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Eden Yonas April 12, 2022

The Looming Threat of Reduced Storm Decay:
Measuring Multi-Regional State and Local Preparedness and Responsiveness to Hurricanes

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Abstract
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One of the most consequential impacts of climate change is hurricanes that are strengthened by reduced storm decay. Before the severe impacts of climate change and the resultant increased of ocean surface temperatures, storms weakened as they moved over cooler air and dissipated soon after or even before they could cause severe damage on land. Increasingly warmer ocean waters decreased the hurricane decaying process. This not only elongated their duration and widened the area of devastation, but also increased the frequency of the onset of hurricane. Historically, hurricane seasons in the Atlantic basin were major threats primarily to states in the Gulf Coast region of the United States. With the worsening impact of climate change, northern states started to see hurricanes as their new normal. Local and state governments faced increasing challenges to develop proactive mitigation measures and adoption policies.

This thesis hypothesizes that the more that in-land communities that are impacted by destructive hurricanes, the more local, state, and federal governments react and take preventative actions in the future, drawing from past experiences. A corollary hypothesis that follows from here is that Northern states benefit from lessons learned in the South to mitigate the devastations of hurricanes and adopt their lifestyles as well as business and government practices as the new normal increasingly daunts these areas. To test both hypotheses, I utilize two northern states (New York and New Jersey) and two southern states (Texas and Florida) and analyzed their hurricane preparedness and responsiveness before and after hurricane hit. The lack of readily available data and difficulties of gathering data from disparate sources restricted the scope of the

study and limited the utility of the outcome of the study. However, the findings of the study that shed preliminary light on this matter rejected the primary hypothesis but rejected the corollary.

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I. Introduction

Hurricanes are one of the most deadly and costly devastations that the U.S. coastal regions face from year to year (Ting et al.). Emanuel et al. and Villarani & Vechhi have shown that there is an increase in the destruction Atlantic storms cause in recent decades. The intensity, frequency, and duration of hurricanes in the US, as well as the frequency of the strongest hurricanes, have all increased since the early 1980s (4th National Climate Assessment). The observed increases in intensity, frequency, and longevity are caused by rising sea temperatures, the brown ocean effect, and other phenomenon that cause hurricanes to have more power than ever before.

On August 30th, 2021, Hurricane Ida made landfall near Port Fourchon, Louisiana, as a Category 4 storm. The storm devastated the lives of millions of people across the eastern United States, causing over $95 billion in damages according to Accuweather (The Inquirer). It was the fifth costliest hurricane in United States history (CNBC). The strength and covered ground of this storm not only shocked the American public, but also overwhelmed the systems and programs put in place to build communities back up after such a detrimental natural disaster. Having such a lasting impact on states over a thousand miles from its original landfall location, Hurricane Ida drew attention to this issue that climate experts and governmental institutions will have to deal with for years to come.

State and local governments in the North are beginning to be confronted with destructive hurricanes that begin near Southern states. This is due largely to a phenomenon called reduced storm decay, triggered by an increase in sea surface temperatures. Before the onset of climate change, storms weakened as they moved over cooler waters and they gradually lost their energy and power soon after or even before they made landfall. Increasingly warmer ocean waters

decreased the hurricane decaying process. Rather than decaying or losing their strength, hurricanes pick momentum and in strength and intensity (Holland and Bruyere 2013).

Reduced storm decay signifies storms that carry their severity longer in terms of time and area covered. This may be caused by a plethora of factors, chief among them is warming temperatures and the brown ocean effect.

Reduced storm decay is forcing states and municipalities in the Northeast to prepare for an increase in hurricane damage, as local governments struggle to deal with not only storms that make landfall on their adjacent coast, but storms that originate from the Gulf Coast as well. As the impacts of reduced storm decay become regular destructive occurrences, local, state and federal governments face urgent administrative challenges and political pressure to act. The challenges are often daunting because of budget restrictions and the enormity of the challenge to strengthen hurricane-resilient infrastructure and building effective bureaucratic institutions.

As tropical cyclones increase in frequency, size, and intensity, hurricanes prove themselves to be one of climate change's most devastating consequences because of the sweeping havoc they wreck in economic livelihood and infrastructure. In the past, these storms were confined to a 6-month "hurricane season". However, according to the National Oceanic Atmospheric Association (NOAA), "the length of the hurricane season increases by about 40 days per degree Celsius of warming" (NOAA). This has also created precedent for meteorologists at the NOAA and the National Hurricane Center (NHC) to consider changing the start of the season to May 15th instead of June 1st (NPR).

As these storms continue to wreak havoc on areas not accustomed to dealing with them, many questions arise on how best to prepare communities and government agencies alike. My research seeks to answer this question: As hurricanes become more destructive on inland

communities, how has that affected local and state government preparedness to mitigate and withstand the impacts of these storms across multiple states?

I hypothesize that the more in-land communities are impacted by destructive hurricanes, the more local, state and federal governments react and take proactive and reactive mitigation actions, drawing from past experiences. A corollary hypothesis that follows from here is that northern states benefit from lessons learned in the South in shaping their policies to mitigate damages to life and property.

To test my hypothesis, I used two northern and two southern states and analyzed eight of their hurricanes over a span of 41 years, using Hurricane Katrina (2005) as a turning point in proactive hurricane mitigation strategies and reactive actions. Katrina was a Category 5 storm that left Southern states, particularly Louisiana, in a state of disarray. Although this storm occurred almost 17 years ago, many families and communities are still recovering. This storm showed the true impact that a Category 5 storm can have on communities, particularly exposing what weak bureaucratic institutions, lack of sufficient resilience funding, and neglecting preventative actions can do to residents of the areas on the paths of devastating hurricanes.

