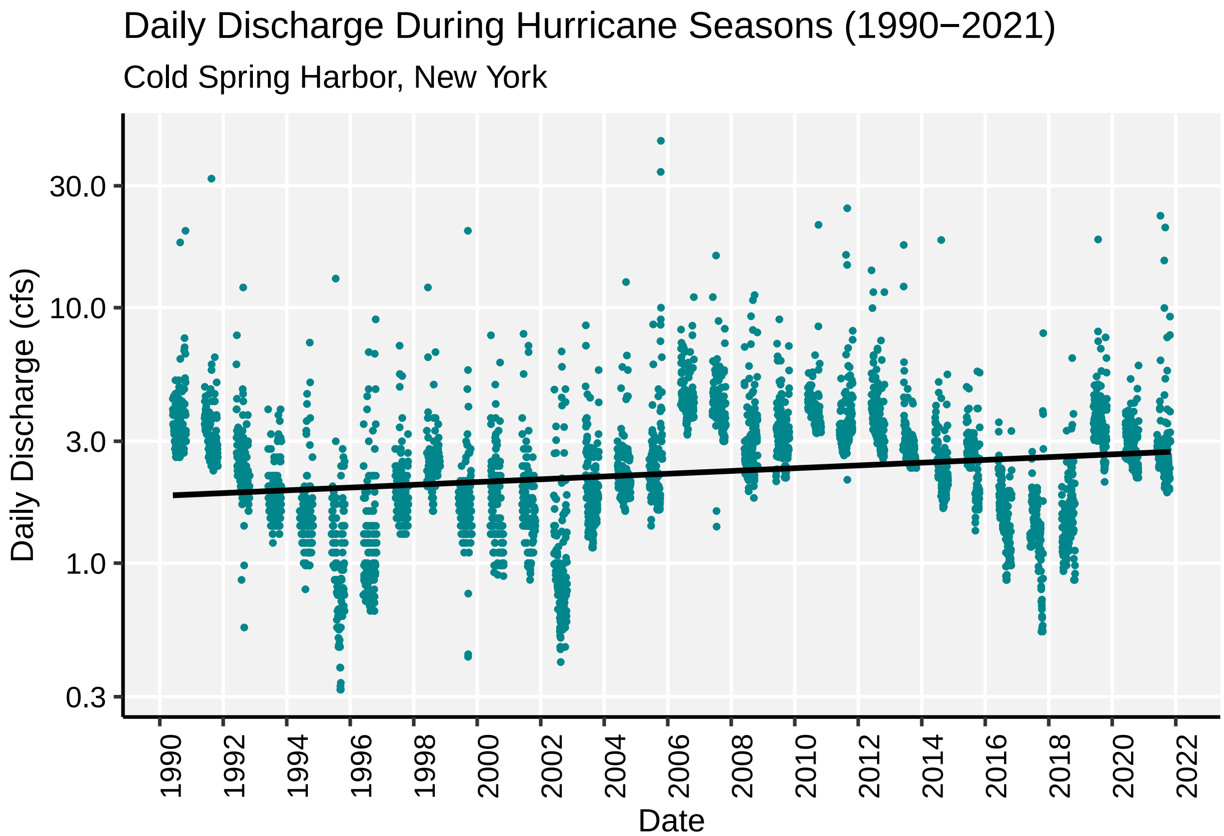

Figure 3: New York Discharge (cfs) 1990-2021

Analysis

The analysis of these datasets centers on creating time series objects of the discharge data. These time series objects are then decomposed to analyze the trend, seasonality, and remainder for the data values. New dataframes were then created with these three aspects of the time series. Within these dataframes, the trend and remainder values for each data point were combined to create a “non-seasonal” discharge value in order to better understand the actual changes in hurricane intensity and frequency during the hurricane season.

These non-seasonal values were then used to create another time series object which was graphed to visualize potential trends that may be occurring in the data as well as the spread of the discharge values. The spread of the discharge values indicates differences in discharge which is a proxy for hurricane intensity. To analyze trends statistically, rather than visually, a Mann Kendall test was performed. The Mann Kendall test produced a tau value which indicated whether the trend was increasing or decreasing. The tau values were compared across all three research locations in addition to p-values which displayed statistical significance of the results.

