Inter-American Development Bank

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Country Department Caribbean Group

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TECHNICAL NOTE Nº IDB-TN-1857

January 2020

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IDB
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Cataloging-in-Publication data provided by the
Inter-American Development Bank
Felipe Herrera Library
Impact of hurricane Dorian in The Bahamas:
a view from the sky / María Alejandra
Zegarra, Juan Pedro Schmid, Luis Palomino,
Bruno Seminario.
p. cm. — (IDB Technical Note ; 1857)
Includes bibliographic references.
1. Hurricanes-Economic aspects-Bahamas.
2. Economic development-Bahamas. 3.
Gross domestic product-Bahamas. 4.
Bahamas-Economic aspects. I. Zegarra,
María Alejandra. II. Schmid, Juan Pedro. III.
Palomino, Luis. IV. Seminario, Bruno. V.
Inter-American Development Bank. Country
Department Caribbean Group. VI. Series.
IDB-TN-1857




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## Abstract

Hurricane Dorian has been among the most devastating natural disasters ever to hit The Bahamas. The estimated damages and losses from it amount to US$3.4 billion (IDB, 2019), a number equivalent to a quarter of the country's GDP. Dorian's effects also resulted in the revision of The Bahamas economic growth forecast. The IMF reduced GDP growth estimates for 2019 to 0.9 percent, and the economy is expected to contract in 2020. Under these circumstances, this paper proposes a methodology to track the economic recovery of The Bahamas on a monthly basis. The results suggest that the GDP growth rate in most of the 19 islands that comprise The Bahamas suffered a sharp decrease because of Hurricane Dorian. The islands that suffered the most from this event have recorded significant decreases in their economic activity. Abaco shows a reduction in monthly economic activity of 54 percent comparing September 2019 to September 2018, and Grand Bahama registered a 34 percent decrease. These estimates were obtained by comparing the spatial variation of satellite night lights as an indicator of the country's economic activity before and after Hurricane Dorian. Satellite night lights observed from the space are publicly available and have been used before to measure economic activity. This study also presents a new annual series of regionalized GDP estimates by island from 1992 to 2018, and on a monthly basis, from January 2012 to September 2019.



**Key words**: night lights, GDP, The Bahamas, Hurricane Dorian

**JEL Codes**: C82, N16, Q54

## Introduction

The Bahamas is a high-income Caribbean country that has positioned itself as one of the main tourist destinations in the region. Despite its high levels of average income, the country still faces significant vulnerabilities that could jeopardize its achievements, particularly natural disasters. Between September 1 and 3, 2019, The Bahamas experienced the destructive fury of Dorian, a category 5 Atlantic hurricane, which took at least 70 human lives, left another 282 people missing and affected 30,000 people by destroying their homes and property. Dorian is registered as one of the most devastating natural disasters to strike The Bahamas in modern times.

The destructive power of this natural disaster reversed the country's recent economic progress (World Economic Outlook, 2019) and caused about US$3.4 billion in damages and losses (ECLAC, 2019), equivalent to one-fourth of the country's GDP. According to ECLAC (2019), most of the damage and losses were sustained in the private sector, primarily in the housing and tourism sectors. The Abaco Islands and Grand Bahama sustained the brunt of the damage and losses. Given the magnitude of this event and The Bahamas' geographical characteristics, such as the dispersion of settlements and uneven quality of public services throughout the islands, reconstruction will take several years.

This study aims to identify the impact of Hurricane Dorian on Bahamian GDP using a methodology that estimates regionalized GDP from January 1992 until September 2019 and the same series on an annual basis from 1992 to 2018. It maps economic activity throughout the Bahamian territory using satellite light maps and national accounts information before and after Hurricane Dorian hit The Bahamas. This result is obtained by allocating a proportion of total GDP of the country given the level of luminosity on the surface of The Bahamas. Special attention is given to Abaco and Grand Bahama, where damages were concentrated.

The rest of the document is organized as follows: Section 1 explains the importance of studying the impact of catastrophic natural disasters. Section 2 describes the impact of past hurricanes in The Bahamas. Section 3 provides more information about Hurricane Dorian and maps the satellite night lights before and after it hit The Bahamas. Section 4 describes the methodology used to estimate the economic impact of Hurricane Dorian. Section 5 describes the data, and Section 6 shows the results. Section 7 concludes.

