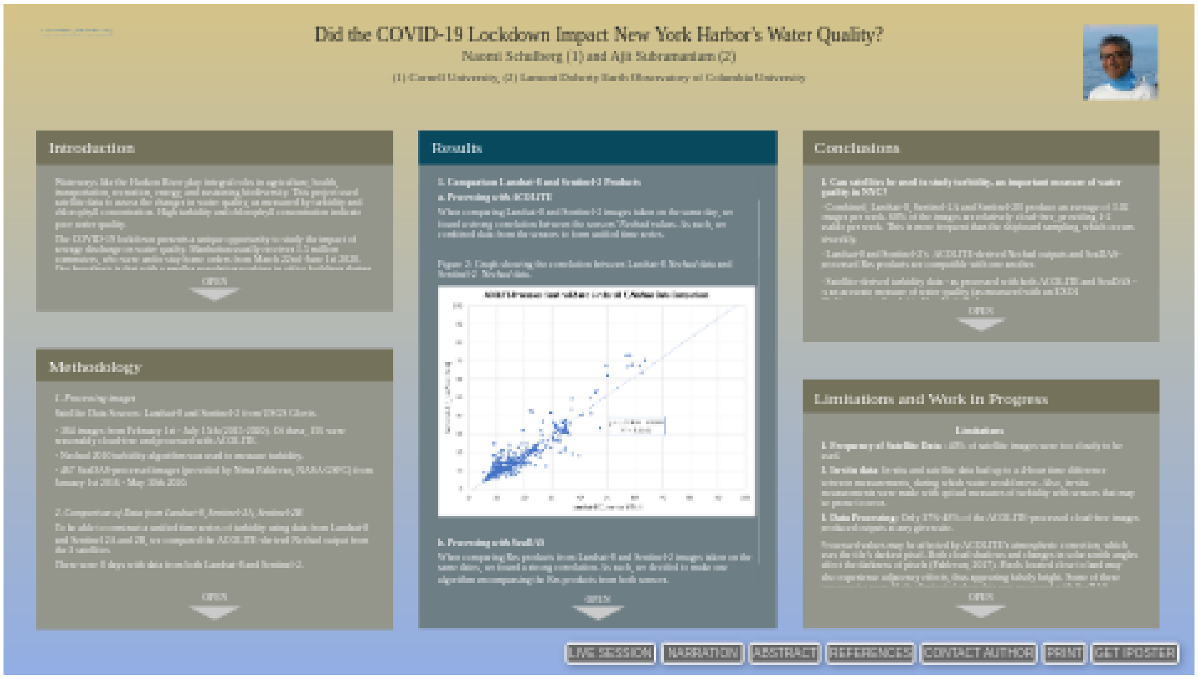
Did the COVID-19 Lockdown Impact New York Harbor's Water Quality?



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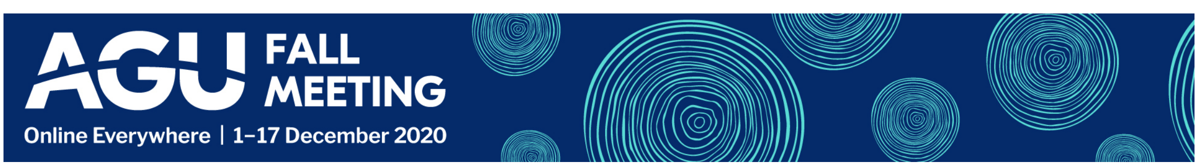


INTRODUCTION

Waterways like the Hudson River play integral roles in agriculture, health, transportation, recreation, energy, and sustaining biodiversity. This project used satellite data to assess the changes in water quality, as measured by turbidity and chlorophyll concentration. High turbidity and chlorophyll concentration indicate poor water quality.

The COVID-19 lockdown presents a unique opportunity to study the impact of sewage discharge on water quality. Manhattan usually receives 1.5 million commuters, who were under stay home orders from March 22nd -June 1st 2020. Our hypothesis is that with a smaller population working in office buildings during the lockdown, there will be less pollution from water pollution control plants (WPCPs) in Manhattan.

Satellite data has previously been used to measure water quality in the Hudson River (Hellweger, 2004), but this research project is the first to study water quality using modern satellite and recently developed high spatial resolution algorithms in the waters around New York City. Thus, in addition to answering our research question, we sought to validate the use of satellite data, as processed with two processors, in measuring turbidity.

Satellite data provides a synoptic coverage of areas, which cannot be achieved by field data. During the COVID-19 lockdown, in situ measurements decreased, so satellite data is especially useful in measuring water quality during this time.

METHODOLOGY

1. Processing images

Satellite Data Sources: Landsat-8 and Sentinel-2 from USGS Glovis.

- 384 images from February 1st - July 15th (2015-2020). Of these, 195 were reasonably cloud-free and processed with ACOLITE.

- Nechad 2010 turbidity algorithm was used to measure turbidity.

- 467 SeaDAS-processed images (provided by Nima Pahlevan, NASA GSFC) from January 1st 2016 - May 30th 2020.

2. Comparison of Data from Landsat-8, Sentinel-2A, Sentinel-2B

To be able to construct a unified time series of turbidity using data from Landsat-8 and Sentinel 2A and 2B, we compared the ACOLITE-derived Nechad output from the 3 satellites

There were 8 days with data from both Landsat-8 and Sentinel-2.

In addition, we compared data from the 655 nm band from Landsat-8 and Sentinel-2 processed using the SeaDAS processor for 5 images.

