Dynamic Interplay:

Hurricanes and Surface Water Salinity Levels

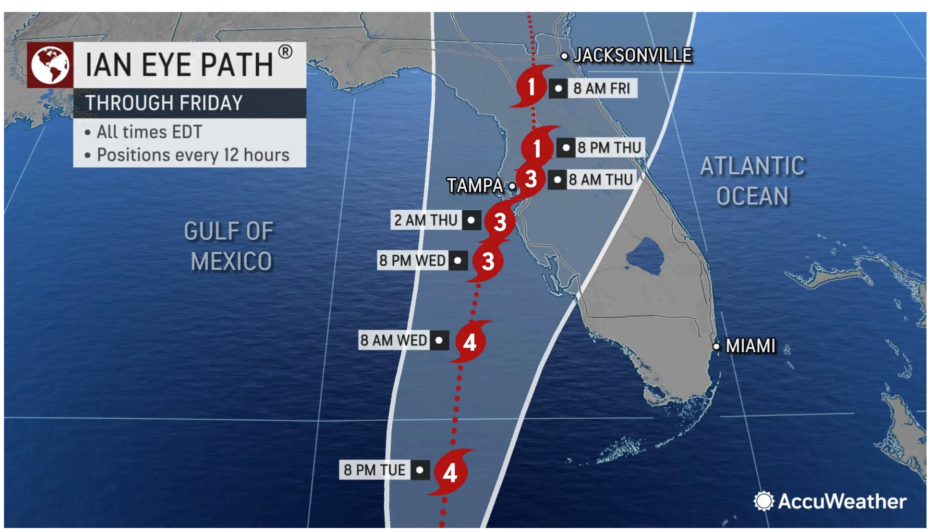
Contributors:

Christopher Andalia, Joseph Hallack, and William Thomas

April 28th 2024

Hurricane Nicole:

Hurricane Ian:



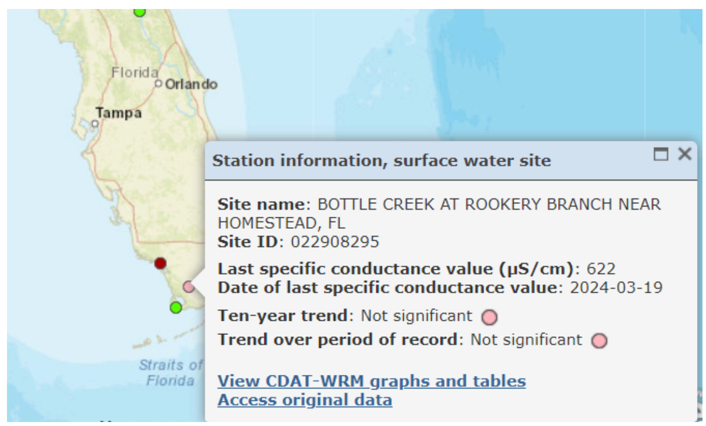
Background:

Hurricane Nicole, a Category 1 hurricane, hit eastern Florida in early November 2022 (Beven, 2022). Though Hurricane Nicole was a smaller hurricane compared to the likes of Irma and Ian, salinity levels are still bound to fluctuate as water from the ocean gets dispersed into the groundwater. In South Florida, groundwater plays a large role in providing freshwater to its surrounding areas. When these monstrous storms hit the state, it causes the salt water from the ocean to be pushed onto land called storm surges. When the storm surge hit land, it mixes with fresh surface water and then infiltrates into the groundwater causing salinity levels to spike. Therefore, rise in salinity levels for surface water are directly proportional to a rise in groundwater salt content. We will take data from surface water sites and highlight the negative impact increased salinity has on surface ecosystems and other aspects.

Higher salinity levels in surface water can have significant impacts on the environment as a whole. Increased salinity can lead to a decrease in the diversity of aquatic plants and animals, as many species are sensitive to changes in salinity levels (Canedo-Arguelles, 2013). This can disrupt the balance of ecosystems and food webs. High salinity can also alter the chemical composition of water, affecting nutrient cycling, pH levels, and dissolved oxygen concentrations (Herbert, 2015). These changes can have cascading effects on the entire aquatic ecosystem. Elevated salinity levels can inhibit the growth and survival of riparian and wetland vegetation, leading to changes in plant community structure and composition (Jolly, 2008). This can further affect wildlife that depends on these habitats. When high-salinity water is used for irrigation, it can lead to the accumulation of salts in the soil, reducing soil fertility and limiting agricultural productivity (Machado, 2017). This can have economic and food security implications.