## 1 Why is it important to study the impact of catastrophic natural disasters?

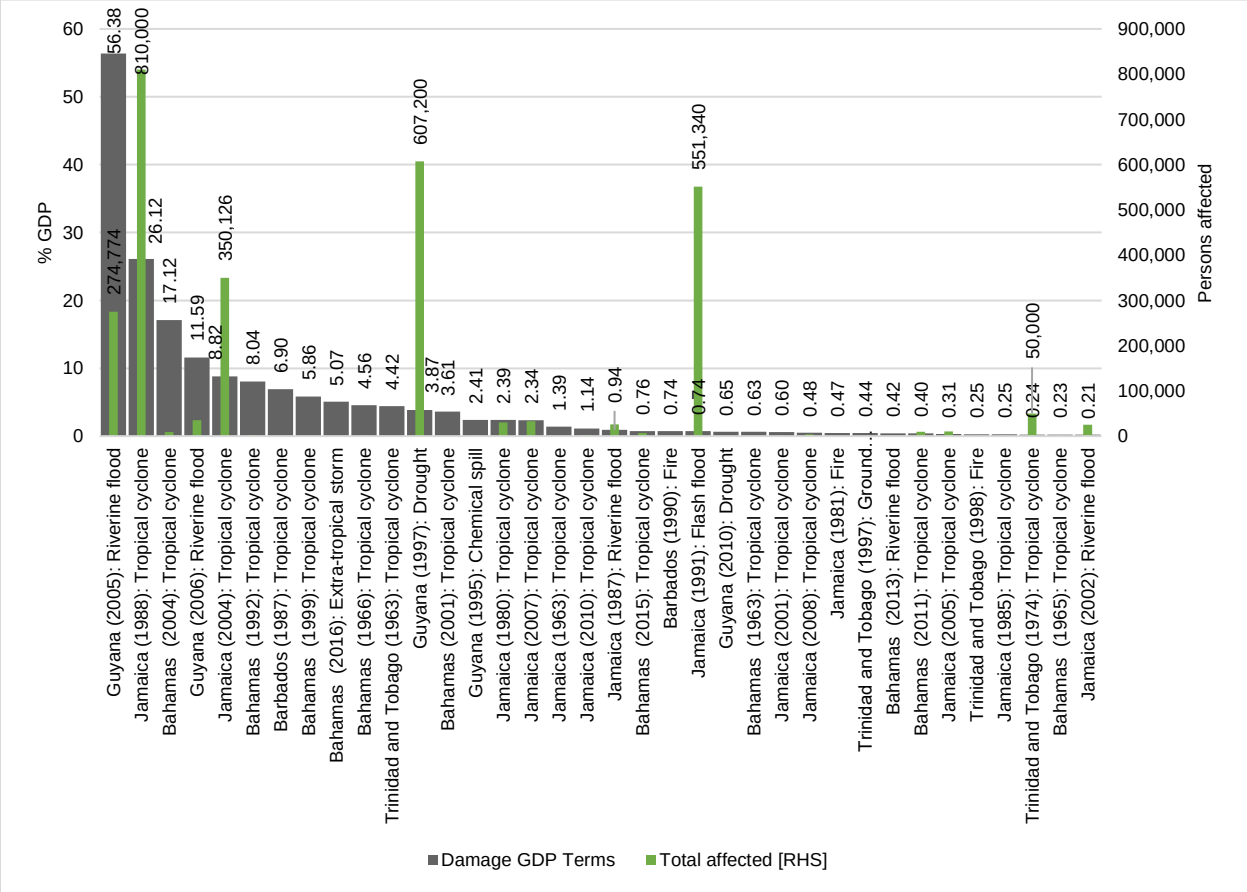
Was Hurricane Dorian a one-time, extremely rare event or a sign of a recurring threat? Despite their rarity, the intensity and frequency of category 5 hurricanes have been steadily increasing. Among the negative effects of climate change, hurricanes are expected to become more frequent, stronger (in terms of wind speed), and more destructive as higher sea levels amplify their strength. Sea level in The Bahamas has already risen 0.3 meters in the past 100 years, and there is a small but important risk (<0.1%) of at least one flood over 1 m taking place between today and 2050 in The Bahamas area (Strauss and Kulp, 2018). This makes the Bahamian economy and population particularly vulnerable to climate change, since the main financial and tourism activity areas lie adjacent to the coastal zones, and about 130,000 people live on land below 1 m. For these reasons, The Bahamas has been included in the list of countries at risk of major natural disasters (IMF, 2019).

Natural disasters are considered a major threat to economic activity, consumption, and investment not only for The Bahamas, but also for the rest of Caribbean countries. In recent years,

most Caribbean countries have experienced economic losses and internal displacements[1] as a consequence of natural disasters. With a few exceptions, small island states in the Caribbean and the Pacific have suffered annual average damage due to natural disasters of around 2 to 3 percent of GDP between 1980 and 2017 (IMF, 2019).

In the Caribbean, six of the countries that work with the IDB (The Bahamas, Barbados, Guyana, Jamaica, Suriname, and Trinidad and Tobago) have experienced significant damage from natural disasters. Between 1963 and 2018, these countries experienced 52 natural disasters, equivalent to 1 per year, which had an average impact on GDP of 3.5 percent and affected more than 3 million people during these years (see Figure 1). During this period, these countries experienced 34 tropical cyclones, which occurred on average every 1.6 years, had an average impact of 3 percent on GDP, and affected about 1.5 million people. Given these circumstances, preventive actions should be taken to minimize the damage and loss of disruptive climate events in the future.

**Figure 1. Disaster Damage (% GDP) and Number of People Affected in the Caribbean, 1963-2016**




Sources: Center for Research on the Epidemiology of Disasters (2019), IMF (various years), and Mooney and Rosenblatt (2019).

According to the Lima Climate Change Conference (COP20), climate change will continue to aggravate negative effects by increasing the frequency and devasting power of natural disasters.

[1] These are people who have been forced to flee their homes as a result of natural or human-made disasters and who have not crossed an international border.