3. Validation with in situ data

We compared satellite data at pixels corresponding with 156 Department of Environmental Protection (DEP) field sites with in-situ turbidity measurements to assess the accuracy of the ACOLITE-processed Nechad 2010 turbidity algorithm and SeaDAS-processed 655 nm band.

Daily discharge rates for four water treatment plants (North River, Newtown Creek, Hunts Point, Ward Island) was obtained from the New York DEP.

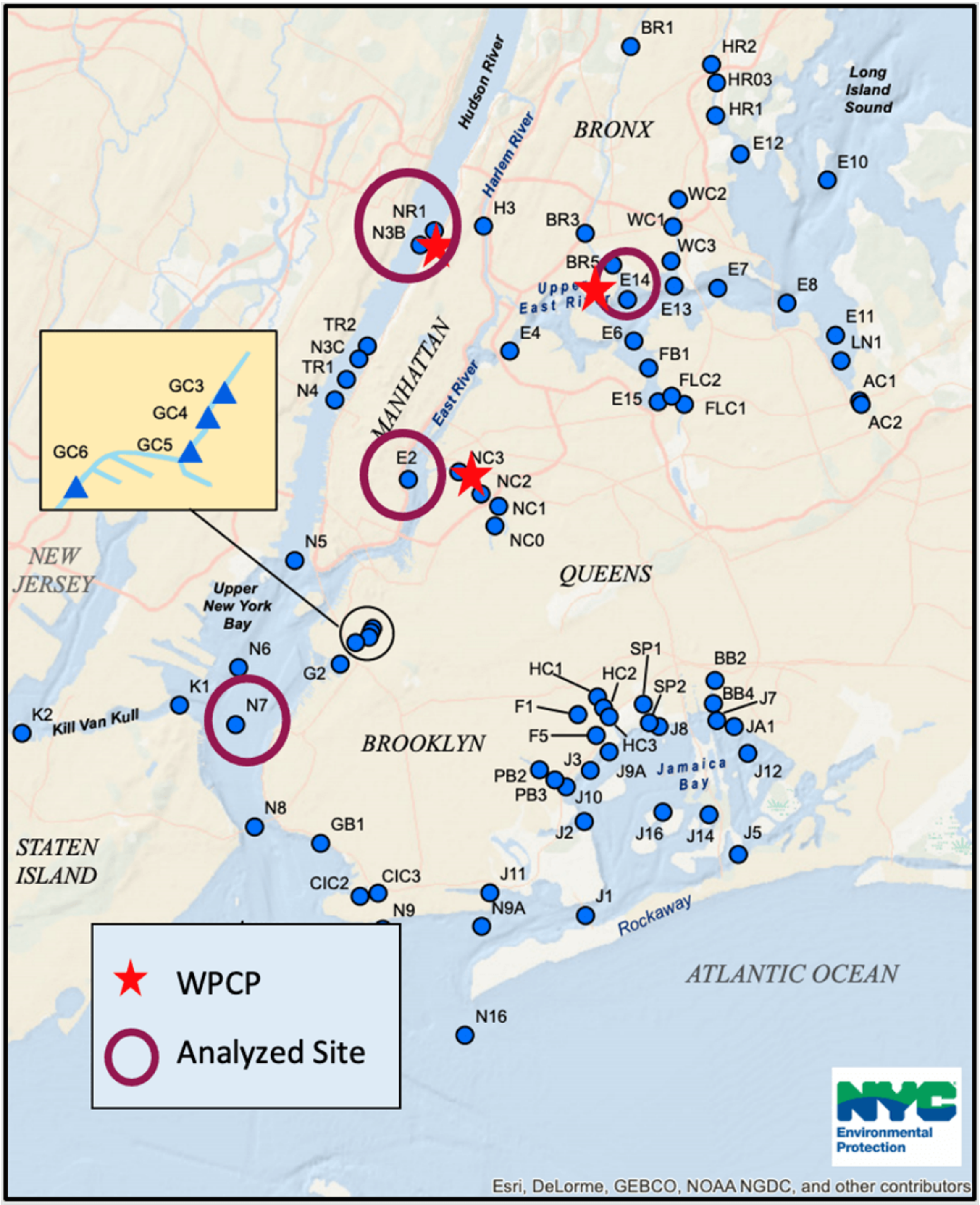
Daily precipitation data was obtained from NOAA (https://www.weather.gov/okx/CentralParkHistorical (https://www.weather.gov/okx/CentralParkHistorical)).

4. Statistical Tests

We analyzed data from five DEP sites: two near North River WPCP (NR1, N3B), one near Hunt's Point WPCP (E14), one near Newtown Creek WPCP (E2), and one in the center of the harbor (N7).

An ANOVA test was performed on 2015-2019 data for each site. If the years' values did not differ significantly from one another, a Mann Whitney U test was used to compare a 10-day average of turbidity from 2015-2019 against values from 2020.

Figure 1: Map of DEP Field Sites annotated to show the locations of studied sites in relation to WPCPs.



- An ANOVA test was used to assess differences in monthly precipitation between 2015-2020.

- ANOVA tests were performed on daily discharge data from 2017-2020. If the years' values did not differ significantly from one another, a Mann Whitney U test was used to compare average daily discharge from 2017-2019 against values from 2020.