New York Analysis

The following plot displays the decomposed daily discharge components of the time series run on the New York dataset during hurricane season (Figure @ref(fig:NY-time-series-analysis)).

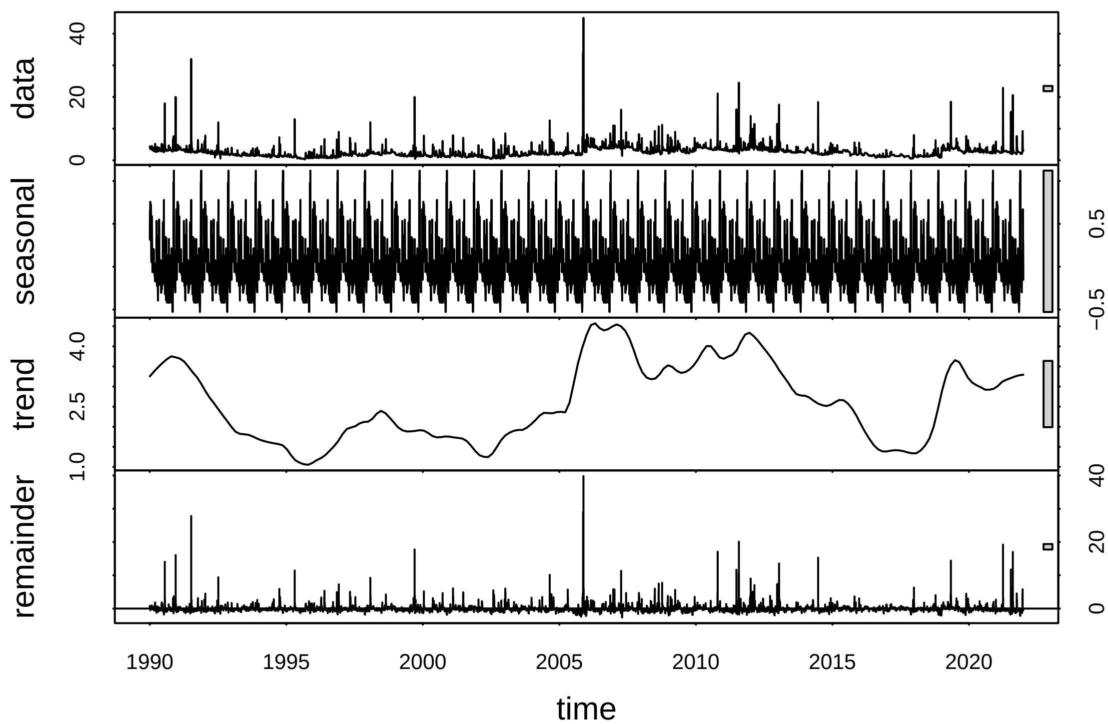

Figure 4: Decomposed Components of the New York Discharge Time Series

```
## tau = 0.13, 2-sided pvalue =< 2.22e-16
```

The Mann Kendall analysis performed on the New York non-seasonal time series produced a tau value of 0.13 with a p-value of less than 0.05. As a result, the data displays a significant, increasing trend for New York.

The plot below displays the non-seasonal daily discharge data in the New York time series which was produced by removing the seasonal component from the time series (Figure @ref(fig:NY-time-series-analysis-continued)).