Additionally, to account for the difference between preventative and reactionary actions, I observe actions that occur both immediately before and after the hurricane hits. This is important to see to what extent storm decay impacts how states react after a hurricane and influences preventative actions.

The goal of my research is to investigate how the reactions of southern states to hurricanes influence northern state reactions and assistance to affected communities as northern states combat hurricanes. In order to control for other causes for changes in assistance, I consider

how issues like political ideologies, hurricane intensity, and infrastructural differences may influence reactions to hurricanes as well.

II. The Impacts of the Climate Problem

Climate change is a catalyst for many natural disasters around the world, including wildfires, floods, and above all hurricanes, whose devastations affect numerous states with monstrous strength. It has contributed to worsening hurricane conditions, both in terms of their intensity and the area of their devastation (Holland and Bruyere 2014). According to Chen et al., "a majority of tropical cyclones in the North Atlantic develop from African easterly waves (AEWs), which originate along both the southern and northern flanks of the mid-tropospheric African easterly jet" (Chen et al. 2008).

In simpler terms, winds from Africa's west coast blow from east to west, where hot winds originating from the dry Sahara Desert clash with cooler winds emanating from wetter regions in the South and produce high altitude winds. When the easterly jet forms, it brings with it a tropical wave with heavy rains and storms, propelling them towards the Atlantic Ocean. The strength of these waves produces storms moving towards the Atlantic basin. Depending on different factors, they either strengthen and become a hurricane or dissipate before they hit land. As Bender et al. present strong evidence that hurricanes in the Atlantic above Category 3 are increasing in frequency, it is crucial to understand the specific characteristics of how this environmental phenomenon changes the nature and frequencies of hurricanes over time.

Additionally, it is important to note the role of warm ocean water in the formation of hurricanes. Hurricanes typically originate near the equator in tropical environments where ocean water is roughly 80 degrees Fahrenheit ~50 meters below the surface (SciJinks). When

discussing how climate change increases the frequency of hurricanes and their severity, warm ocean water is an important factor to consider as a key factor causing reduced storm decay.

A. Defining Reduced Storm Decay

The severity and consequential impacts of hurricanes are worsened by the phenomena of decreased storm decay. Before climate change and the resultant increase in the ocean surface temperatures, storms weakened as they moved over cooler waters and died soon after or before they made landfall. Hurricanes draw their energy from rotating storms fueled by moisture that arises from the ocean waters. Increasingly warmer ocean waters not only decreased the hurricane decaying process but also propelled the storms forward with intensity. This elongated their duration, widened the area of their devastation, and increased the frequency of the onset of hurricanes.

In essence, reduced storm decay allows hurricanes to maintain their intensity inland, rather than losing it due to cooler air entering the storm and sucking out its energy. In the past, hurricane related devastations were restricted to narrow coastal areas. Global warming and the resultant reduced storm decay altered this.

Li and Chakraborty (2020) discuss the role that climate change plays in intensifying the severity of hurricanes, noting that little is known about how climate change influences hurricane decay. Their article proposes a strong argument for how warmer air leads to more intense hurricanes that travel beyond their usual bounds. Their article attempts to shed light on the process and historical progress of reduced storm decay, and the underlying causes for it. To achieve their goal, they analyzed over 50 years of data on North Atlantic landfalling hurricanes. Their findings show: 1) hurricane decay is slowing, and 2) it is directly correlated to sea surface temperature rise.

Although hurricanes are usually considered tropical storms once their intensity drops below 33ms-1, their article considers tropical storms to be hurricanes. In the four hurricanes they observed, “decay past landfall carries a clear signature of their development over the ocean before the landfall. The intensities of the hurricanes that developed over warmer oceans decay at a slower rate” (Li & Chakraborty, 232). Specifically, as the τ decay timescale increases, they find sea surface temperature (SST) goes up as well. The timescale τ is defined as a decay timescale with a unit of hours. Their study found a notable relationship between sea surface temperature rise and the longevity associated with the decay of hurricanes. They also analyzed how this sea surface temperature in action causes slower hurricane decay.

Using computational simulations, these researchers show that warming sea surface temperatures cause more evaporation which, in turn, contributes to the stock of moisture that a hurricane holds as it makes landfall (Li & Chakraborty 230). Since moisture is fuel for these storms, it allows them to travel further inland than they have before. The study further notes, “...in the late 1960s, a typical hurricane lost about 75 percent of its intensity in the first day past landfall, now the corresponding decay is only about 50 percent” (Li & Chakraborty, 230). If climate change is not addressed with urgency, the decrease in the decaying process is likely to get worse.

Li and Chakraborty are not the only researchers to assert a causal link between climate change and hurricane intensification. Their study adds to the chorus of other voices raising awareness about the destructive consequences of decreased storm decay and providing recommendations for hurricane mitigation actions and policies. Some of the notable studies include Kaplan and DeMaria (1995); Tuleya (1994); and Colbert et al (2013).

There are numerous factors that go into this phenomenon that cause such exacerbated hurricane conditions. Detailing each of them provides a deeper understanding of how slow-moving climate change impacts can cause rapid, deadly cyclones in a matter of days. Each of these factors plays a crucial role in the development of reduced storm decay.