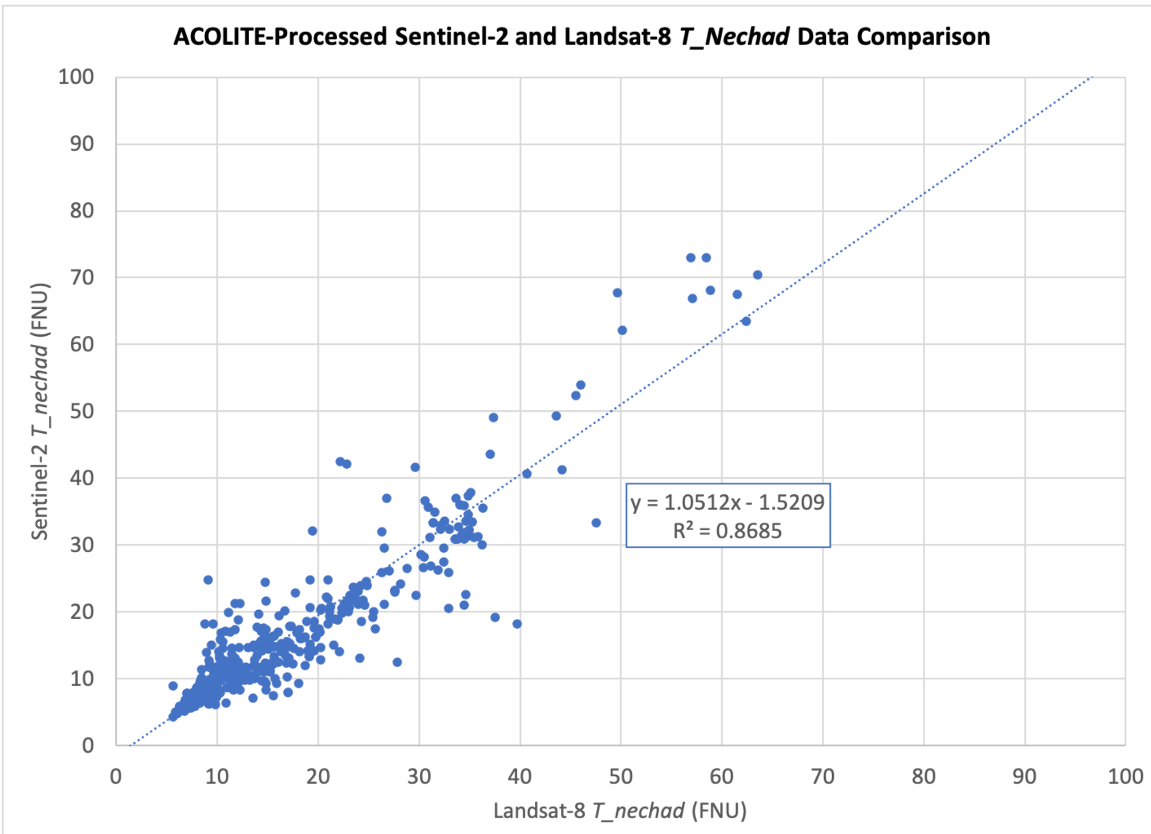
RESULTS

1. Comparison Landsat-8 and Sentinel-2 Products

a. Processing with ACOLITE

When comparing Landsat-8 and Sentinel-2 images taken on the same day, we found a strong correlation between the sensors' *Nechad* values. As such, we combined data from the sensors to form unified time series.

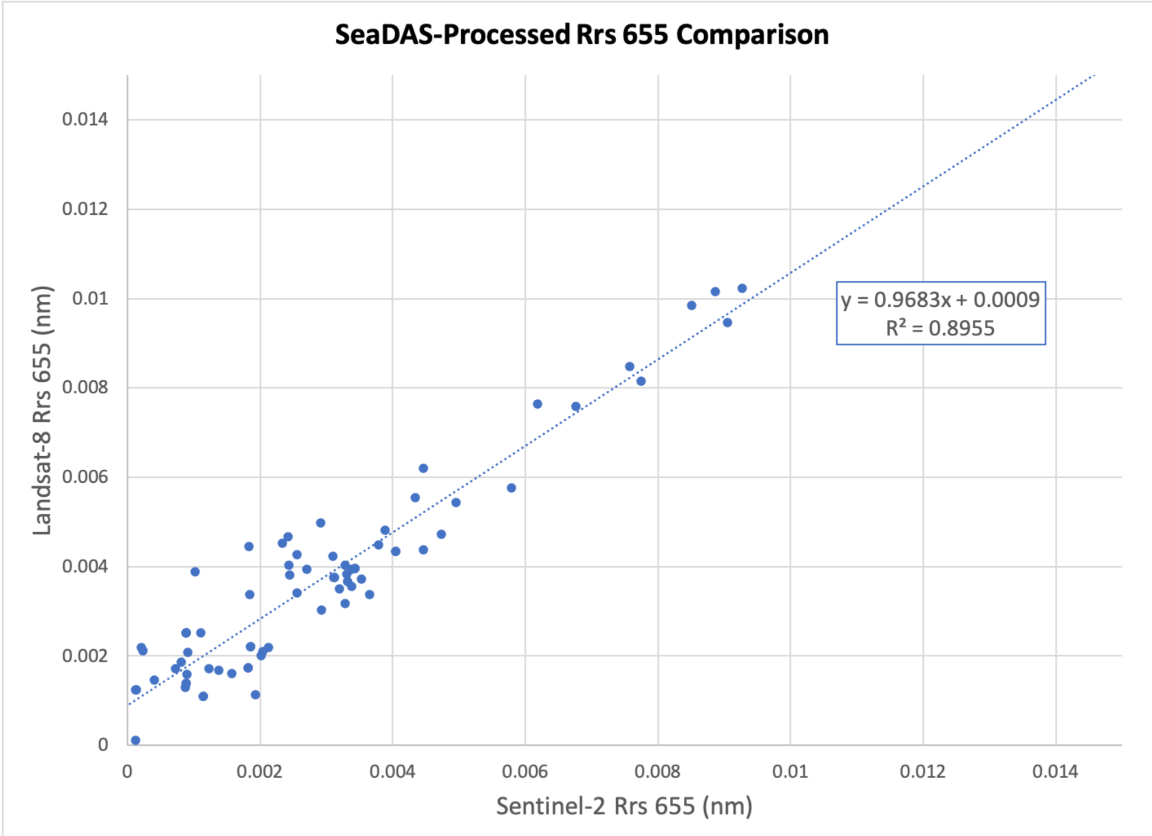
Figure 2: Graph showing the correlation between Landsat-8 *Nechad* data and Sentinel-2 *Nechad* data.