Saltwater intrusion into groundwater aquifers can occur when surface water salinity increases, particularly in coastal areas (Werner, 2013). This can compromise the quality of drinking water sources and impact groundwater-dependent ecosystems. High salinity levels can accelerate the corrosion of metal surfaces and concrete structures, leading to increased maintenance costs and reduced lifespan of infrastructure such as pipes, bridges, and water treatment facilities (Babei, 2014). Consuming water with high salinity levels can have adverse health effects, such as dehydration, hypertension, and kidney problems (Talkuder, 2017). This is particularly concerning in regions where alternative freshwater sources are limited.

Objectives:



In this study, we concentrate on a single sample site near Homestead (right), Florida, to investigate the impact of multiple hurricane events on surface water salinity levels. By gathering salinity data from the USGS website across various dates spanning the hurricane seasons during which Hurricane Ian and Hurricane Nicole occurred, we aim to discern localized effects with higher resolution. Leveraging Python for data analysis, we conduct comprehensive assessments of salinity fluctuations before, during, and after each hurricane event, by graphically depicting the behavior of salinity. Our analysis delves into the intricate interplay between hurricanes and surface water salinity, revealing nuanced patterns and underlying mechanisms governing hydrological dynamics near Homestead, Florida. Through this focused investigation, we provide valuable insights into the resilience of coastal ecosystems to extreme weather events, allowing us to point out how this knowledge will guide mitigation strategies when big storm events impact salinity levels.

Methods and Data:

Investigating the differences in surface water salinity levels following a category 1 (Hurricane Nicole) and a category 5 (Hurricane Ian) hurricane, we utilized a comprehensive approach. Initially, we accessed and imported salinity data from the USGS website, compiling it into a .csv file for analysis. This data was then read into JupyterLab using the Pandas extension, facilitating efficient data manipulation and exploration.

	SITE	DATE	SALINITY	SALINITY_UNITS
0	NaN	NaN	NaN	ppt
1	2.508021e+14	2009-02-20	34.0	ppt
2	2.508021e+14	2009-02-21	35.0	ppt
3	2.508021e+14	2009-02-22	34.0	ppt
4	2.508021e+14	2009-02-23	34.0	ppt
...	...	...	...	...
4537	2.508021e+14	2024-04-05	28.0	ppt
4538	2.508021e+14	2024-04-06	28.0	ppt
4539	2.508021e+14	2024-04-07	27.0	ppt
4540	2.508021e+14	2024-04-08	30.0	ppt
4541	2.508021e+14	2024-04-09	33.0	ppt

4542 rows × 4 columns

	SALINITY	SALINITY_UNITS
DATE		
2020-01-01	32.0	ppt
2020-01-02	32.0	ppt
2020-01-03	32.0	ppt
2020-01-04	33.0	ppt
2020-01-05	32.0	ppt
...	...	...
2023-12-22	28.0	ppt
2023-12-23	29.0	ppt
2023-12-24	29.0	ppt
2023-12-25	28.0	ppt
2023-12-26	27.0	ppt

1201 rows × 2 columns

Ensuring robust analysis, we resampled the data to a daily frequency, enabling a more precise examination of salinity trends over time (right). Subsequently, we identified the dates corresponding to the landfall of Hurricane Ian and Hurricane Nicole, allowing us to isolate relevant data points for each storm event. Utilizing filtering techniques, we excluded irrelevant data (NaN and site location ID) from our analysis, ensuring that our findings were well-targeted and specific to our research objectives.

Upon cleaning the dataset and constructing appropriate tables, we graphically depicted the relationship between time and salinity levels. We hypothesized that surface water salinity levels would exhibit a distinct decrease around the time of Hurricane Nicole's landfall, with a comparative analysis against Hurricane Ian, which made landfall farther north. This hypothesis was updated when we realized that the relationship between hurricanes and surface water salinity levels is far more dynamic. By focusing on daily values of salinity, our analysis provided an understanding of the temporal dynamics of surface water salinity in response to hurricane events.