B. Warming Sea Surface Temperatures and Their Implications

As sea surface temperatures warm, they intensify wind speeds for tropical storms, making these storms more harmful when they make landfall. The National Oceanic and Atmospheric Administration (NOAA) suggests that this could contribute to an increase in Category 4 and Category 5 hurricanes (Center for Climate and Energy Solutions). Additionally, with more evaporation occurring because of rising temperature, there is a 10-15% increase in precipitation (Knutson et al. 2015). We can see examples of this in recent hurricanes like Hurricane Harvey (2017) where there were over 60 inches of rain in some locations, and Hurricane Florence (2018) where there were over 35 inches of rain in certain select locations. This increase in rainfall intensifies the destruction communities experience by causing devastating floods and water damage to infrastructures ill-prepared for this type of storm (Center for Climate and Energy Solutions).

C. Brown Ocean Effect

Since hurricanes thrive on moisture, some scientists are beginning to research how soil moisture can contribute to the continuation of hurricane intensity in land. This is known as the "brown ocean" effect (Yoo et al. 2020). Hurricane Erin made landfall in the summer of 2007 and showcased hurricane behavior that confused scientists because the storm got stronger as it moved inland, which was extremely unprecedented. This influenced Theresa Andersen and J. Marshall Shepherd of the University of Georgia to start the first study regarding post-landfall strength and

the structure of inland tropical cyclones (NASA). Published in 2013 in the *International Journal of Climatology*, this article details Andersen and Shepherd's use of NASA's data for tropical cyclones that met specific requirements between the years 1979 and 2008. Of 45 hurricanes, 16 had the same intensification process as Hurricane Erin, where the storm maintained their tropical warmth characteristics instead of cooling down and dissipating at a high rate (Andersen and Sheperd 2014). These scientists said that a "brown ocean environment" consists of these three characteristics:

1. The lower level of the atmosphere is acting as a tropical environment with very small variation in temperature;
2. Soils near the storms need to contain ample moisture;
3. Soil moisture evaporation gives off latent heat that measures to at least 70 watts averaged per square meter (Andersen and Sheperd 2013).

Although the brown ocean effect is not always what causes the maintenance of increased strength of a tropical cyclone over land, it is a viable explanation for why these storms continue to worsen over time and shows the deep impact climate change has by increasing the amount of moisture there is in the environment. As these storms work their way higher and higher into the continental United States, Southern states become the example for Northern states that are dealing with hurricanes from other parts of the country.

III. Research Design

A. Analytic Framework

The goal of my research is twofold: to see if sufficient actions are taken by local and state governments to mitigate hurricane damages caused by the increasing frequency and intensity of

hurricanes, and if Northern states have benefited from the experiences of Southern states and made use of the lessons learned and policies adopted in the Southern states, who have endured years of devastating hurricanes.

In order to answer my research question, I perform a comparative case study analysis where I compile data of governmental preparedness pre-landfall and responses post-landfall in four states: Texas, Florida, New Jersey, and New York. For each state I identified two hurricanes within a roughly 40-year time period, possessing minimum Category 3 strength.

B. The States: Similarities and Differences

In order to control for how differences in state characteristics influence government responses to hurricanes, I made sure to include pairs of states that were similar in ways that are relevant to my research questions. Besides the fact that they are regional companions, these states share other characteristics that can play significant roles in how they react to hurricanes.

Table 1 details how the chosen states relate to one another on characteristics that are relevant to this study.

Table 1: Comparison of Florida' and Texas' Relevant Characteristics

Characteristics	Texas	Florida
Coastal Areas	367 miles[1]	770 miles (Gulf Coast Only) 1,350 miles (Total Mileage)[2]
Population	29 million[3]	21.5 million[4]

[1] CRS Report for Congress: This is number represents the coastal area that borders the Gulf Coast in Texas. According to NOAA, the *total* shoreline mileage in Texas is roughly 3,400 miles (NOAA Shoreline Mileage of the United States)
[2] Floridian Nature
[3] U.S. Census Bureau
[4] U.S. Census Bureau

Political Partisanship and Ideology	Republican trifecta since 2003[5] - before then, the governor's office and state senate were both Republican between 1997 and the trifecta in 2003[6]	Republican trifecta since 2011[7] -an independent in the governor's office in 2010 was what broke the Republican trifecta that existed since 1999[8]

Table 2: Comparison of New Jersey's and New York's Relevant Characteristics

Characteristics	New Jersey	New York
Coastal Areas	126 miles[9]	127 miles[10]
Infrastructure	Aged and combined sewage systems[11] Vertical cities[12]	Aged and combined sewage systems[13] Vertical cities[14]
Political Partisanship and Ideology	Democratic trifecta since 2018[15] -before then, both there was a Republican governor between 2010 and 2017 but the Senate and House were still majority Democratic -Additionally, Republican trifecta from 1994-2001[16]	Democratic trifecta since 2019[17] -before then, the Governor's office and House were Democratic between 2007 and 2008 as well as 2011 and 2018[18]

[5] Ballotpedia: A trifecta is when "one political party holds the governorship, a majority in the state senate, and a majority in the state house in a state's government."
[6] Ballotpedia
[7] Ballotpedia
[8] Ballotpedia
[9] State of New Jersey Coastal Management Program
[10] The Coastline of the United States, Volume 550
[11] Politico
[12] New York and New Jersey cities that are relevant to my study are very dense in terms of not only population, but how many buildings are fit into very small areas, which impacts the impacts of flooding and evacuation planning
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[15] Ballotpedia
[16] Ballotpedia
[17] Ballotpedia
[18] Ballotpedia

Firstly, Texas and Florida both are large coastal areas, making them highly vulnerable to hurricanes at their highest intensity when they are still in the ocean. Florida's gulf coast spans over 770 miles, while Texas' gulf coast covers over 367 miles (NOAA Shoreline Mileage). Although there is a large difference in these sizes, it shows how much of each of these states' coastal areas are vulnerable to direct impact. Additionally, Texas and Florida both have quite large populations; as of 2019, Texas had 29 million residents and Florida had 21.48 million residents (U.S. Census Bureau).