b. Processing with SeaDAS

When comparing Rrs products from Landsat-8 and Sentinel-2 images taken on the same dates, we found a strong correlation. As such, we decided to make one algorithm encompassing the Rrs products from both sensors.

Figure 3: Graph showing the correlation between Landsat-8 and Sentinel-2 SeaDAS-processed satellite *655 nm* data.

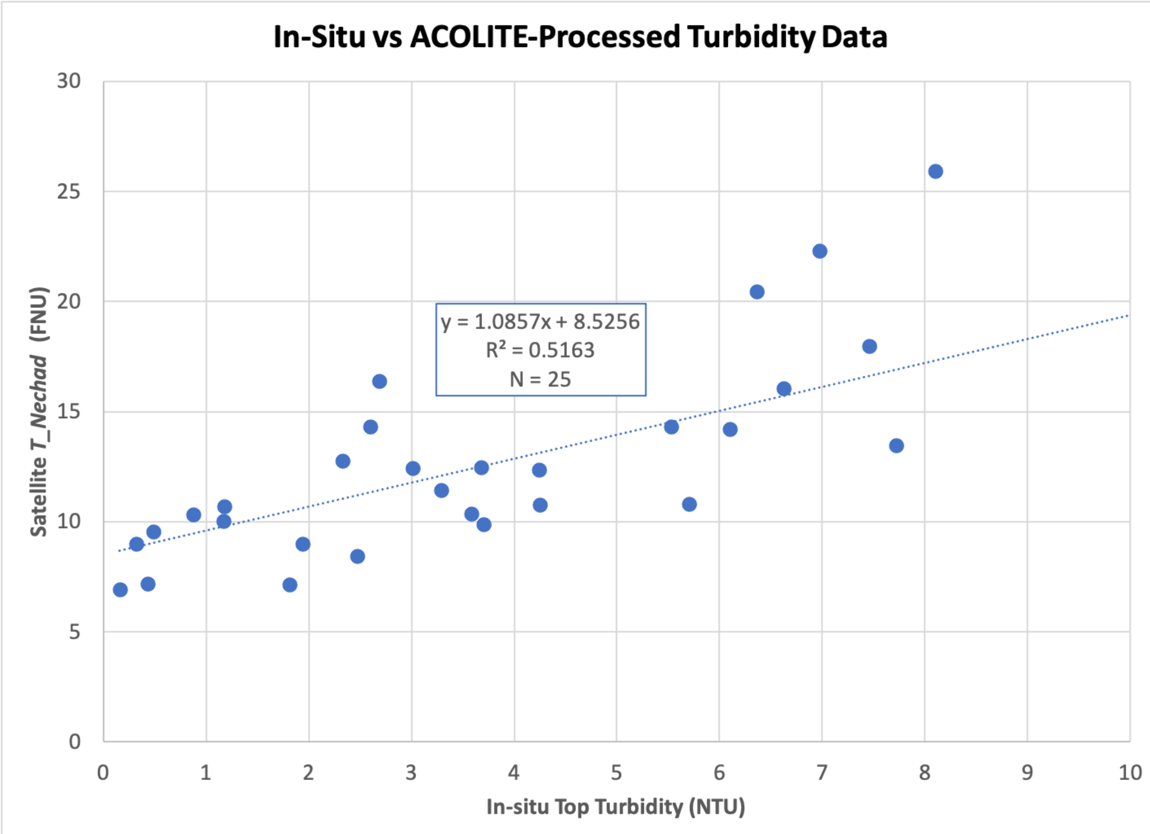


2. Comparison to in situ data

a. Processing with ACOLITE

We found a correlation between satellite data and in situ turbidity data measured with an EXO1 Multiparameter Sonde. The optical turbidity measurements used different wavelengths of light, so the correlation was not 1:1.

Figure 4: Graph showing the correlation between satellite *Nechad* data and DEP Top Turbidity data.