The impact of Hurricane Dorian is an unfortunate example of what could happen to Caribbean countries if adaptive measures and policies are not adopted soon. The urgency of this topic transcends the destruction of infrastructure and the loss of human lives. According to the IMF (June 2019), large natural disasters can set back output growth and contribute to a significant rise in public debt. Since the impact of disasters can be partially contained but not eliminated, disasters will still create sizable fiscal and financing shocks that need to be anticipated. This is another reason why investing in structural resilience should be a high priority. The Bahamas and other Caribbean countries, such as Dominica, Grenada, Jamaica, St. Kitts and Nevis, and St. Vincent and the Grenadines, are exploring or already have mechanisms to self-insure. They also have access to risk transfer through insurance, generally parametric, provided by regional pooling arrangements like the Caribbean Catastrophe Risk Insurance Facility (CCRIF).[2]

Given the small size of the countries in the region, efforts to adopt policies to help them adapt to climate change are central. The IMF (2016) has developed a roadmap of policy responses to natural disasters and climate change. They recommend aligning macro, fiscal, and financial policies to support resilience-building while maintaining stability and sustainability. Among the actions that should be taken is systematic planning for disasters and a more challenging physical environment. This includes a range of fiscal institutions and policies to help manage vulnerabilities posed by natural disasters and climate change. These span public financial management and debt management practices, carbon taxation and energy pricing reform, and approaches for achieving fiscal and debt sustainability.

## 2 Hurricanes in The Bahamas

Since the beginning of the 20th century, The Bahamas has suffered around 55 hurricanes, 13 of which were of high intensity (see Table 1). Given the increasing frequency of high-intensity hurricanes, and with the appearance of Hurricane Dorian, a discussion on the categorization of hurricanes has begun.

[2] The CCRIF was formed in 2007 as the first multi-country risk pool in the world and was the first insurance instrument to successfully develop parametric policies backed by both traditional and capital markets. It was designed as a regional catastrophe fund for Caribbean governments to limit the financial impact of devastating hurricanes and earthquakes by quickly providing financial liquidity when a policy is triggered.

**Table 1. List of Hurricanes that Have Hit The Bahamas**

| Start date | End date | Duration (days) | Name | Category | Notes |
|---|---|---|---|---|---|
| 10/30/1932 | 11/14/1932 | 15 | The Great Abaco Hurricane | 5 | Struck The Bahamas at peak intensity. More than a dozen people were reportedly killed, and hundreds injured. |
| 8/27/1965 | 9/13/1965 | 17 | Hurricane Betsy | 4 | Caused an estimated $14 million in damage across The Bahamas primarily to crops. |
| 8/16/1992 | 8/28/1992 | 12 | Hurricane Andrew | 5 | Made landfall on Eleuthera at that strength but weakened to Category 4 while traversing the archipelago. It destroyed hundreds of houses in The Bahamas and reportedly left four people dead. |
| 9/7/1999 | 9/19/1999 | 12 | Hurricane Floyd | 4 | Caused extensive material damages. |
| 8/24/2004 | 9/10/2004 | 17 | Hurricane Frances | 4 | Knocked out power and damaged homes in the Bahamas. |
| 8/23/2005 | 8/31/2005 | 8 | Hurricane Katrina | 5 | Traversed the Bahamas as a tropical storm causing minimal damage. |
| 10/16/2005 | 10/27/2005 | 11 | Hurricane Wilma | 5 | Passed by the Bahamas producing hurricane-force winds and a powerful storm surge leading authorities to order evacuations. |
| 8/21/2011 | 8/28/2011 | 7 | Hurricane Irene | 3 | Made four landfalls in The Bahamas, causing widespread material damage but no reports of fatalities. |
| 10/22/2012 | 11/2/2012 | 11 | Hurricane Sandy | 3 | Passed over The Bahamas before reaching the United States. |
| 9/28/2015 | 10/15/2015 | 17 | Hurricane Joaquin | 4 | Meandered over the southern Bahamas battering its islands for over two days, causing extensive devastation. Its storm surge trapped hundreds in their homes. Offshore, the American cargo ship El Faro and her 33 members were lost to the hurricane. |
| 9/28/2016 | 10/10/2016 | 12 | Hurricane Matthews | 5 | Caused massive destruction in Haiti and damaged several islands in The Bahamas. |
| 8/30/2017 | 9/13/2017 | 14 | Hurricane Irma | 5 | Passed over Inagua and South Acklins islands where downed power lines knocked out communications and damaged homes. |
| 8/24/2019 | 9/8/2019 | 15 | Hurricane Dorian | 5 | Passed over Grand Bahama and Abaco. Average wind speed of 180 mph. |

Source: Press (2019).

Hurricanes are categorized using the Saffir-Simpson scale, which has five categories. The highest classification is category 5, which is used to label storms with sustained winds over 156 mph (251 km/h). The Saffir-Simpson scale provides some indication of the potential damage and flooding that a hurricane will cause upon landfall. Since accurate satellite measurements began in 1983, only 7 percent of the 243 Atlantic hurricanes observed since then have reached a category 5.

While passing though The Bahamas, Hurricane Dorian reached an average wind speed of 185 mph. Only five Atlantic hurricanes in recorded history have reached this threshold, and only eight if the threshold is lowered to 180 mph (see Table 2). While these hurricanes are rare, their frequency has been increasing. Between 1935 and 2019, there has been one hurricane with wind

speed over 180 mph every 18 years, but during the 21st century, they have occurred on average once every 5 years. Despite the fact that the frequency has increased, the average wind speed has declined slightly.