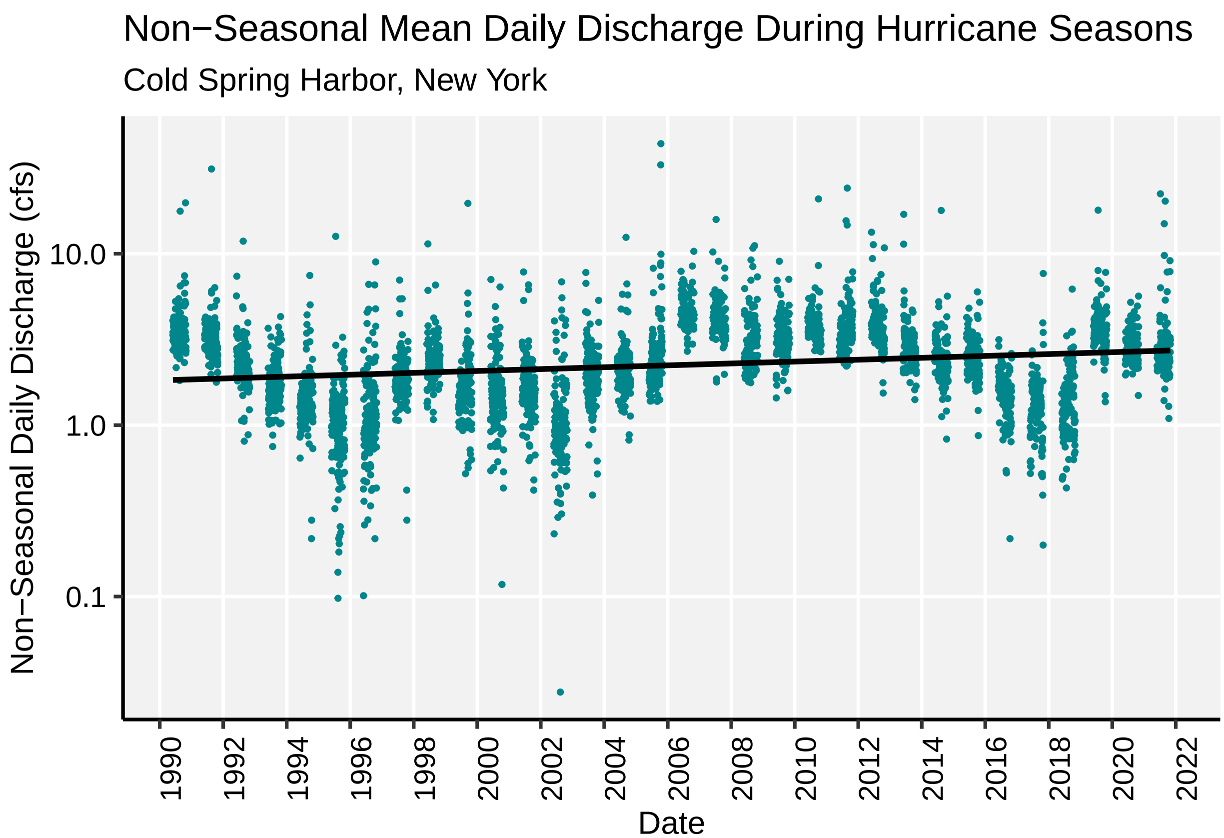

Figure 5: Nonseasonal Data from the New York Discharge Time Series

North Carolina Analysis

```
## tau = 0.0572, 2-sided pvalue =< 2.22e-16
```

Above is the decomposed time series of the North Carolina discharge data during hurricane months (Figure @ref(fig:NC-time-series-analysis)). The Mann Kendall Test yielded a tau value of 0.0572 and a 2-sided p value of =< 2.22e-16.

The plot above displays the non-seasonal data in the North Carolina time series which was produced by removing the seasonal component from the time series (Figure @ref(fig:NC-time-series-analysis)).