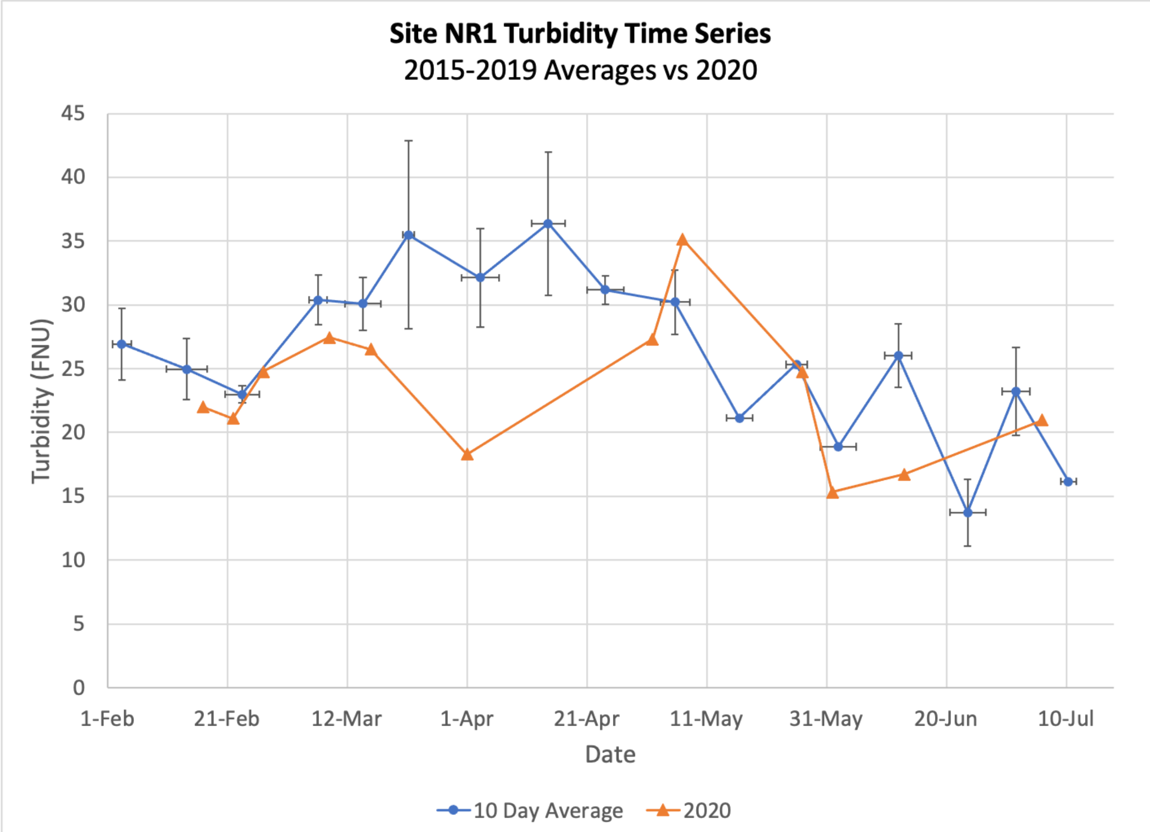
4. Analyzing differences in Turbidity

a. Processing with ACOLITE

The Mann Whitney U test showed that during the lockdown period, the difference between turbidity values from 2020 was significantly different from average values from 2015-2019 (U = 14, U crit. = 15).

Site NR1 is located near the North River WPCP, which treats water from both residential and financial areas of Manhattan. The site's decreased turbidity indicates that the lockdown caused a decrease in sewage pollution.

Figure 5: Time series showing turbidity at Site NR1.

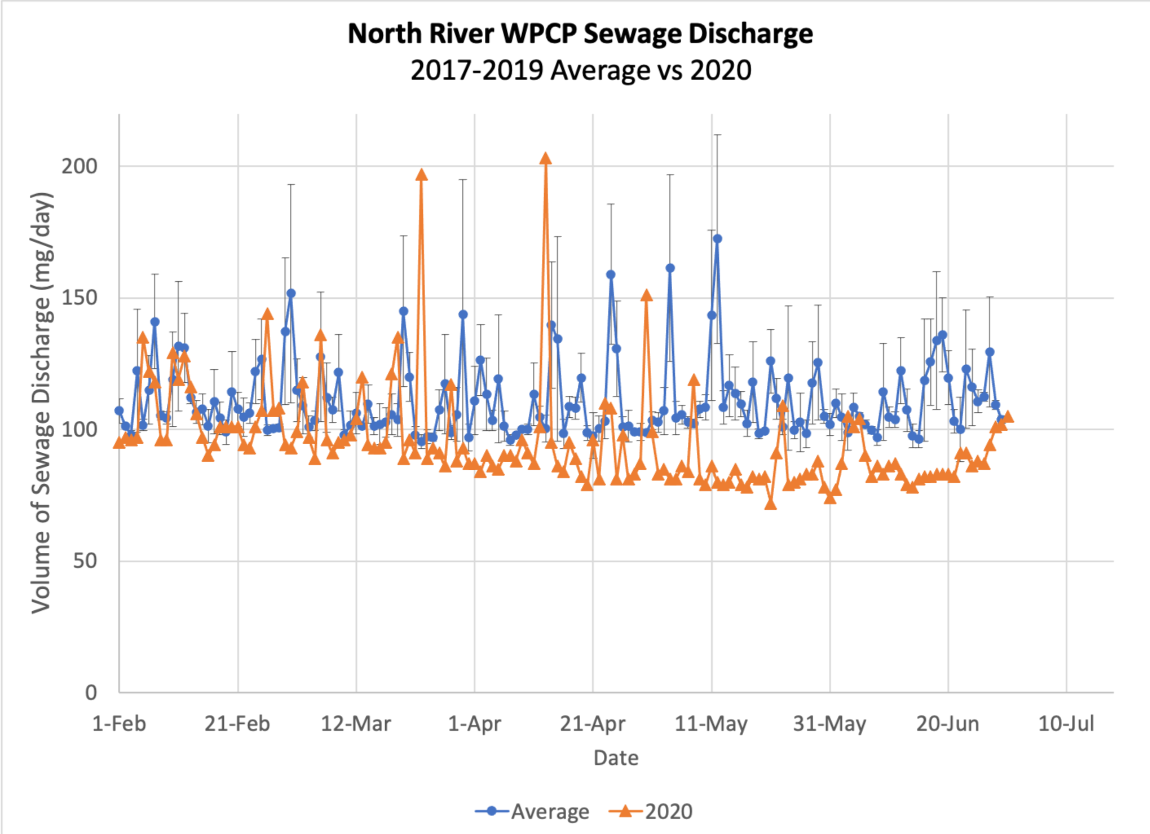


Taking average turbidity values over 2015-2019 lessened the effect of any individual precipitation event on data. Images from 2020 were subject to influence from precipitation events, however, we found a very low correlation between precipitation events and turbidity values ($R^2 < 0.07$ at every site), showing that precipitation is just one factor affecting turbidity at any given site.

