Evaluating Potential Coastal Environmental Impacts from the COVID-19 Shutdown at Puerto Rico

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1. INTRODUCTION

- On an island where most of the population lives within 7 km of the sea, it is important to preserve the coastal environments, which contain vital natural resources and habitats for marine organisms and humans. (Rodríguez et al., 1994)
- Water quality measurements are important for (1) drinking water reservoirs and (2) monitoring aquatic ecosystems and marine organisms. (Slonecker et al., 2016)
- Air pollution is one of the main causes for the development of respiratory diseases. In 2015, polluted air was responsible for 6.4 million deaths worldwide, 4.2 million from ambient air pollution. (Landrigan, 2017)

2. RESEARCH OBJECTIVES

- To study potential changes in air pollution and water quality for Puerto Rico's coastal region after the COVID-19 shutdown.
- To evaluate tropospheric NO_2 and CDOM concentrations using satellite data.

NO_2 - Nitrogen **D**ioxide

- Its presence in air contributes to the formation and modification of other air pollutants.

CDOM - Colored **D**issolved **O**rganic **M**atter

- Largest reservoir of organic matter in aquatic environments.

3. AREA OF STUDY

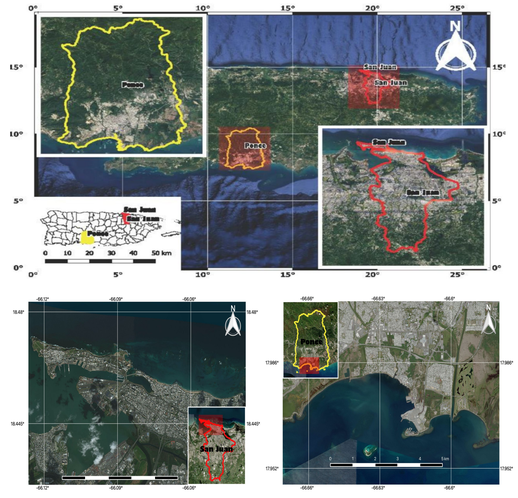

Figure 1. Map of Puerto Rico.
Study sites: Ponce (yellow) and San Juan (red).

4. METHODOLOGY

4.1 Acquiring NO_2 Data

- **AURA/OMI**
  - Temporal Resolution: Daily
  - L3 NO_2 Tropospheric Column Density (30% Cloud Screened)
- **Matlab**
  - Extracting and plotting NO_2 concentrations

4.2 Acquiring CDOM Data

- **Landsat 8 Spacecraft (L8)**
  - Temporal Resolution: 16-days
  - Level 1 Data, from: **EarthExplorer**

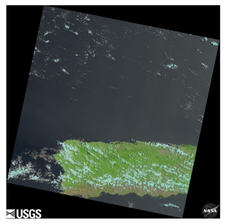

Figure 2. Level 1 Data.
L8 natural color image of Puerto Rico.
Date: 2020-04-18
(from: USGS, EarthExplorer)

  - Atmospheric Correction, using **SeaDas**
    - Level 1 to Level 2 Data
- **Matlab**
  - Extracting and plotting CDOM
    - Costal/aerosol band

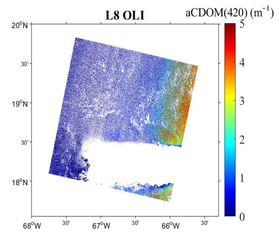

Figure 3. Level 2 Data.
Map of CDOM concentrations.
Date: 2020-04-18
(After running the Matlab algorithm)

4.3 Statistics

- Ran descriptive statistics and one-directional paired t-TEST.

5. RESULTS

5.1 NO_2 Data

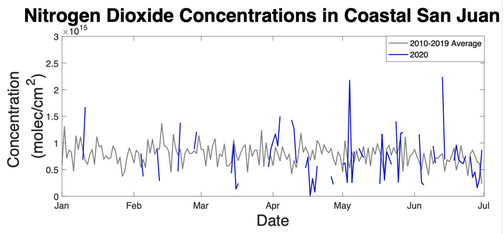

Figure 4. Nitrogen Dioxide Concentrations
2020 NO_2 concentrations in San Juan (blue) and Ponce (red) compared with the 2010-2019 average from Jan through June.

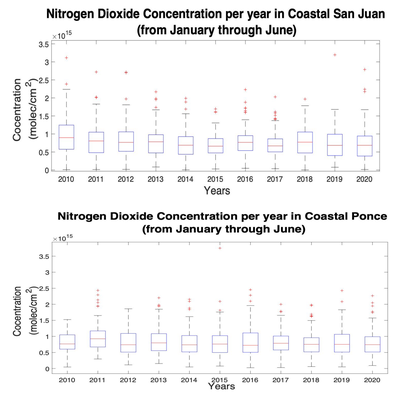

Figure 5. Nitrogen Dioxide Concentrations
Distribution of NO_2 values per year (2010- 2020)

Table 1: Percentage Difference
Years with a higher Jan-June average (molec/cm^2) of NO_2 concentration than 2020 (green).