Challenges:

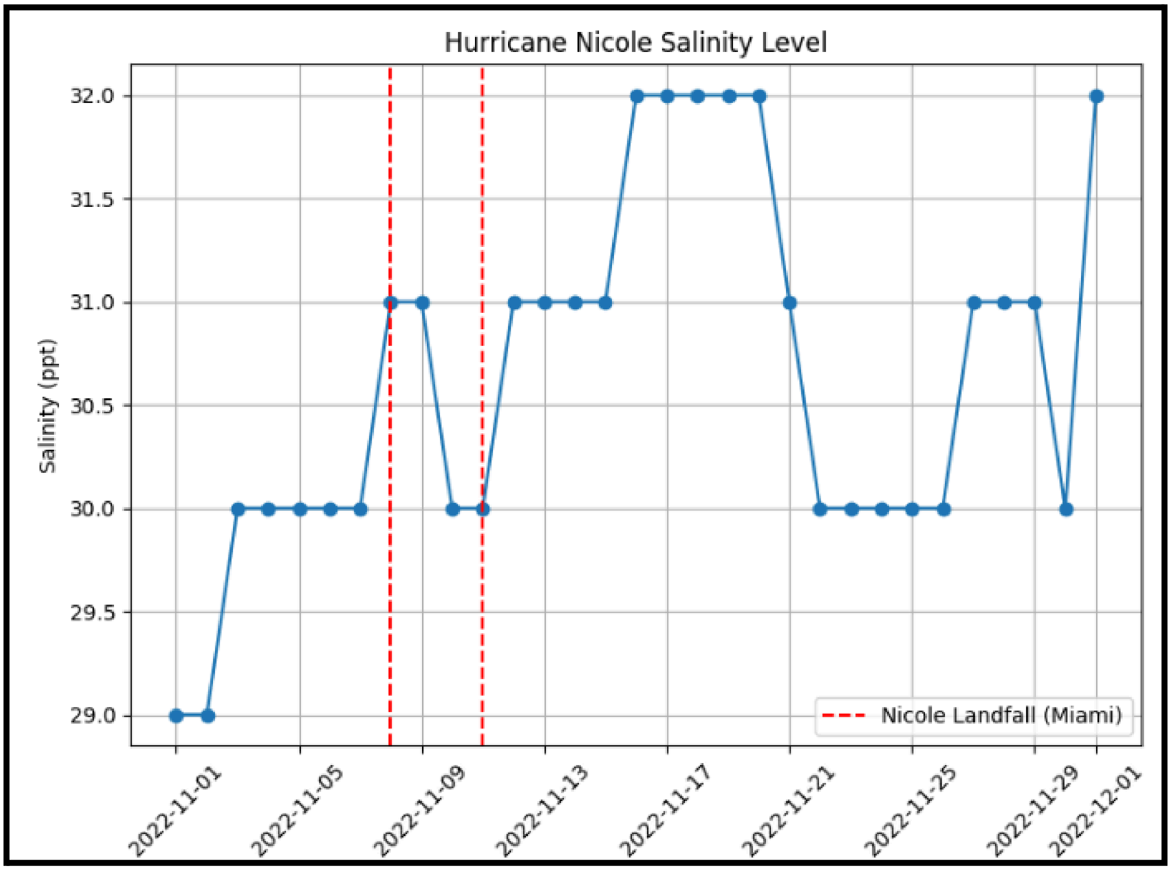
The greatest challenge we have faced has been finding the correct United States Geological Survey (USGS) data that corresponds to our research question, and will allow us to perform analysis. After talking with a USGS representative and doing our own research we discovered that the majority of groundwater data that they have is already analyzed and graphed. This is the reason we decided to switch our analysis to encompass surface water, which will allow us to perform the specified analysis and come to our own conclusions on salinity level increases.

Determining which location in Florida that has data that will be useful for our question has been a challenge, as specified earlier. In the process of looking for usable data on the USGS website we have found that there are lots of data points, but many do not have the salinity concentration levels. This limits the amount of usable data. We have attempted to conquer this challenge by carefully going through the USGS website and searching for keywords such as, salinity and groundwater. Not finding the raw data for groundwater has led us to interpret salinity to surface water instead of groundwater, which will open up more options for Python usage.