Lastly, Florida and Texas have relatively similar conservative political ideologies, and both have Republican trifectas in their state government (i.e., Republican governor and Republican majorities in both chambers of the state legislature) that date back a decade or more, which may or may not influence their reactions to climate change-induced issues due to the politicization of climate change in recent years. For example, in 2015, Florida governor Rick Scott forbade the usage of the term "climate change" in any state agency communications (NPR).

New York and New Jersey, on the other hand, both share progressive ideologies. Both states have recently established Democratic trifectas. Additionally, these two states share similar infrastructural landscapes. New York, particularly New York City and its five boroughs, has infrastructure that is deeply impacted by even the smallest flash flood and heavy rainstorm. This is heavily attributed to the landscape of New York City, which is almost surrounded by water.

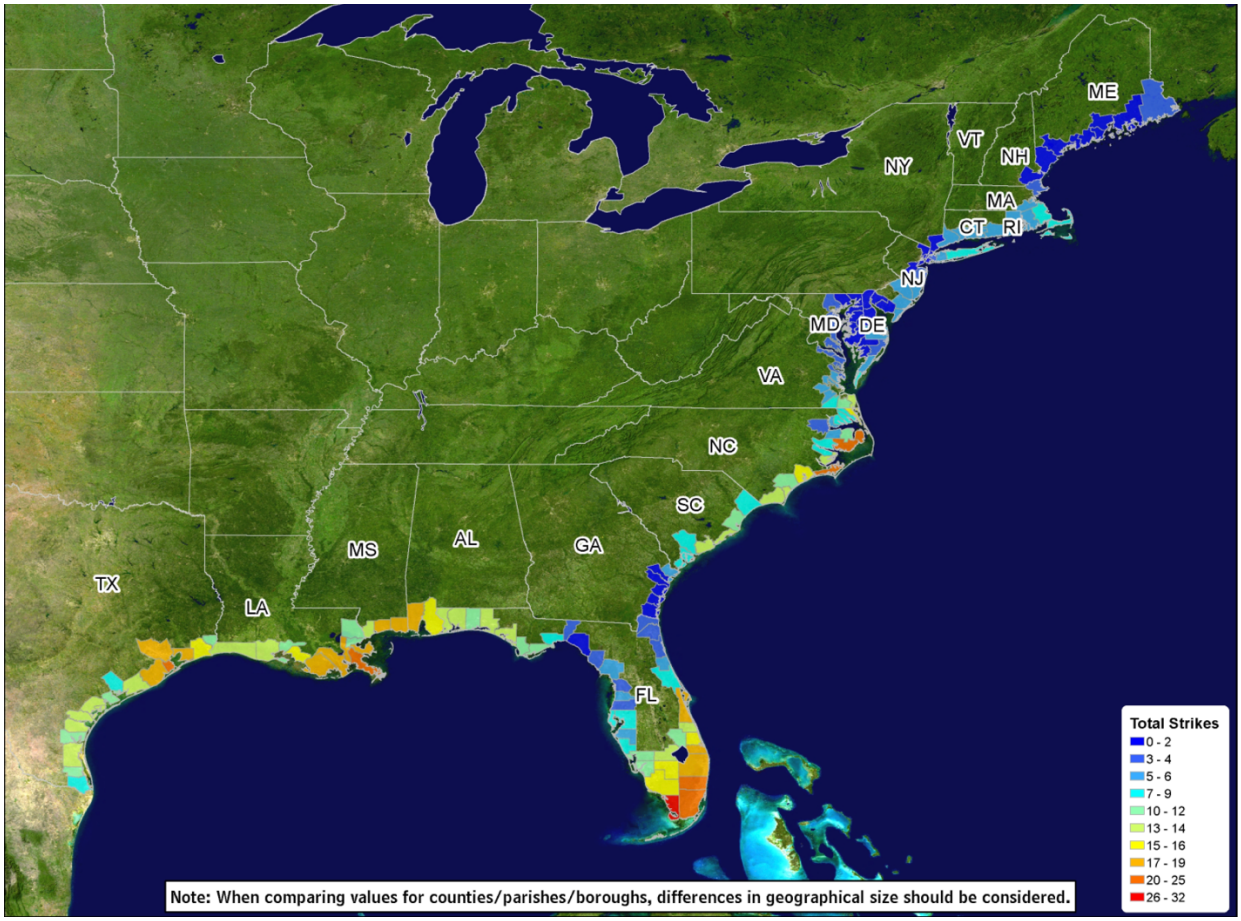
Parts of New Jersey are similar as well, with a coastline that extends over 130 miles (Stockton). This is not only a result of their aged sewage systems or density of buildings, but also by the prevalence of underground public transportation and how it functions in these areas. We are considering the denser parts of New York and New Jersey because both states' populations

heavily reside in dense, urban areas. This will provide a better look at how governments react to hurricanes that impact politically influential constituents congested in relatively confined areas.

C. Defining Lessons Learned

Southern states historically have more experience dealing with hurricanes than Northern states. NOAA has maps that summarize the number of hurricanes that have hit the Gulf Coast and Eastern states between 1900 and 2010. The warmer toned colors represent a high number of hurricanes on the key while the cooler toned colors represent a lower number of hurricanes. The main takeaway from this image is more hurricanes have made landfall in Gulf Coast and other southern states than Northern states.