**Table 2. Category 5 Atlantic Hurricanes with Average Wind Speed of 180-190 mph**

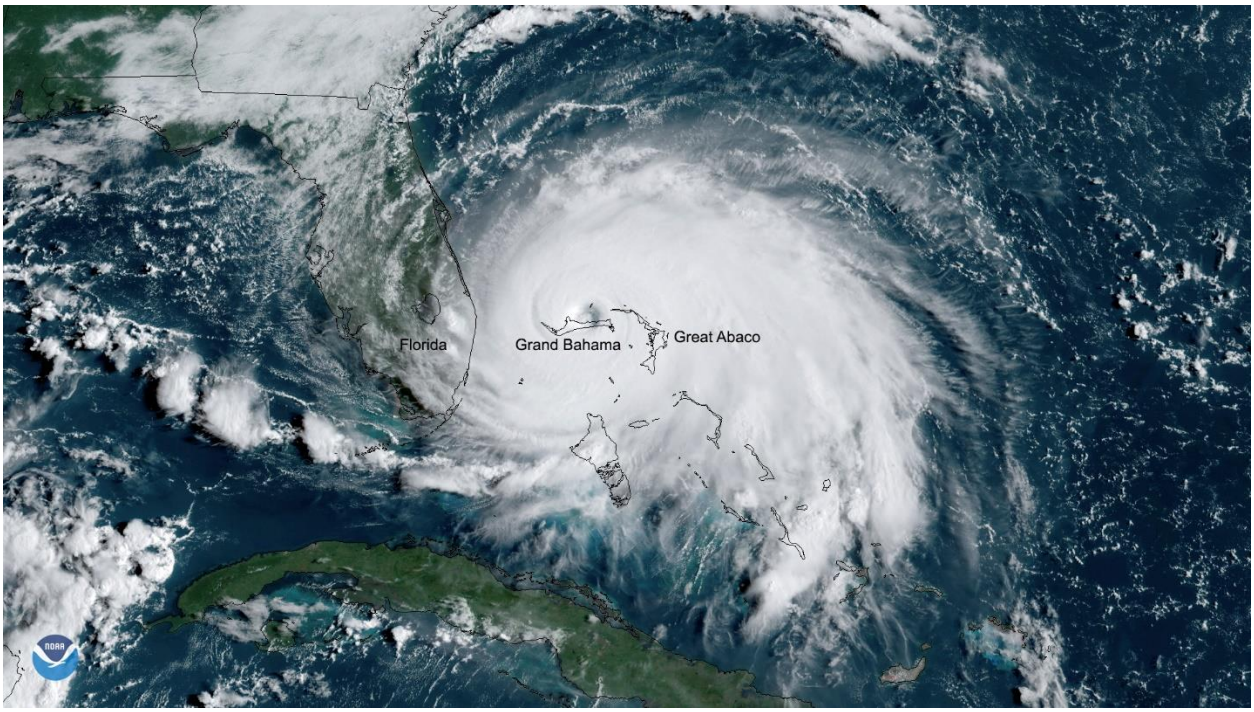
| Wind speed (mph) | Name | Year | Range (years) |
|---|---|---|---|
| 190 | Labor Day | 1935 | - |
| 185 | Allen | 1980 | 45 |
| 185 | Gilbert | 1988 | 8 |
| 185 | Mitch | 1998 | 10 |
| 185 | Rita | 2005 | 7 |
| 180 | Wilma | 2005 | 0 |
| 180 | Irma | 2017 | 12 |
| 180 | Dorian | 2019 | 2 |
| 186 | Average | 20th century | 18 |
| 181 | Average | 2000-2019 | 5 |

Given the difference between Hurricane Dorian and category 5 average wind speeds, the possibility of adding a category 6 with a minimum threshold of 180 mph has been considered. According to the National Hurricane Center, despite the Saffir-Simpson Hurricane Wind Scale non-linearity, an increase of intensity in one category results in approximately four times more wind damage. This implies that Hurricane Dorian, on average, had more wind damage than any other common category 5 hurricane.

## 3 Hurricane Dorian

On September 2, 2019, the residents of Abaco and Grand Bahama islands woke up with their main towns flooded, their homes shattered, boats torn from moorings, dragged vehicles, and debris everywhere. The truly exceptional Category 5 Hurricane Dorian powered ashore on Great Abaco Island on September 1, with sustained winds of 185 mph and gusts up to 220 mph. Winds of this strength would make Dorian worthy of a category 6 rating, if it existed. Overnight and into Labor Day, Catastrophic Hurricane Dorian slowed to a crawl over Grand Bahama Island (see Figure 2). At a 200-mph pace, the Category 5 storm swept away entire cities, affecting the homes and properties of more than 70,000 people.