TEST	VALUE	CRITICAL VALUE
ANOVA (2016-2019)	P = 0.164932098508692	P = 0.05
MANN WHITNEY U (2016-2019 AVERAGES VS 2020)	U = 13	U = 5

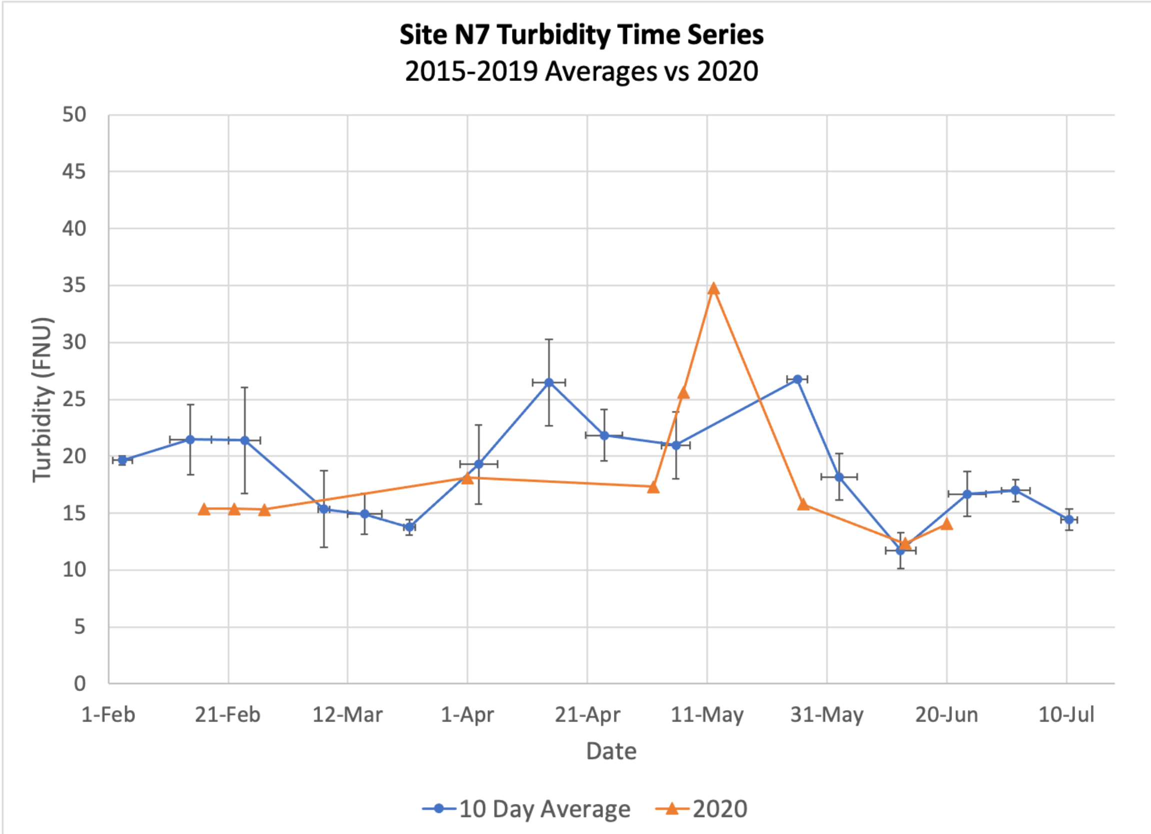
When comparing discharge data from the North River WPCP with NOAA's precipitation data, we found that every day with over 150 mg of discharge corresponded with high precipitation. Despite precipitation-caused spikes in discharge, each year from 2017-2019 had the same daily average sewage discharge volume of 110 mg, whereas the average discharge from 2020 was 97 mg. Thus, we can infer that 2020's low discharge was not caused by changes in precipitation.

Figure 6: Time series showing turbidity at the North River WPCP.