Figure 1: Total number of hurricane strikes by counties/ parishes/ boroughs, 1900-2010



Source: https://www.nhc.noaa.gov/climo/images/strikes_us.jpg

It is important to understand the differing amounts of hurricanes that hit both regions because it displays how Southern states reactions to hurricanes can serve as a model for Northern states now discussing how to deal with an increase in hurricane frequency. Discussions between local and state officials regarding hurricane preparedness exist in various formats.

In 2005, after Hurricane Katrina ravaged the Gulf Coast, the National Grand Bureau and U.S. Northern Command banded together to create an annual hurricane workshop, where senior federal officials, local officials, military officials, and other external attendees, discuss ways to improve disaster response. Lt. Gen Guy Swan III, U.S. Army North commanding general, commented on the importance of this workshop and highlighted "One of the things we want to avoid is meeting each other for the first time during an emergency event…This helps us build relationships and provides us an opportunity to look at where we can mutually support one another" (U.S. Northern Command). Leaders from the North and the South can use this to corroborate hurricane resiliency plans, serving as an example of exactly *how* Northern states can directly learn lessons from Southern states.

D. Time Period and Hurricane Data

The time period I chose for this study is from 1980-2021. I chose this timespan for a of couple reasons: 1) the period covers a sufficient time span to see how hurricanes and their behaviors evolve over time and 2) it provides ample time to study changes in government responses. As noted earlier, I consider Hurricane Katrina (2005) to be a turning point in hurricane history because the hurricane brought to light that the federal, state, and local governments were ill-prepared to handle a hurricane of that magnitude, influencing significant changes in hurricane policy and mitigation strategies and efforts.

I observed hurricanes in the 25 years before and the 16 years after Hurricane Katrina, up until Hurricane Ida in August 2021. In total, I have compiled qualitative data for two hurricanes per state, totaling six hurricanes. Each of these hurricanes is between a Category 3 and Category 5 intensity on the Saffir-Simpson Hurricane Wind Scale when it made landfall, except for Hurricane Floyd that was a Category 2 storm when it made landfall. It was imperative that I chose hurricanes that had similar intensity levels as to not compare hurricane resiliency efforts between entirely different circumstances. The same two hurricanes are used for New York and New Jersey due to the lack of data on hurricanes that fit the criteria I have noted above. For the state of Texas, the hurricanes used are Alicia (1983) Category 3, and Harvey (2017), Category 4. For Florida, the two hurricanes are Andrew (1992) Category 4 and Irma (2017) Category 5, both category 5. Hurricanes Floyd (1999) Category 2 and Ida (2021) Category 4 are used for New Jersey and New York. Both are Category 4. One hurricane will be before the 2005 benchmark and the other will be after in order to observe how responses to these hurricanes have changed after this political, social, and economic turning point.

Below, I have included track maps of each hurricane I analyze in this study, organized by each state they are categorized with. The colors on the paths of the storms correspond with wind speeds and pressure observations, which were taken at 6-hour intervals (Historical Hurricane Tracks). All maps come from NOAA except for the map of Hurricane Ida because NOAA did not include this storm in the historical hurricane tracks database. I have provided storm categories and color-coded keys to show how wind speeds translate to which category the storm is in throughout each phase of its development.

Definitions to Keep in Mind

Extratropical Storm: A cyclone of any intensity for which the primary energy source is baroclinic, that is, results from the temperatures contracts between warm and cold air masses
Tropical Depression: A tropical cyclone in which maximum sustained surface wind speed (using the U.S. 1-minute average) is 33 kt (38 mph or 62 km/hr) or less
Tropical Storm: A tropical cyclone in which the maximum sustained surface wind speed (using the U.S. 1-minute average) ranges from 34 kt (39 mph or 63 km/hr) to 63 kt (73 mph or 118 km/hr)
Source: https://www.nhc.noaa.gov/aboutgloss.shtml

Texas:

Figure 2: Path of Hurricane Alicia (1983)