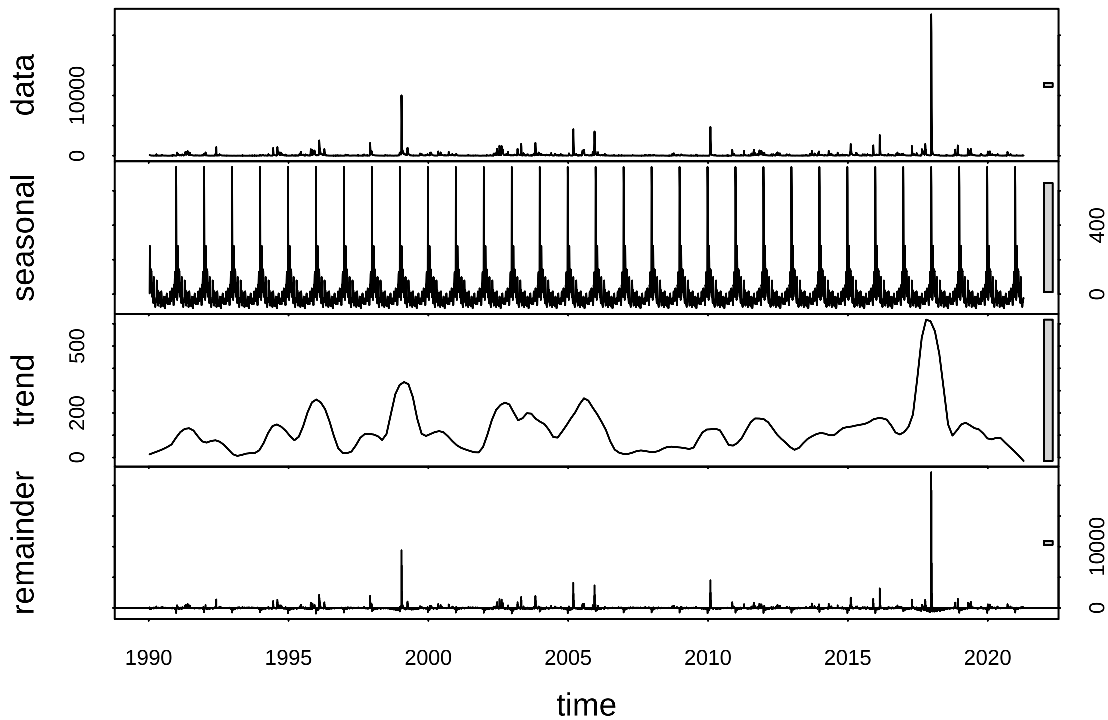

Figure 6: Decomposed Components of the North Carolina Discharge Time Series

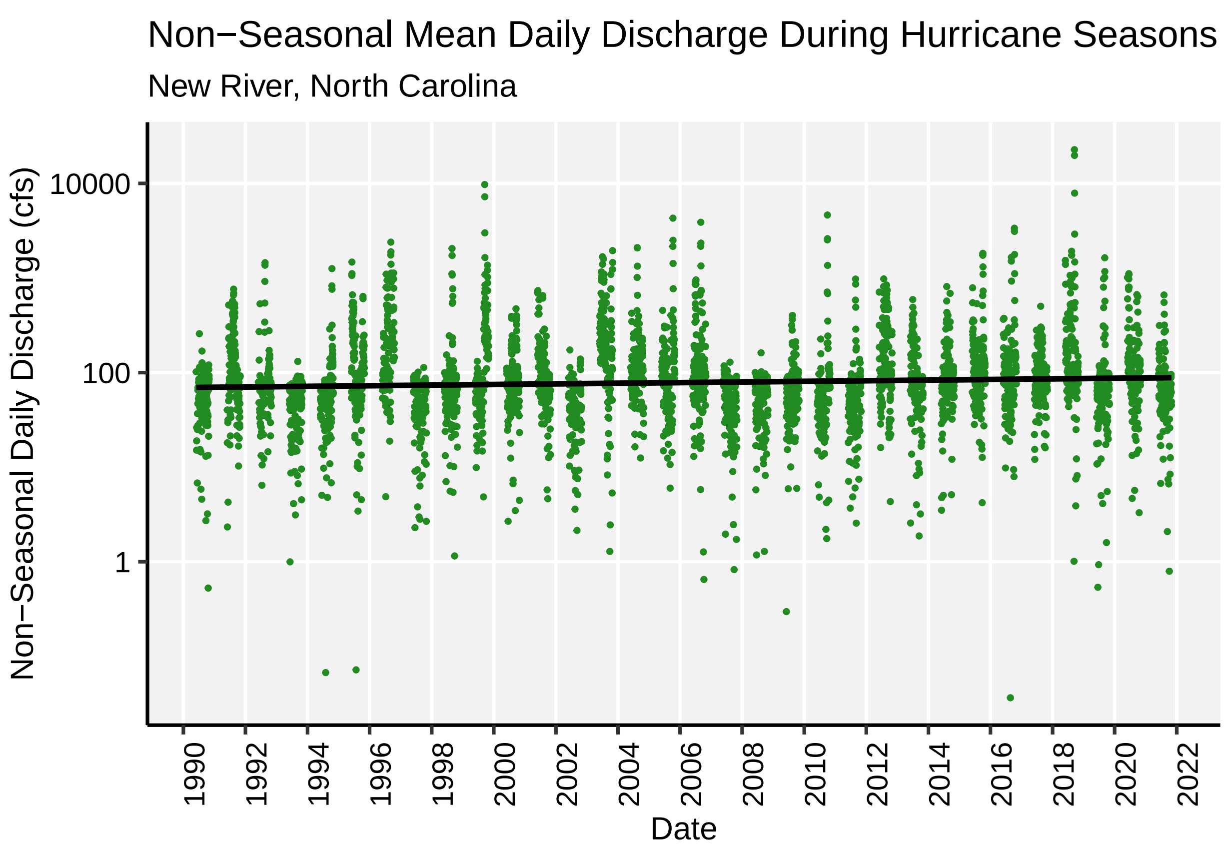

Figure 7: Nonseasonal Data from the North Carolina Discharge Time Series

Florida Analysis

Seen below is the decomposed time series of the Florida discharge data during hurricane months (Figure @ref(fig:FL-anlaysis-time-series)).

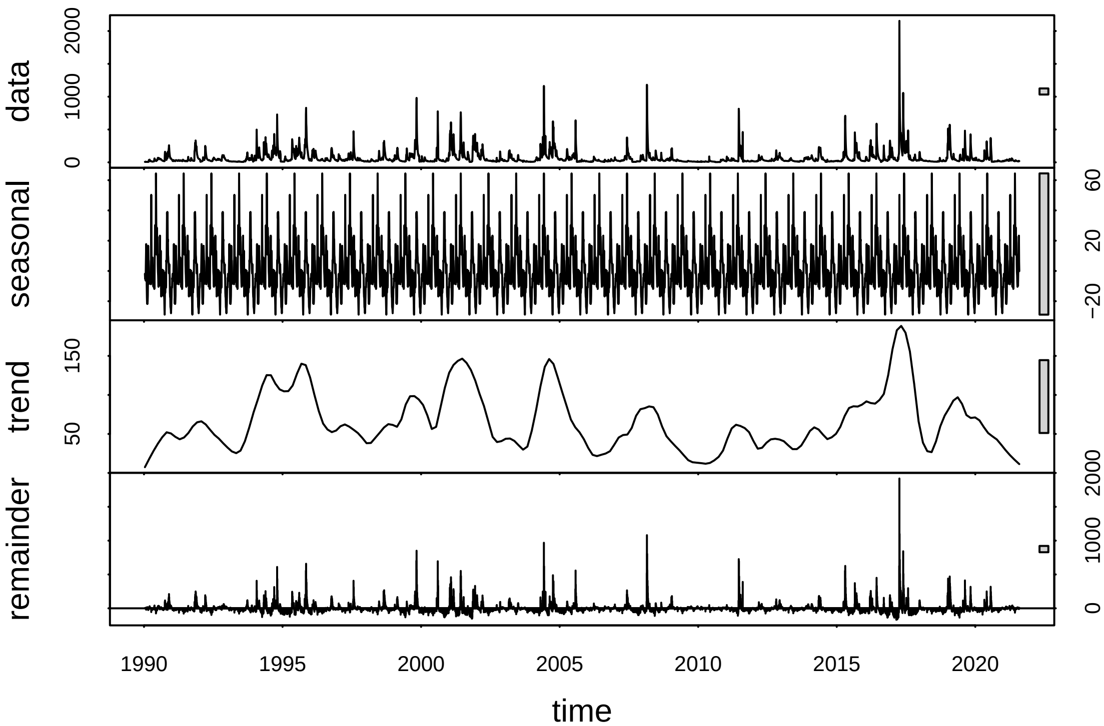

Figure 8: Decomposed plot of Florida discharge time series

```
## tau = -0.0516, 2-sided pvalue =7.7953e-08
```

From running a MannKendall nonseasonal trend analysis on the Florida discharge data set there is a significant overall decline in discharge over time with a tau value of -0.0516 (p = 7.7953e-08). Below this trend is visualized in a plot of the non-seasonal time series of Florida discharge with the significant decreasing trend shown with the black line (Figure @ref(fig:FL-analysis-final-plot)).

Comparison between Sites

Each of the locations non-seasonal time series and trends are visualized and compared in the figure below (Figure @ref(fig:combined-plot)). The color patterns are the same as above with Florida in pink, North Carolina in green, and New York in turquoise.

From this visual we can see that New York and North Carolina are seeing upward trends while Florida is seeing a downward trend in discharge. Also the overall discharge in New York is less than that of Florida and North Carolina.