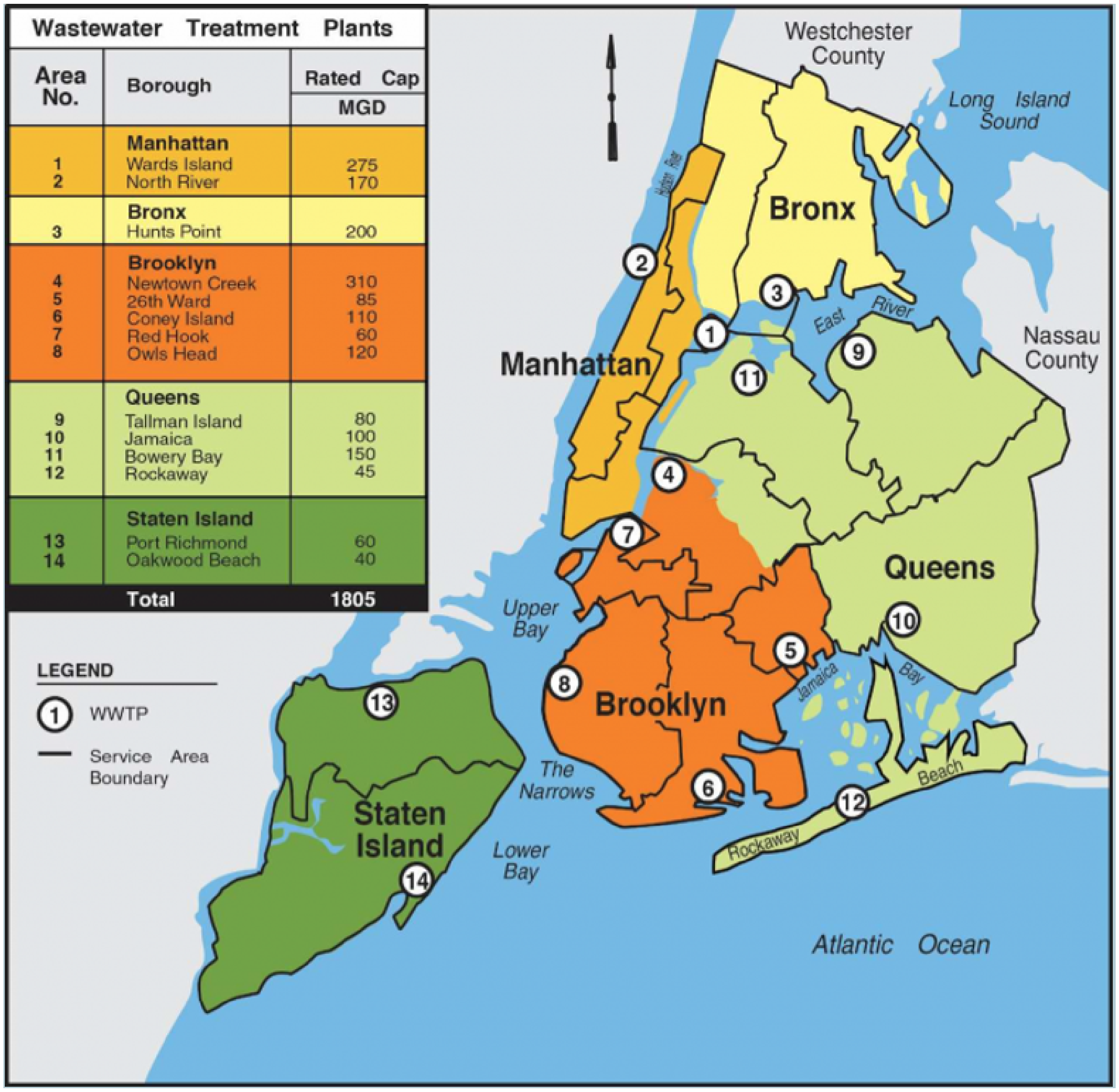
At Sites E14 , E2, N3b, and N7, 2020 turbidity did not differ significantly from any previous years, indicating that the COVID-19 lockdown did not change sewage outfalls at Hunts Point and Newtown Creek WPCPs, nor affect water quality in Central New York Harbor. Both Hunts Point and Newtown Creek's sewersheds include outer boroughs where stay home orders did not seem to significantly change the water quality (see Figure 8).

Figure 7: Time series showing turbidity at the Site N7.



The Mann Whitney U test showed no significant difference between 2020 values and 2015-2019 values of turbidity (U = 22, U crit. = 9).

Figure 8: Map showing the location of Water Pollution Control Plants in New York City (Source: DEP, 2017).



Wastewater Treatment Plants

Area No.	Borough	Rated Cap MGD
	Manhattan	
1	Wards Island	275
2	North River	170
	Bronx	
3	Hunts Point	200
	Brooklyn	
4	Newtown Creek	310
5	26th Ward	85
6	Coney Island	110
7	Red Hook	60
8	Owls Head	120
	Queens	
9	Tallman Island	80
10	Jamaica	100
11	Bowery Bay	150
12	Rockaway	45
	Staten Island	
13	Port Richmond	60
14	Oakwood Beach	40
	Total	**1805**

CONCLUSIONS

1. Can satellites be used to study turbidity, an important measure of water quality in NYC?

- Combined, Landsat-8, Sentinel-2A and Sentinel-2B produce an average of 3.02 images per week. 60% of the images are relatively cloud-free, providing 1-2 usable per week. This is more frequent than the shipboard sampling, which occurs biweekly.

- Landsat-8 and Sentinel-2's ACOLITE-derived Nechad outputs and SeaDAS-processed Rrs products are compatible with one another.

- Satellite-derived turbidity data - as processed with both ACOLITE and SeaDAS - is an accurate measure of water quality (as measured with an EXO1 Multiparameter Sonde) in New York Harbor.

2. How did the COVID-19 lockdown impact water quality?

While the COVID-19 lockdown didn't significantly change turbidity around Newtown Creek, Hunts Point, and in Central New York Harbor, turbidity near the North River WPCP significantly decreased during the COVID-19 lockdown. This change coincided with a significant decrease in sewage discharge from the North River plant.

LIMITATIONS AND WORK IN PROGRESS

Limitations

1. Frequency of Satellite Data : 40% of satellite images were too cloudy to be used.

2. In-situ data: In-situ and satellite data had up to a 4-hour time difference between measurements, during which water would move. Also, in-situ measurements were made with optical measures of turbidity with sensors that may be prone to error.