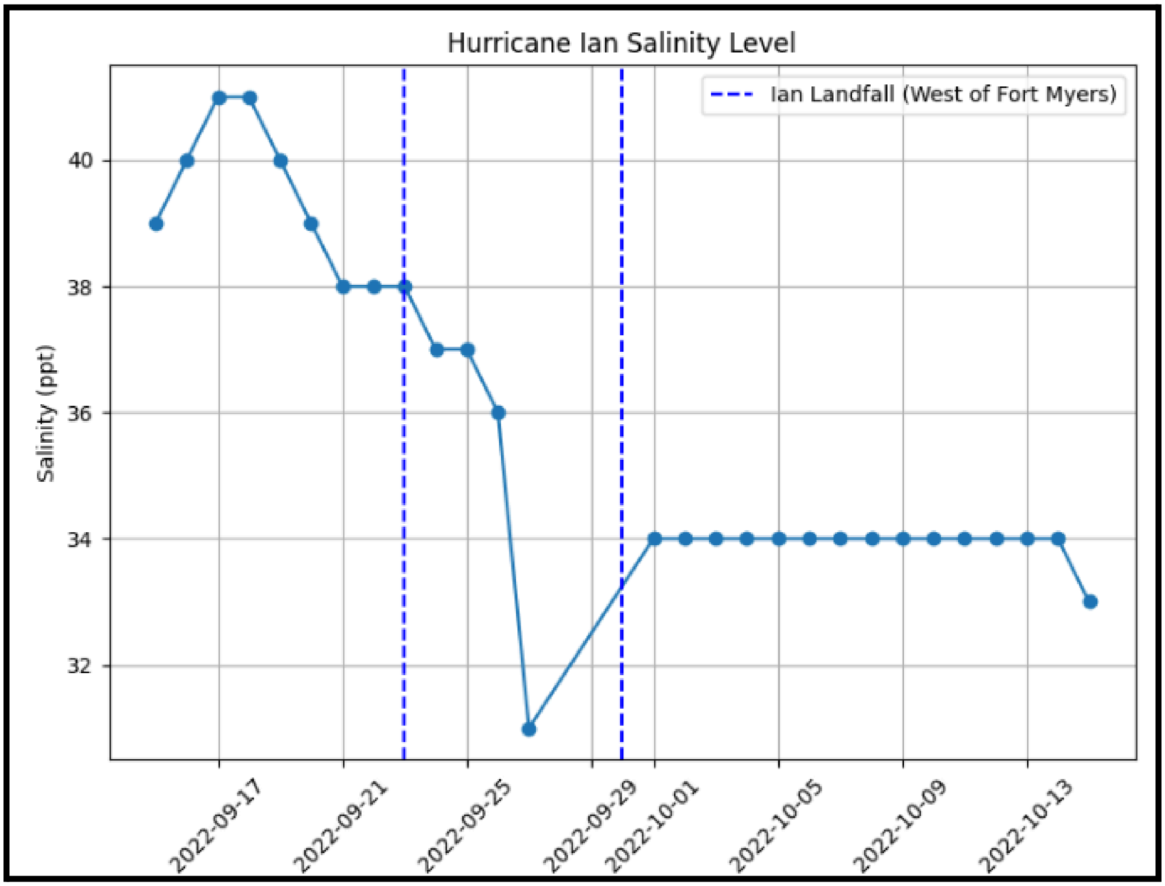
A further challenge that arises multiple times during the project is the coding. Using Python has proved to have its troubles with a few errors occurring during the coding process. These errors can be solved by a tremendous amount of trial and error with most of the errors being caused by one simple misplaced parentheses. With more difficult errors, we have found the use of LLM's, or more specifically, Chat GPT to be very useful when it comes down to pointing out which line is wrong and giving a suggestion on how to fix that problem.

Analysis and Graphs:

The data analysis uncovered dynamic relationships between surface water salinity levels and the landfall of Hurricane Nicole and Hurricane Ian in distinct geographical locations along the Florida coast. (scroll to next page).



Following Hurricane Nicole's landfall on the east side of Florida near Miami, our analysis revealed an initial decline in salinity levels. This decline can be attributed to the heavy freshwater rainfall associated with the outer bands of the hurricane. However, a few days later, as the salt-laden storm surge traversed across the state and reached our sample site location, salinity levels experienced a significant increase, reaching a maximum of 32.0 parts per thousand (ppt). This pattern underscores the complex interplay between hurricane-induced rainfall and storm surge dynamics, highlighting how these meteorological phenomena influence surface water salinity in coastal regions.