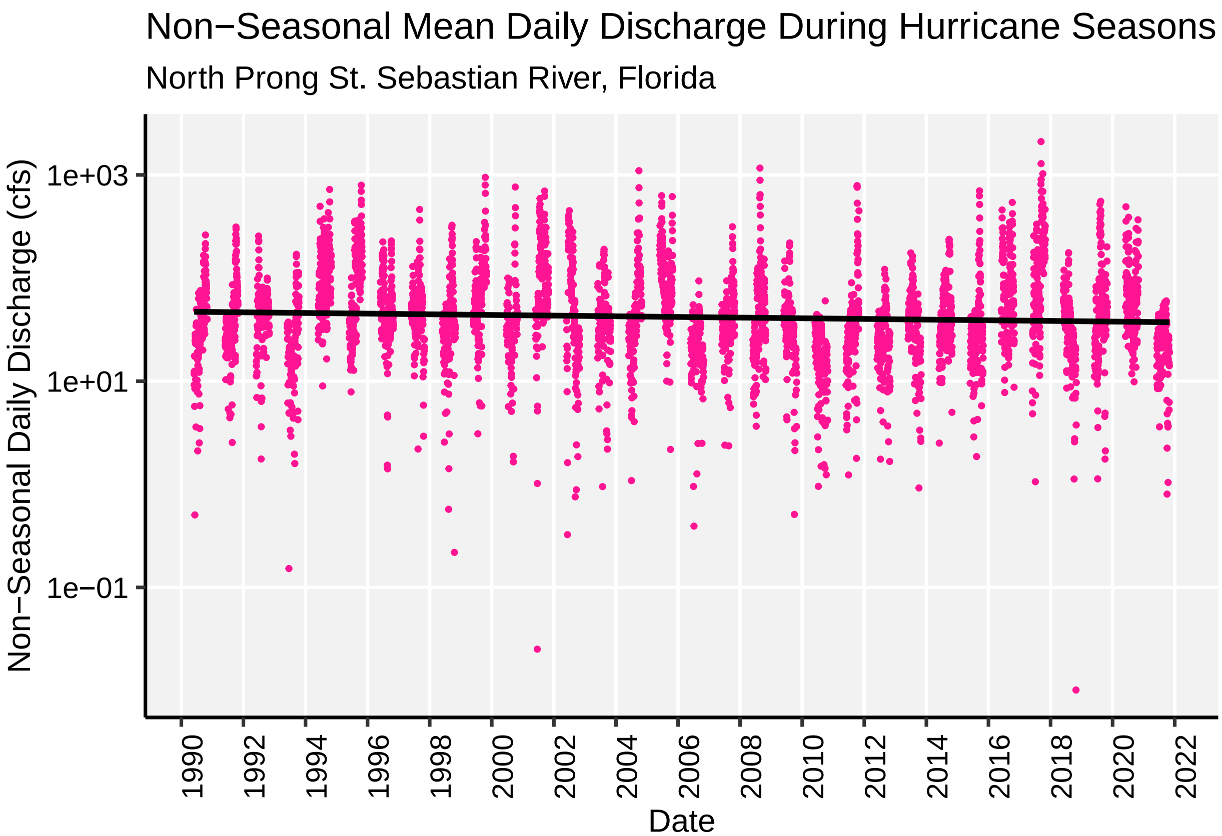

Figure 9: Plot of nonseasonal time series of Florida discharge and overall trend

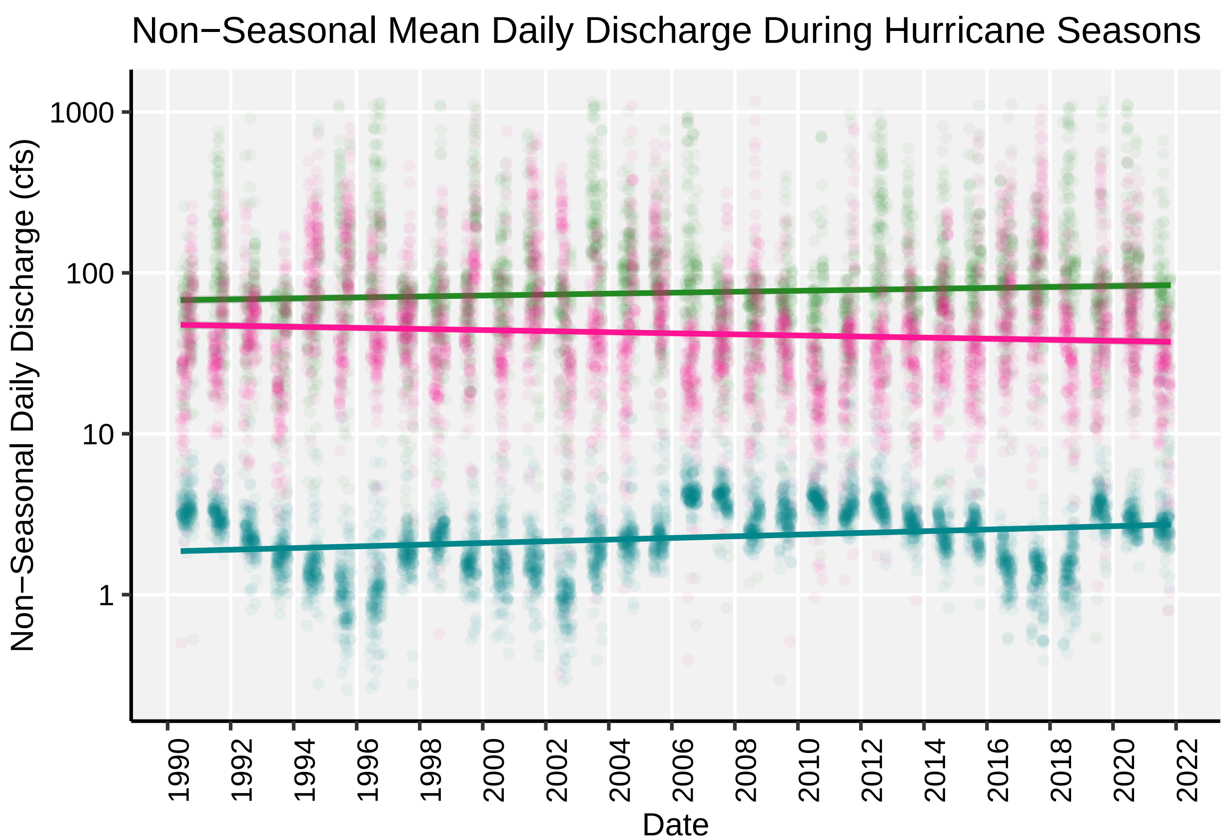

Figure 10: Non-Seasonal Discharge Plot for all Gage Sites (cfs)

Summary and Conclusions

A poleward hurricane trend is apparent based on the daily discharge values associated with hurricane months across the East Coast of the U.S. Although discharge is noticeably greater in Florida and North Carolina, hurricane discharge trends are increasing in New York and North Carolina while the last 30 years yielded a slightly decreasing trend in Florida (Table @ref(tab:table2)). The effect of poleward hurricane movement with increasing hurricane frequency/intensity could potentially lead to exacerbated natural disasters in northern states of the U.S. Large urban centers such as New York City are not equipped to handle such severe rain events. Given the substantial amount of impervious surface cover attributed to urbanization, future disastrous flooding events are inevitable (Coch 2015). Further research on the analysis could possibly include more sites along the East Coast to better comprehend the trends that may be occurring in terms of where hurricanes are becoming more/less frequent and intense.

Table 2: List of tau values and p-values from non-seasonal time series analyses.

State	Tau value	P-value
New York	0.1300	=< 2.22e-16
North Carolina	0.0572	=< 2.22e-16
Florida	-0.0516	7.7953e-08

References

Coch, N. K. 2015. Unique vulnerability of the New York–New Jersey metropolitan area to hurricane destruction. Journal of Coastal Research 31:196–212. Mudd, L., Y. Wang, C. Letchford, and D. Rosowsky. 2014. Assessing climate change impact on the US East Coast hurricane hazard: temperature, frequency, and track. Natural Hazards Review 15:4014001. Schmeltz, M. T., S. K. González, L. Fuentes, A. Kwan, A. Ortega-Williams, and L. P. Cowan. 2013. Lessons from hurricane sandy: a community response in Brooklyn, New York. Journal of urban health 90:799–809.