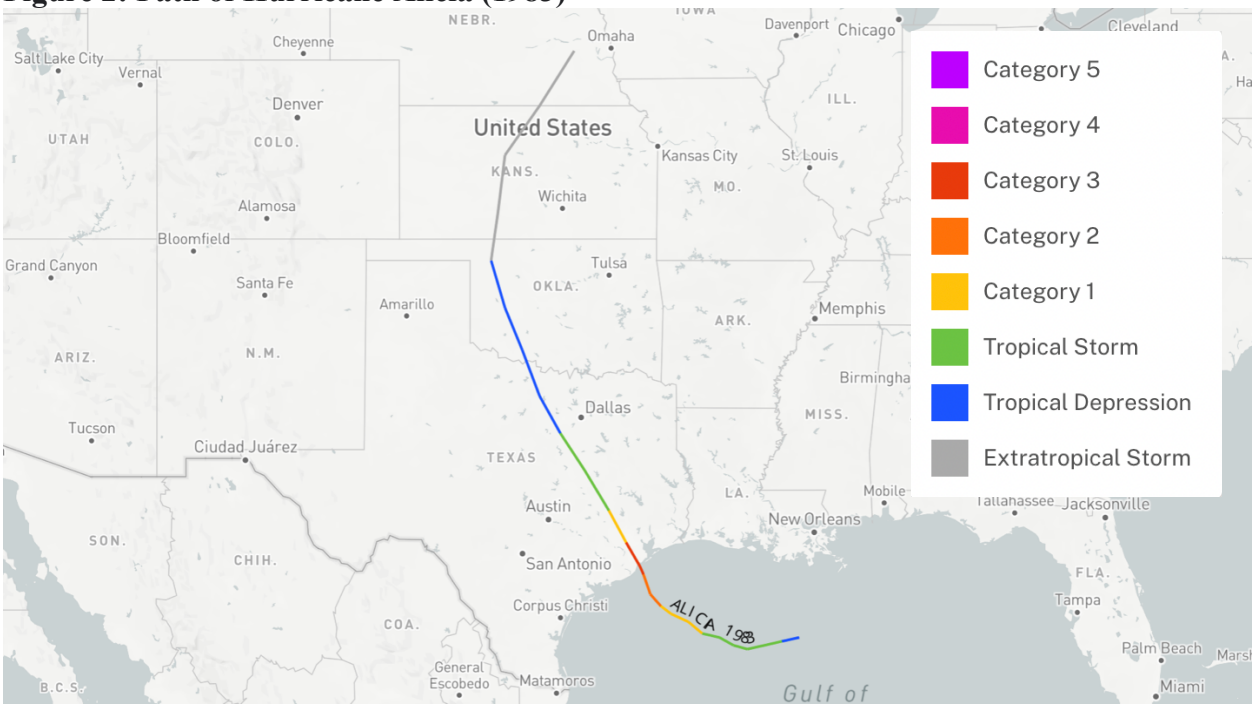
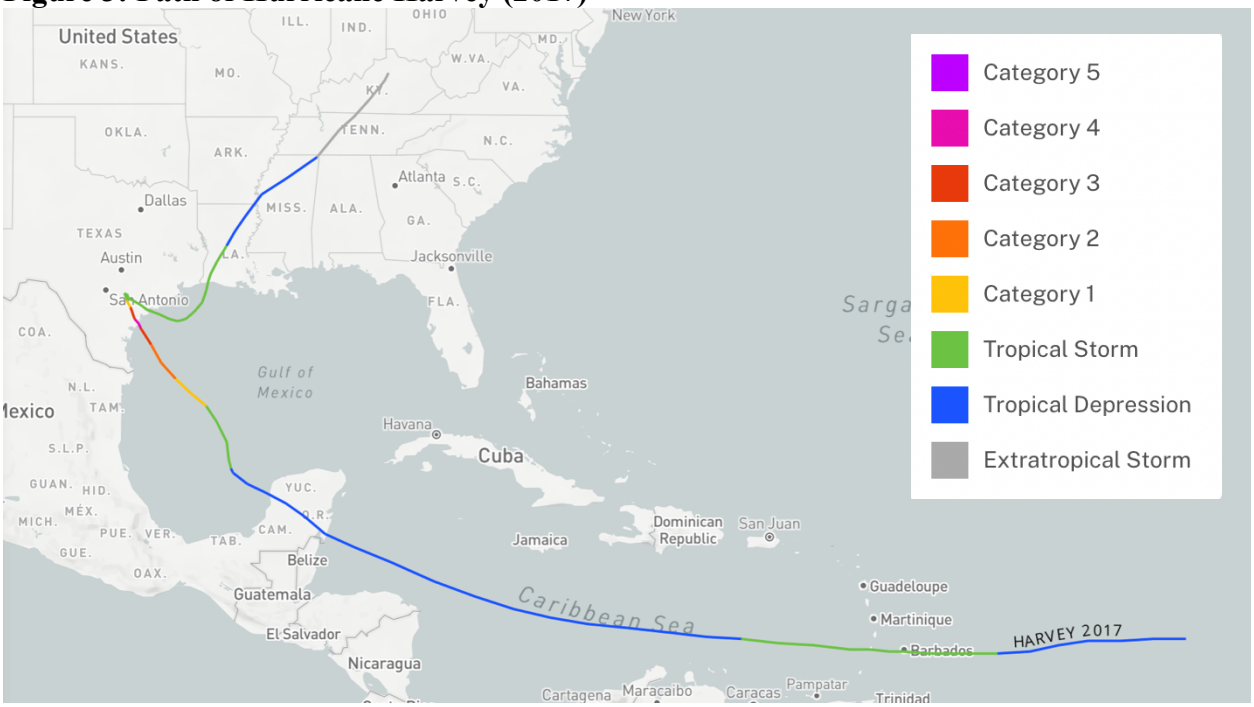


Figure 3: Path of Hurricane Harvey (2017)



Hurricane Alicia was the first hurricane to hit the continental United States since Hurricane Allen in 1980, which was the longest period the U.S. had gone without hurricane landfall at the time. The storm made landfall as a Category 3 storm, mostly impacting Galveston and Houston, Texas. The strength of the storm diminished shortly after landfall and had little to no impact on the Northeast, despite it still possessing tropical properties when it reached Kansas and Oklahoma (Hurricane Alicia Preliminary Report).

Hurricane Harvey was the second costliest hurricane in U.S. history, when considering inflation, behind Hurricane Katrina. The storm almost made landfall as a Category 3 storm, but as it rapidly approached the middle Texas coast, it struck as a Category 4 storm, first devastating areas like Port Aransas, Port Matagorda, Copano Bay, Aransas Bay, San Antonio Bay, and Matagorda Bay. All these areas experienced record-breaking floods. Harvey then moved through Louisiana and Mississippi before losing its tropical properties and becoming an

extratropical over Tennessee and dissipating before it could deeply impact the Northeast. (Blake and Zelinsky 2018).