In contrast, Hurricane Ian, making landfall west of Fort Myers, Florida, exhibited a distinct salinity response. Prior to landfall, our analysis identified a notable spike in salinity levels, which coincided with the arrival of the storm surge at the sample site location. Subsequently, a downward spike in salinity levels was observed, correlating with heavy freshwater rainfall associated with the outer bands of Hurricane Ian. This sequence of events illustrates the intricate interactions between storm surge dynamics and freshwater influx, showcasing how hurricanes can elicit rapid fluctuations in surface water salinity.

Overall, these findings underscore the dynamic nature of the relationship between hurricanes and surface water salinity levels. The contrasting patterns observed for Hurricane

Nicole and Hurricane Ian highlight the variability in salinity responses based on factors such as storm track, intensity, and geographic location of landfall. By explaining these dynamics, our analysis contributes to a deeper understanding of the complex interactions between meteorological phenomena and coastal hydrology, with implications for ecosystem resilience and disaster preparedness in vulnerable coastal regions.

Important Note (answer to question during presentation):

It is crucial to note that both Hurricane Nicole and Hurricane Ian made landfall during a high tide, amplifying their impact on surface water salinity levels and coastal inundation (National Oceanic and Atmospheric Administration, 2020). This convergence of extreme weather events with high tide magnifies the potential for coastal flooding and saltwater intrusion, exacerbating the challenges faced by coastal communities and ecosystems. The coincidence of hurricane landfall with high tide underscores the need for comprehensive disaster preparedness measures and adaptive management strategies to mitigate the impacts of such events on coastal infrastructure, water resources, and ecological habitats (United States Environmental Protection Agency, 2017). Understanding the synergistic effects of hurricanes and high tide is essential for enhancing resilience and fostering sustainable coastal development in the face of increasing climate variability and sea level rise.

Discussion:

There is no doubt that hurricanes are a very serious natural disaster that has major implications on things that humans use in their everyday life. Most people just think about their own possessions and not a thought on how it would affect nature. Though our hypothesis that hurricanes would spike the salinity level proved to be false, it was important to note that the salinity levels were in fact affected and did spike the salinity levels before the hurricane made landfall. Since the levels did not continue to spike or stay at the high level, it would not have an affect on the ecosystem or the wildlife that occupies it. As the fresh water rained down as the hurricane made landfall, it was fascinating to see the salinity levels drop down to lower than average, as if the hurricane was correcting the error it made by adding the salt water to the freshwater. As for our findings for Hurricane Nicole specifically, the return to high salinity levels that occurred after the hurricane's impact on the testing site could be due to a period of high tide experienced by the ocean. As most of the Everglades is connected by channels in the lower part of Florida, the rising tides could have mixed in with the fresh water causing the salinity levels to rise unnaturally high.

Conclusion:

The study unveils dynamic links between Hurricane Nicole's landfall and surface water salinity shifts near Homestead, Florida, depicting initial declines succeeded by substantial increases due to salt-laden storm surge. In contrast, distinct responses during Hurricane Ian reveal notable salinity spikes prior to landfall, followed by declines associated with heavy freshwater rainfall.

By employing Python for data analysis, the research offers valuable insights into the localized effects of hurricanes on surface water salinity, enhancing understanding of coastal ecosystem resilience and disaster preparedness. Despite challenges in accessing pertinent USGS data and encountering coding errors during analysis, the study contributes to addressing the complexities of coastal hydrology dynamics. The study's focus on a single sample site may limit its ability to capture broader regional variations in surface water salinity responses to hurricanes. Additionally, constraints in groundwater data availability and coding challenges further restrict the study's scope and potential insights. Future research endeavors could broaden the analysis to encompass multiple sample sites and integrate additional variables such as wind speed and storm intensity to deepen comprehension of surface water salinity dynamics during hurricanes. This expanded understanding would inform the development of adaptive management strategies aimed at mitigating the impacts of climate change on coastal regions.

Github code link:

The following link contains the code and data used.

https://github.com/WillTh03/Salinity_hurricanes_dynamics

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