Detecting Saltwater Intrusion in Rivers Using Remote Sensing

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Introduction

Saltwater Intrusion: Phenomenon where oceanic saltwater moves upstream into freshwater rivers or over land.

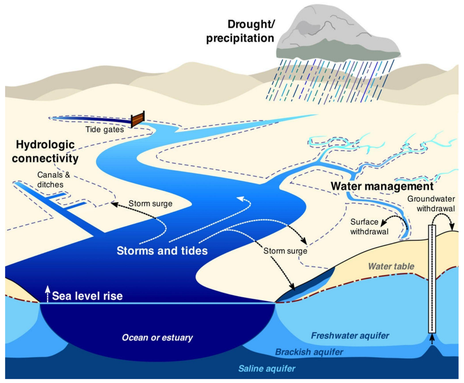

Figure 1: Most causes linked to **climate change**:
1. Sea level rise
2. Storms and tides
3. Drought
4. Water management and artificial waterways

Saltwater intrusion inflicts **heavy loss of life** on coastal ecosystems and contaminates freshwater aquifers.

Figure 2: Ghost forests, coastal vegetation cannot handle high salinity

Figure 3: Eutrophication, overloading of nutrients and cause of algal blooms

Objectives

Using **satellite imagery**, we will analyze the salinity and water quality of coastal **blackwater rivers**.
- Cannot measure salinity directly → use **color** instead
- Monitor **changes** and **patterns** over several years

Figure 4: The freshwater's black color is caused by **dissolved organic matter**

When salt binds to dissolved organic matter, the black color fades and the water **clears**.

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Methodology

Figure 5: Flowline collection
- Compiled river mouth coordinates along SE US coast
- Mapped & downloaded flowlines using NHD

Figure 6: Flowline pixel buffering
- 100 m on both sides of flowline

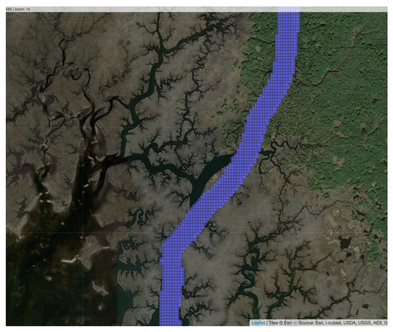


Figure 7: Cloud masking
- Removes clouds via a pixel quality band from image

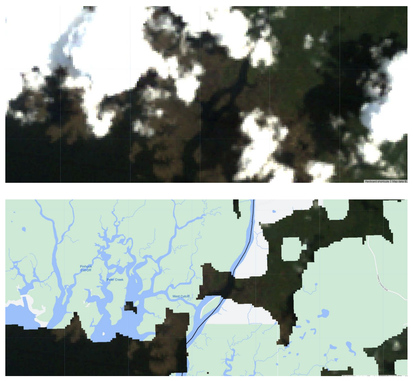
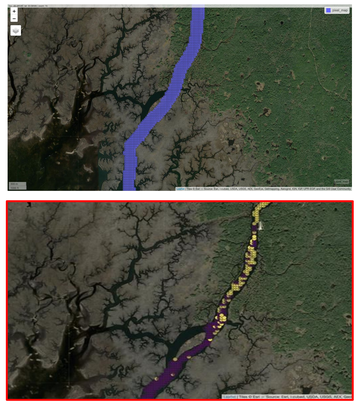


Figure 8: Water masking
- Remove land and vegetation pixels



Results

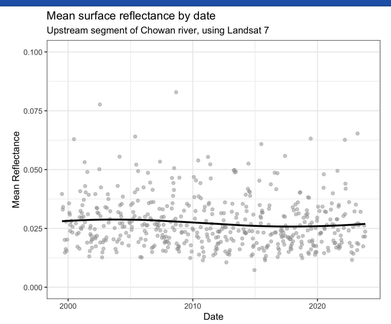


Figure 9: Mean surface reflectance of a flowline **far upstream** of the Chowan River, NC 1999-2024

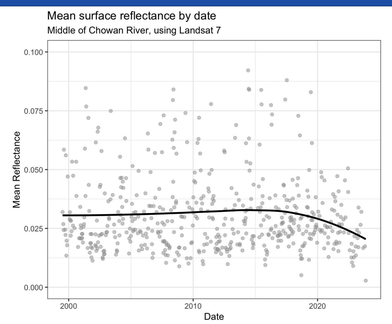


Figure 10: Mean surface reflectance of a flowline near the **center** of the Chowan River, NC 1999-2024

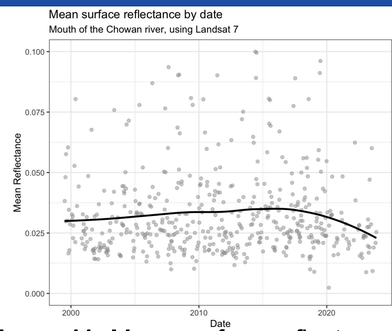


Figure 11: Mean surface reflectance of a flowline near the **mouth** of the Chowan River, NC 1999-2024

Formula for surface reflectance:

$$\frac{R + B + G + NIR}{4}$$

- Lower surface reflectance indicates darker color

Analysis

Based on the surface reflectance (SR) of a flowline:
- The SR of flowlines **fluctuates** much more the **further downstream** they are (Figures 9-11), most likely due to the higher **vulnerability** of downstream ecosystems to environmental changes
  - e.g., pollutants or nutrients flowing downstream, more exposure to saltwater, etc.
- Higher SR during **summer** months (Figure 12), correlating with ocean warming & rising sea levels
- Over the past 40 years, the Chowan River has experienced a decrease in SR and we expect a similar correlation **with increasing blackwater**
  - However, the reflectance change over a few time periods may instead be due to outside phenomena (e.g, sudden decrease in SR around 2023 is likely due to an **algal bloom**)

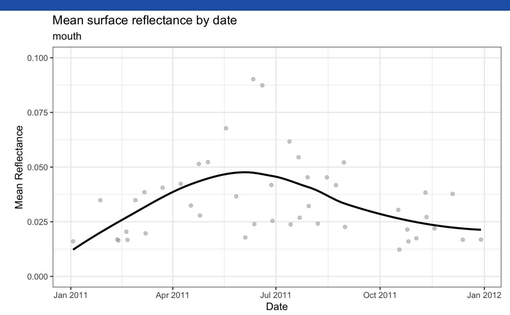


Figure 12: Surface reflectance of the mouth of the Chowan River over one year

Conclusion

We have created a **dataset** of rivers long the US East Coast, and through remote sensing, analyzed their water quality and salinity levels. Specifically, by monitoring their **mean surface reflectance**, we can see patterns in blackwater occurrence and predict general trends for the future. We have also designed a website and **R-Shiny** app to better **visualize** their conditions and plot tools such as flowline color and various graphs.

Finally, causes of potential error may be differences in **quality** based on the different satellites and lack of data over specific time periods due to **cloud cover** or other weather phenomena. Further analysis is needed to understand the impact of these factors.

Website

Jones, J.W. (2019). *Improved Automated Detection of Subpixel-Scale Inundation—Revised Dynamic Surface Water Extent (DSWE) Partial Surface Water Tests*, MDPI.
Gardner, J. R.; Yang, X.; Topp, S. N.; Ross, M. R. V.; Altenau, E. H.; & Pavelsky, T. M. (2021). *The Color of Rivers*. Geophysical Research Letters, 48, e2020GL088946.
Milczarek, Marta; Robak, Anna; & Gadawska, Alicja. (2017). *Sentinel Water Mask (SWM) - New Index for Water Detection on Sentinel-2 Images*.