Florida:

Figure 4: Path of Hurricane Andrew (1992)

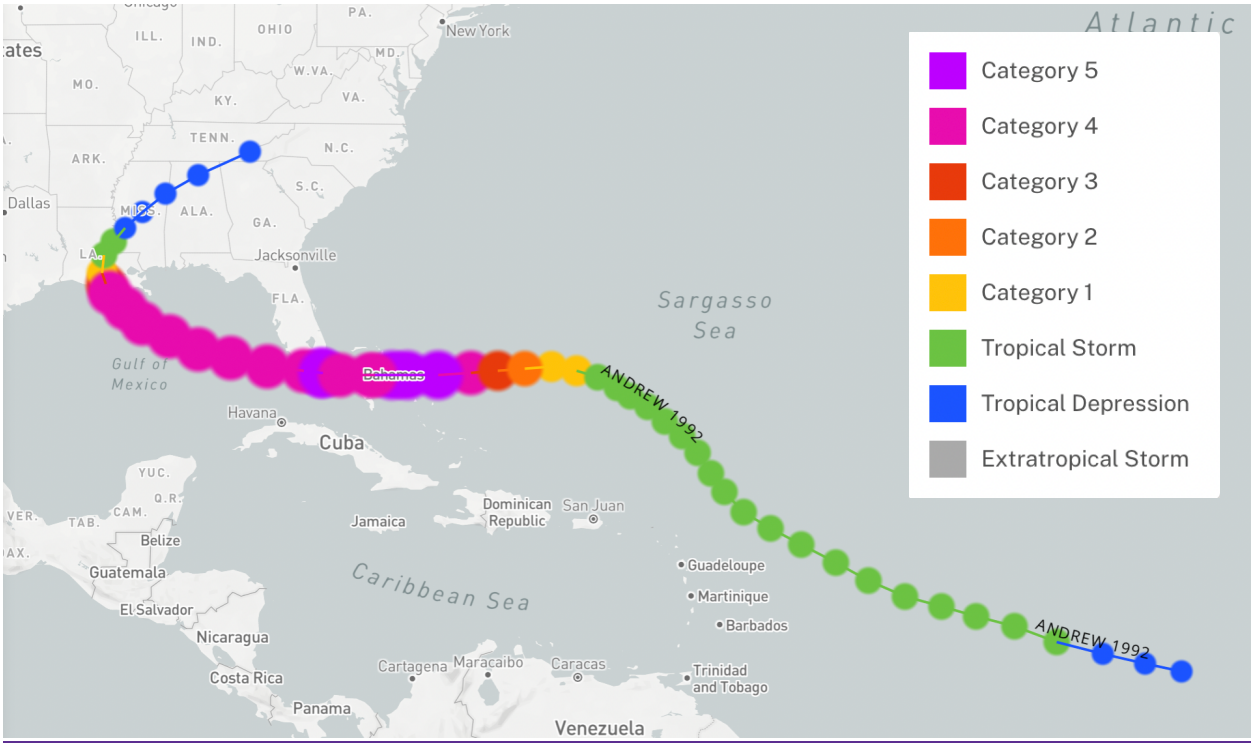
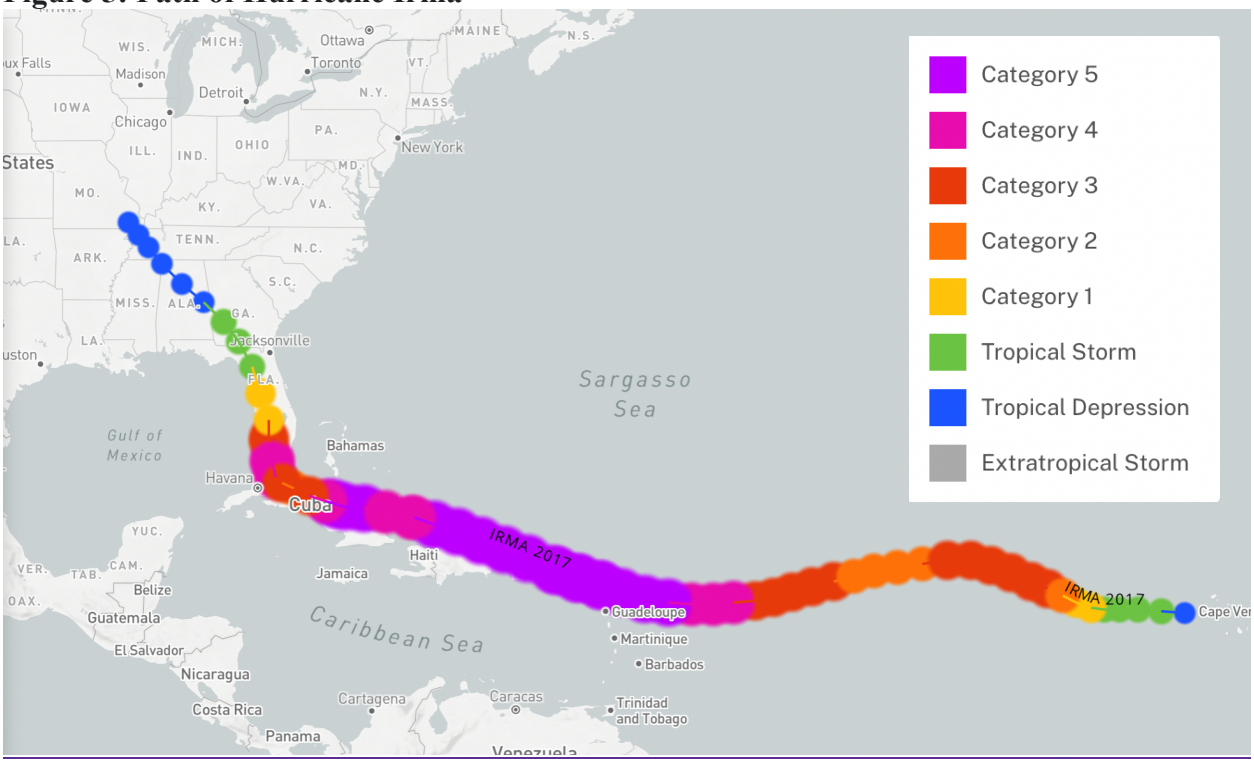