**Figure 2. Category 5 Hurricane Dorian over Grand Bahama Island on September 2, 2019.**

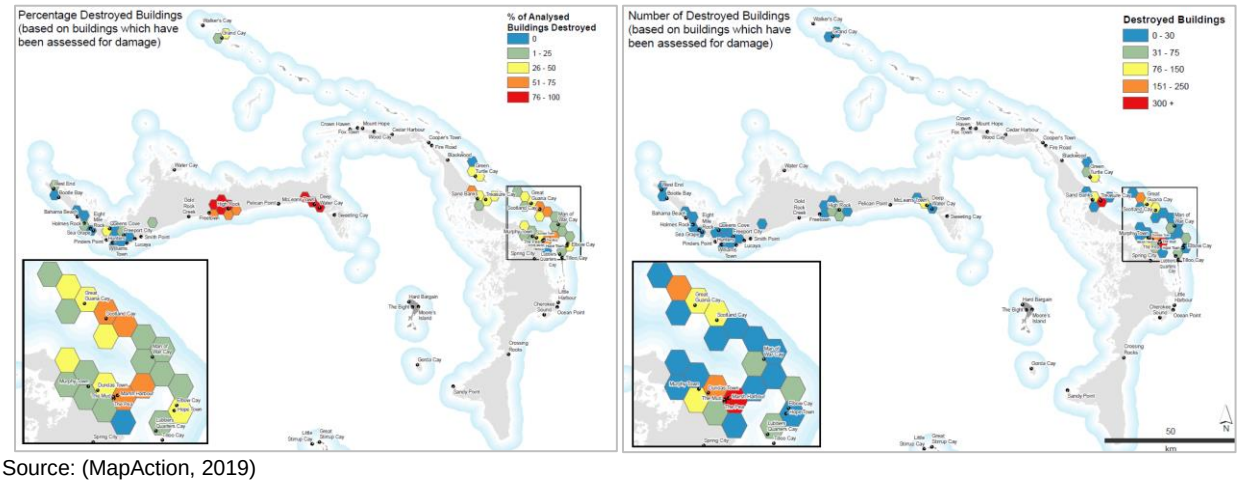



Source: NOAA.

Dorian is tied for the strongest Atlantic hurricane landfall on record with the 1935 Labor Day hurricane, according to the National Hurricane Center. Grand Bahama and Abaco are the second and third most populated islands in The Bahamas, with 14 percent and 5 percent of the total population in their territories, respectively. Together they account for around 76,000 of the population of The Bahamas, many of whom lost their homes (see Figure 3).

**Figure 3. Number and Percentage of Buildings Destroyed across a 10km2 Hexagonal Grid of Grand Bahama and Abaco**

**a. Percentage of buildings destroyed** **b. Number of Destroyed Buildings**




Source: (MapAction, 2019)

Grand Bahama, in addition to being a residential island, is also home to an important share of total industrial production in The Bahamas. Administratively, the island consists of the Freeport

Bonded Area and the districts of East Grand Bahama and West Grand Bahama. Dorian affected mostly the west side of the island, which is the residential part of the territory. However, major infrastructures, such as the Grand Bahama International Airport, were affected, exacerbating the costs associated with this event (see Figure 3).

## 4 Methodology

Recent studies have shown that luminosity measured by night lights observed from space is correlated with economic activity (Amavilah, 2018; Pinkovskiy and Sala-i-Martin, 2016; Nordhaus and Chen, 2015; Henderson, Storeygard and Weil, 2012; Michalopoulos and Papaioannou, 2012). In this study we use an alternative methodology to calculate the GDP of the islands of The Bahamas for the period 1992-2019.

In order to have an accurate estimate of the impact of the hurricane, it is necessary to estimate the GDP on a monthly frequency. Since monthly statistical series are not available, we used the Denton methodology (1971) to construct a monthly series. We divided the annual GDP in a monthly frequency for the period 2012-2018 using the monthly maps of luminosity and the methodology of Denton (1971) implemented in Matlab. After estimating the monthly GDP levels, we used the growth rate of the brightness level of each island to estimate its monthly GDP for the period 01/2019-09/2019. We summarized the estimation of the GDP by island in the following six phases:

- The first phase consists of processing the satellite imagery of luminosity obtained from NOAA's National Geophysical Data Center. The processing consists of obtaining the average brightness level for each of the islands. We used ArcGIS with Python for this purpose.

- The second phase consists of obtaining the population density for each island from the population censuses of 1990 and 2010. Population series for each island were generated using the census information and the Piecewise Cubic Hermite Interpolating Polynomial function implemented in Matlab.

- The third phase consists of estimating the parameters of a production function where the factors are the level of luminosity and the population density. Using the estimated parameters, the GDP is estimated for each of the islands.

- The fourth phase consists of generating GDP for a base year. We chose 2013 as the base year due to the availability of a household survey that contained information about income and expenses. The GDP in 2013 was derived for each island using the household income from the survey and the estimated GDP of the third phase.

- The fifth phase consists of generating a production index considering the base year and thereby estimating the GDP for the entire analysis period.

- The sixth phase consists of adjusting the estimated GDP to the national GDP for the entire analysis period.