Statistical Analysis for San Juan		
Year	Average	% Difference
2010	9.94E+14	13.87%
2011	8.24E+14	4.58%
2012	8.42E+14	5.64%
2013	7.98E+14	2.96%
2014	7.27E+14	-1.67%
2015	6.99E+14	-3.65%
2016	7.99E+14	2.99%
2017	7.42E+14	-0.68%
2018	7.83E+14	2.01%
2019	7.28E+14	-1.62%
2020	7.52E+14	N/A

Statistical Analysis for Ponce		
Year	Average	% Difference
2010	8.13E+14	0.62%
2011	9.64E+14	9.11%
2012	8.11E+14	0.50%
2013	8.75E+14	4.29%
2014	8.02E+14	-0.06%
2015	8.27E+14	1.47%
2016	8.57E+14	3.25%
2017	8.07E+14	0.25%
2018	7.85E+14	-1.13%
2019	8.10E+14	0.43%
2020	8.03E+14	N/A

Table 2: Max/Min Comparison
Max. and Min. NO_2 Values from 2010-2019 and 2020 (yellow).

Maximun and Minimum NO2 Values in San Juan				
Maximun		Minimun		
Date	Concentration (molec/cm^2)	Date	Concentration (molec/cm^2)	
4/21/10	3.1137E+15	4/4/18	2.0019E+12	
1/21/20	2.7872E+15	4/17/20	1.3980E+13	

Maximun and Minimum NO2 Values in Ponce				
Maximun		Minimun		
Date	Concentration (molec/cm^2)	Date	Concentration (molec/cm^2)	
1/22/15	3.75E+15	1/8/16	2.53E+13	
6/12/20	2.27E+15	9.33E+13	6/21/20	

5. RESULTS Continued...

5.2 CDOM Data

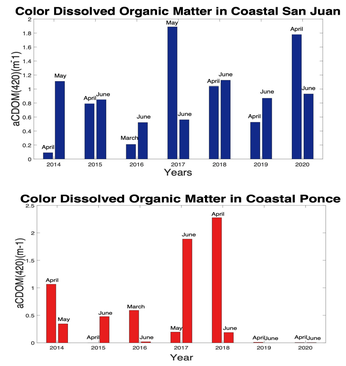

Figure 6. CDOM concentrations (2014-2020).
Concentrations of CDOM at the San Juan Bay (blue) and the coast of Ponce (red).

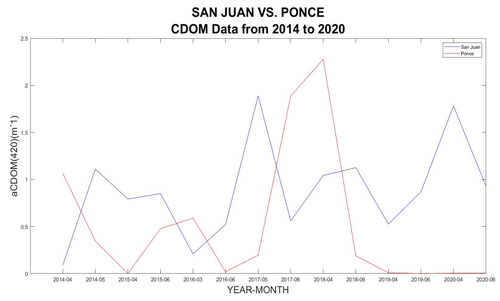

Figure 7. Comparison of CDOM concentrations (2014-2020).
CDOM concentrations comparison between San Juan Bay (blue) *vs.* Ponce (red).

Table 2. Percentage Difference. CDOM concentrations between April 2020 *vs.* April of each year from 2014 to 2019. The same was done for the month of June.

Percentage Difference between 2020

	San Juan Bay	
	April 2020	June 2020
2014	90.33%	---
2015	38.43%	4.45%
2016	---	28.12%
2017	---	24.72%
2018	26.15%	-9.53%
2019	54.41%	3.41%

	Ponce	
	April 2020	June 2020
2014	-99.08%	---
2015	78.18%	-97.97%
2016	---	-59.67%
2017	---	-99.48%
2018	-99.57%	-94.92%
2019	-34.67%	90.96%

- ***t*-TEST**
  All p-values were greater than 0.05. This indicates a high probability that the variation in the data from each year was randomly different to 2020.

6. DISCUSSION

- **NO_2:** Both Ponce and San Juan experienced changes in concentrations after the COVID-19 Shutdown. Ponce's average concentration in 2020 was lower than eight of the ten previous years, only being higher than 2014 and 2018. The studied months in 2018 were months that followed Hurricane Maria's aftermath in the island, which lead to lower power generation, hence lower NO_2 emissions. Also, it was found that, in the last decade, the majority of average concentrations in both sites were within the same range, mainly because both sites have industrialized regions which leads to higher concentrations of NO_2.
- **CDOM:** In San Juan, an increasing pattern of CDOM levels was observed from April to June. In 2020, CDOM levels decreased, which can be linked to the COVID-19 shutdown, although other factors could be related. In Ponce, no pattern was observed. CDOM values for 2019 and 2020 remained very low compared to the years from 2014 to 2018. Fewer data points were available for CDOM, due to atmospheric variables that limited the sensor when acquiring data. San Juan's Bay was also observed to carry higher levels of CDOM than Ponce in most of the studied months. The increase in CDOM can be associated to higher tourism at San Juan, Puerto Rico's capital, and it is more prone to trading activities (e.g. receiving products, public maritime transportation and the arriving/disembark of cruise-ships).

7. CONCLUSIONS

- CDOM and NO2 concentrations were impacted after the COVID-19 shutdown in Puerto Rico (started 2020-03-15), but it was more noticeable in San Juan than Ponce.
- This is mainly due to San Juan being more prone to higher changes in air and maritime traffic, which contribute to fluctuations in air and water pollution.
- Further data is required to explore the link between these changes and the COVID-19 shutdown.

FUTURE RESEARCH

- Continue yearly studies of CDOM and NO2 concentrations around Puerto Rico.
- Compare changes associated with the COVID-19 shutdown with other major events (i.e. hurricanes).

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