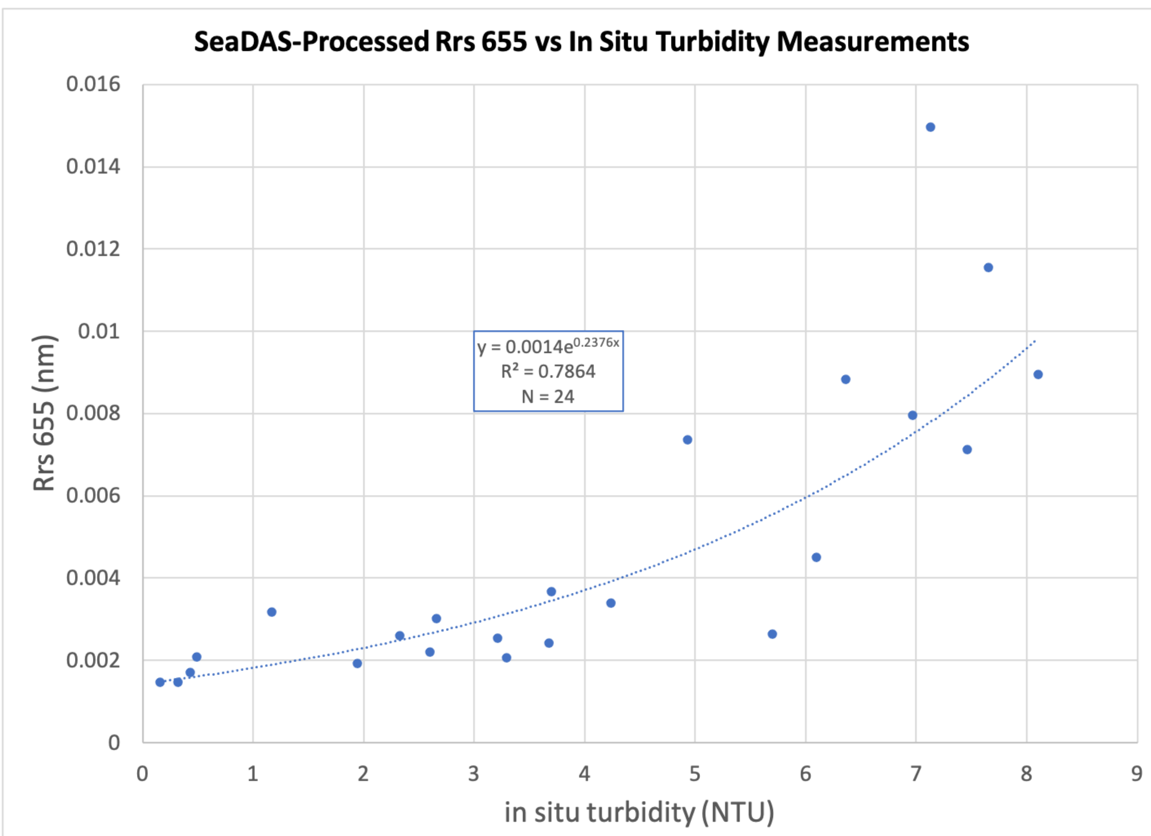
3. Data Processing: Only 37%-48% of the ACOLITE-processed cloud-free images produced outputs at any given site.

Processed values may be affected by ACOLITE's atmospheric correction, which uses the tile's darkest pixel. Both cloud shadows and changes in solar zenith angles affect the darkness of pixels (Pahlevan, 2017). Pixels located close to land may also experience adjacency effects, thus appearing falsely bright. Some of these inaccuracies were likely eliminated when data was processed with SeaDAS.

Current and Future Work

We found a correlation between SeaDAS-processed Rrs 655 nm product against in situ turbidity data. We will use this relationship to form a turbidity algorithm for SeaDAS-processed images.

Figure 9: Graph showing the correlation between SeaDAS-processed satellite *655* data and DEP Top Turbidity data.



Using the algorithm, we will compare SeaDAS-processed data from 2020 to previous years during the lockdown period to confirm our conclusion that the COVID-19 lockdown affected water quality around New York City.

ABSTRACT

Waterways such as the Hudson River play an integral role in agriculture, health, transportation, recreation, energy, and sustaining biodiversity. Although water pollution in New York Harbor has been extensively studied, the reduction of millions of commuters during the COVID-19 lockdown presents an unprecedented opportunity to study human impact on water quality. We used remote sensing data to assess how the COVID-19 lockdown impacted water quality in New York Harbor, particularly in areas near Combined Sewer Outfalls (CSOs). This technique has previously been used to measure water quality in the Hudson River.

We used ACOLITE to process Landsat-8 and Sentinel-2 images from 2015-2020. The algorithms “t_nechad”, “spm_nechad”, and “kdpar_qaasw” were used to measure turbidity, and “chl_oc2”, “chl_oc3”, “chl_re_moses3b”, “chl_re_moses740”, and “chl_re_mishra” to measure chlorophyll concentration. After uploading processed images into SeaDAS, we extracted values from pixels corresponding to Department of Environmental Protection (DEP) field sites. At these sites, the DEP measures Total Suspended Solids and Chlorophyll A Concentration using optical turbidity sensors and fluorometers, respectively. By comparing pixel values with DEP data we determined that the chlorophyll algorithms did not produce accurate readings of chlorophyll concentration in New York Harbor. We focused on analyzing turbidity at five DEP sites, four of which were located around wastewater treatment plants, to assess any CSO-induced changes in water quality.

The frequency of usable satellite data from 2020 was severely limited by cloudiness, so we combined Landsat-8 and Sentinel-2 turbidity measurements (R = 0.8685) to form time series for each site. Although turbidity strongly fluctuated throughout all years, preliminary analysis shows that water was less turbid during the lockdown around the North River WPCP, but there was no significant change in turbidity around other WPCPs.

REFERENCES

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