## 5 Data

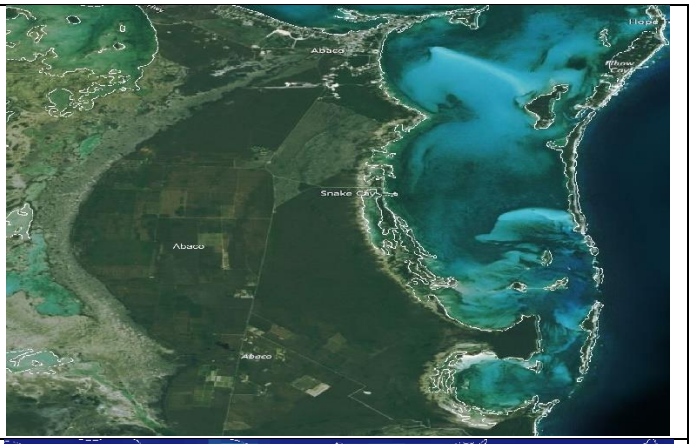
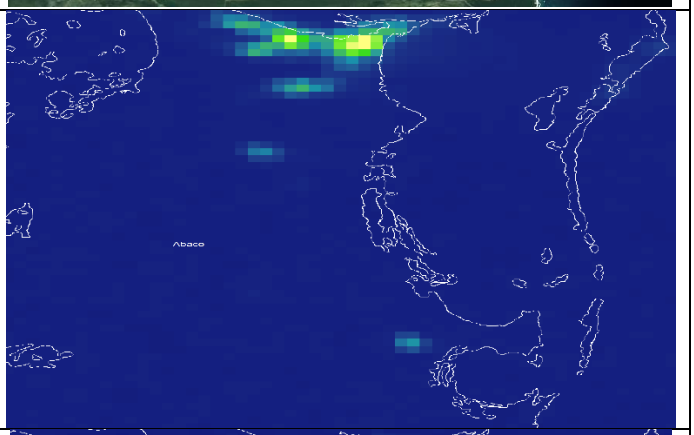
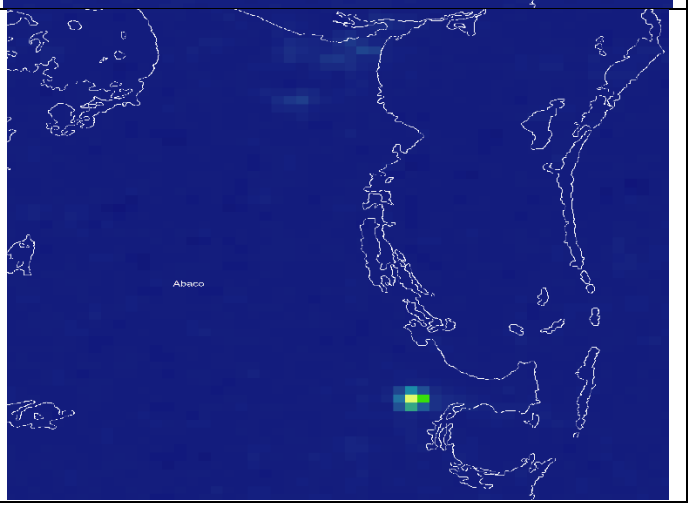
The quality and availability of the satellite luminosity maps is not uniform for the entire analysis period. A first block of maps corresponds to the 1992-2013 period. These maps have an annual frequency, and the map the luminosity of all the countries in the world. A second block of maps

corresponds to the period 2012-2019. These maps have a monthly frequency and are presented in quadrants. They also have better resolution than the maps of the first block.

The islands of The Bahamas are in quadrant 75N-180W. Figure 4 and Figure 5 show the level of luminosity of Abaco and Grand Bahamas in the months of September 2018 and September of 2019. The level of luminosity is represented in squares of 0.42 km.$^2$ Greater yellow in the grid indicates a higher level of brightness.

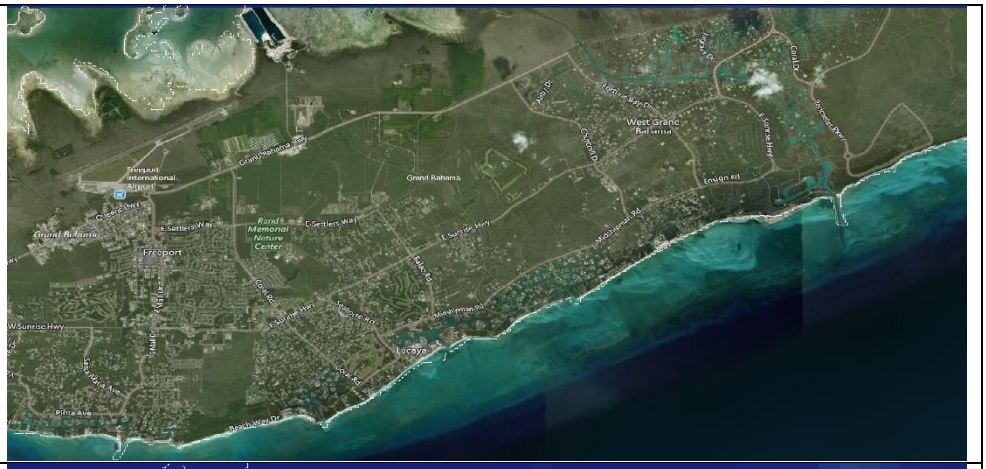
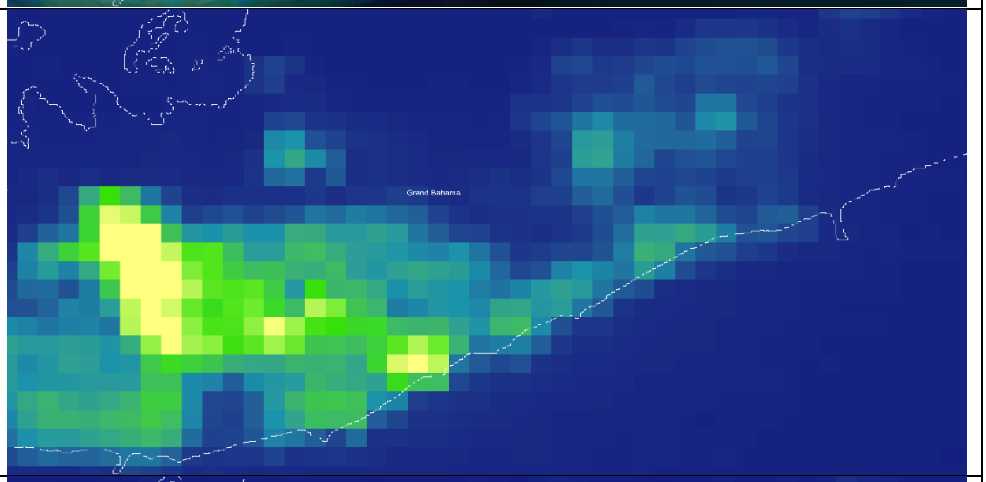
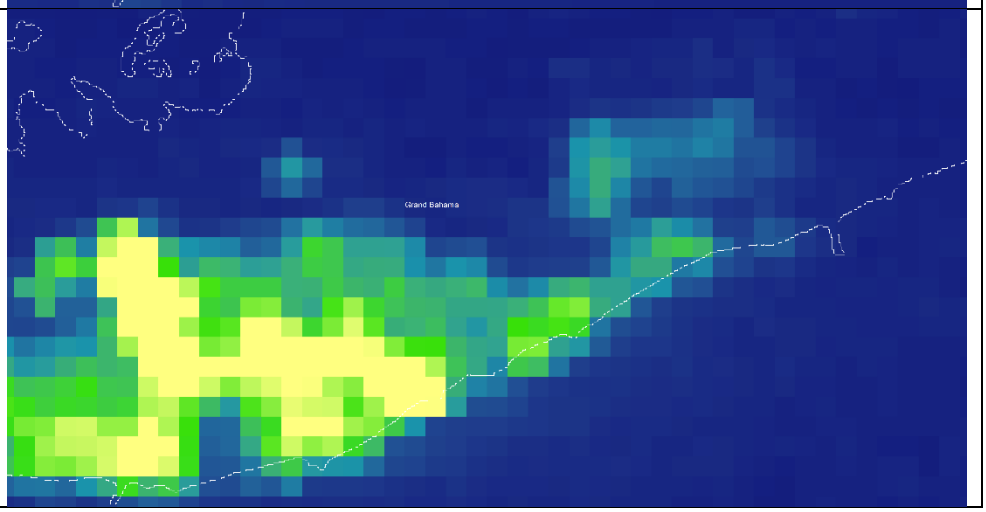
We compared September 2019 to the same month one year earlier to capture seasonal variations. On Abaco, Figure 4 displays fewer yellow squares in September 2019 than in September 2018. This reflects the devastating impact of the hurricane on the Island. Figure 5 shows how the hurricane negatively impacted Freeport International Airport and the West Grand Bahama region. It shows in the West Grand Bahama region a decrease in the number of illuminated grids in September 2019 compared to September 2018. However, the illuminated grids in the Freeport region of Grand Bahama increased in intensity in the month of September 2019 compared to 2018. The higher level of observed intensity could be explained by the displacement of the population from the affected areas to the Freeport region.

**Figure 4. Luminosity Maps - Abaco**

| | |
|---|---|
| **Affected Region** |  |
| **September 2018** |  |
| **September 2019** |  |

Source: NOAA and authors' elaboration.

**Figure 5. Luminosity Maps - Grand Bahama**

| | |
|---|---|
| **Affected Region** |  |
| **September 2018** |  |
| **September 2019** |  |

Source: NOAA and authors' elaboration.

## 6 Results

Table 3 shows the evolution of each island's participation in total GDP for some relevant years based on the methodology using luminosity described above. Despite the reduction of its relative importance in GDP, New Providence Island still had the highest share in economic activity of The Bahamas, with 73.16 percent of total GDP in 2018 being produced in this island. Abaco Island's share of GDP increased from 2.65 percent in 1992 to 5.29 percent in 2018, but due to the impact of Hurricane Dorian it is expected to decrease in to 4.80 percent in 2019. On the other hand, Grand Bahama Island's participation in economic activity has decreased, going from 12.87 percent of total GDP in 1992 to 9.89 percent in 2018, and it is expected to continue to decline to 9.50 in 2019.

**Table 3. Regional GDP as a Share of total GDP based on Luminosity, 1992-2019**

| | 1992 | 1999 | 2004 | 2005 | 2012 | 2016 | 2017 | 2018 | 2019 |
|---|---|---|---|---|---|---|---|---|---|
| Abaco | **2.65** | **2.87** | **3.47** | **3.21** | **3.99** | **3.77** | **5.35** | **5.29** | **4.80** |
| Acklins | 0.10 | 0.11 | 0.14 | 0.14 | 0.10 | 0.07 | 0.13 | 0.15 | 0.13 |
| Andros | 1.92 | 1.58 | 1.76 | 1.57 | 1.37 | 1.18 | 2.03 | 2.04 | 1.77 |
| Berry Islands | 0.28 | 0.25 | 0.33 | 0.33 | 0.23 | 0.32 | 0.43 | 0.47 | 0.52 |
| Bimini | 0.24 | 0.39 | 0.43 | 0.45 | 0.44 | 0.83 | 0.79 | 0.77 | 0.79 |
| Cat Island | 0.10 | 0.14 | 0.15 | 0.15 | 0.11 | 0.09 | 0.15 | 0.16 | 0.13 |
| Crooked Island | 0.02 | 0.04 | 0.04 | 0.04 | 0.03 | 0.02 | 0.04 | 0.05 | 0.04 |
| Eleuthera | 1.30 | 1.68 | 1.58 | 1.70 | 1.66 | 1.49 | 1.88 | 1.99 | 1.78 |
| Exuma and Cays | 1.03 | 1.23 | 2.05 | 1.80 | 1.76 | 1.63 | 2.45 | 2.48 | 2.19 |
| Grand Bahama | **12.87** | **13.86** | **11.89** | **13.46** | **14.58** | **11.38** | **9.19** | **9.89** | **9.50** |
| Harbour Island | 1.48 | 1.66 | 1.35 | 1.33 | 1.52 | 1.76 | 1.68 | 1.71 | 1.67 |
| Inagua | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.02 | 0.05 | 0.05 | 0.05 |
| Long Island | 0.42 | 1.07 | 1.15 | 1.06 | 1.01 | 0.61 | 1.21 | 1.31 | 1.11 |
| Mayaguana | 0.07 | 0.06 | 0.08 | 0.07 | 0.06 | 0.05 | 0.10 | 0.11 | 0.09 |
| New Providence | 77.27 | 74.75 | 75.27 | 74.40 | 72.87 | 76.58 | 74.15 | 73.16 | 75.11 |
| Ragged Island | 0.02 | 0.03 | 0.03 | 0.03 | 0.02 | 0.01 | 0.02 | 0.03 | 0.02 |
| Rum Cay | 0.02 | 0.04 | 0.03 | 0.03 | 0.03 | 0.02 | 0.04 | 0.04 | 0.04 |
| San Salvador | 0.11 | 0.15 | 0.16 | 0.15 | 0.14 | 0.14 | 0.22 | 0.22 | 0.21 |
| Spanish Wells | 0.07 | 0.07 | 0.06 | 0.06 | 0.06 | 0.04 | 0.08 | 0.09 | 0.07 |

Source: NOAA, IMF WEO databases, and authors' calculations.

Table 4 shows the significant impact of Hurricane Dorian on economic growth. The first column presents the annual growth rates from September 2018 to September 2019. The second column presents the accumulated variation from January to September 2019 compared to the same period in the previous year. The third column shows the variation in the period between October 2018 and September 2019 compared to the same period in the previous years. The results suggest that the islands of Abaco and Grand Bahamas had a negative inter-annual growth of 54.65 and 34.31 percent, respectively, in September 2019. However, when we compare the accumulated growth from January to September, the Abaco Island decreased by 23.66 percent, while the island of Grand Bahama decreased by only 0.56 percent. This result suggests that Hurricane Dorian had a greater impact on Abaco. Similar results obtained when the accumulated growth rates are analyzed over 12 months indicate that the island of Abaco had negative growth of 19.83 percent, while the island of Grand Bahama had a positive growth rate of 4.42 percent. Thus, Hurricane Dorian's negative impacts on Abaco and Grand Bahamas had a negative impact on economic growth in The Bahamas.

**Table 4. Evolution of the Monthly GDP in The Bahamas, September 2018-2019**

| | Growth rate (%) | | |
|---|---|---|---|
| | 2019 / 2018 | | Oct 18-Sep 19 / Oct 17-Sep 18 |
| | September | January- September | |
| Abaco | **-54.65** | **-23.66** | **-19.83** |
| Acklins | -17.36 | -18.22 | -14.19 |
| Andros | -11.06 | -23.99 | -20.98 |
| Berry Islands | 34.46 | 26.45 | 21.95 |
| Bimini | -12.55 | -7.41 | -4.25 |
| Cat Island | -21.00 | -25.67 | -21.48 |
| Crooked Island | -16.81 | -17.96 | -14.26 |
| Eleuthera | -11.11 | -7.15 | -4.57 |
| Exuma and Cays | -9.73 | -15.74 | -13.64 |
| Grand Bahama | **-34.31** | **-0.56** | **4.57** |
| Harbour Island | -10.76 | 5.14 | 6.84 |
| Inagua | 21.15 | -7.08 | -8.96 |
| Long Island | -8.67 | -16.21 | -14.03 |
| Mayaguana | 6.83 | -9.59 | -9.57 |
| New Providence | -10.84 | 7.41 | 8.42 |
| Ragged Island | -25.91 | -24.45 | -22.51 |
| Rum Cay | -32.36 | -37.49 | -31.93 |
| San Salvador | -14.84 | -13.66 | -12.51 |
| Spanish Wells | -21.73 | -20.22 | -16.56 |
| **The Bahamas** | **-15.21** | **2.76** | **4.42** |

Source: NOAA, IMF WEO databases, and authors' calculations.

## 7 Concluding Remarks

This study calculated the economic impact of Hurricane Dorian in The Bahamas using a new methodology that enabled monthly GDP by island to be estimated. The results reflect a decrease in economic activity in most of the islands of The Bahamas. This is consistent with other studies that have also addressed the impact of Hurricane Dorian, especially in Abaco Islands and Grand Bahama.

Since the satellite night lights are publicly available for every month of the year, it was possible to follow the reconstruction of the regions affected by Hurricane Dorian and analyze the displacement of economic activity throughout the region at a monthly frequency. This study could be replicated in the future to measure the effectiveness of the actions being taken to recover the dynamism of the Bahamian economy. Finally, according to Donovan (2017), currently 20 percent of the population of the coastal cities of the Caribbean and Pacific small-island developing states (SIDS), or 4.2 million people, live in low-elevation coastal zones that are prone to flooding. This methodology could also be applied in these regions to estimate the potential impacts from rising sea levels and coastal erosion and to plan for adaptation.

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