Figure 5: Path of Hurricane Irma



During its time, Hurricane Andrew was the most expensive disaster in U.S. history. After making landfall in the Bahamas and causing unprecedented damage, the storm made landfall in Miami-Dade County as a Category 4 storm and soon after upgraded to a Category 5 storm for a short period of time. Despite its damage, Hurricane Andrew had a curiously low number of fatalities due to the storm. The storm kept the characteristics of an extreme Category storm as it moved through Florida and the Gulf Coast before making landfall again in Louisiana and quickly downgraded to a tropical storm and then tropical depression in south-central Louisiana (Rappaport 1992).

Hurricane Irma made seven landfalls, causing severe damage in not only the United States, but neighboring islands in the Caribbean like the Bahamas, Barbuda, Turks and Caicos, and Cuba. Before making landfall in Cudjoe Key, Florida, the storm had been a Category 4 storm, but shortly restrengthened into a Category 5 storm before landfalling in the Keys. Hurricane Irma was a Category 3 storm when it made its final landfall in Marco Island, Florida.

Following its trend of fluctuating strength, before the storm left Florida, it increasingly fell to a tropical depression as it moved westwards towards Missouri. Florida took the worst of the storm, striking many areas with flooding so severe that left many structures uninhabitable (Cangialosi et al. 2017).

New Jersey and New York:

Figure 6: Path of Hurricane Floyd (1999)

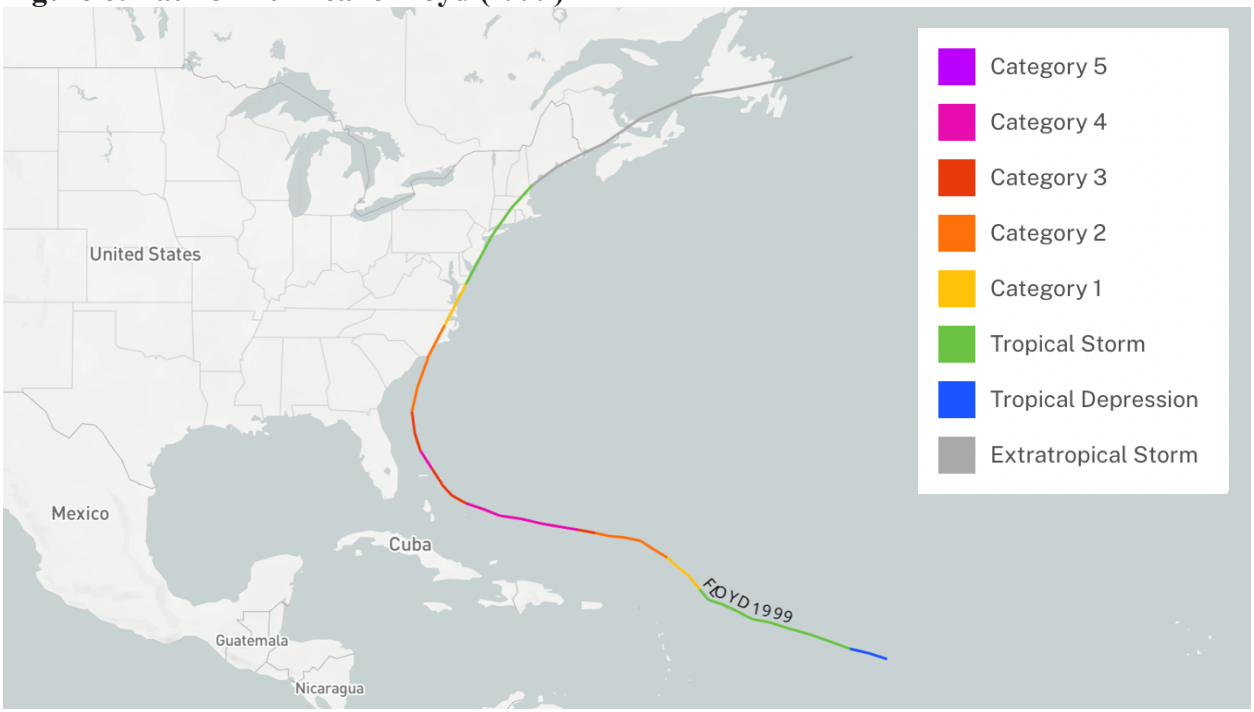


Figure 7: Path of Hurricane Ida (2021)

Source: https://weather.com/storms/hurricane/news/2021-09-02-hurricane-ida-recap-louisiana-south-northeast

Hurricane Floyd is the only storm that was below a Category 3 storm when it made landfall that is analyzed in this study. Due to the lack of storms that matched other criteria I set for this study, I had to overlook one of my criteria to fully complete my research. However, Hurricane Floyd had a significant impact on the Northeast and there is still enough data to making preliminary assertions on how governments react to intense storms in this region (Pasch et al. 1999).

This storm threatened Florida's east coast, but then moved northward to make landfall in Cape Fear, North Carolina as a Category 2 storm. Although the effects of the storm were extreme in North Carolina as the storm travelled through as a Category 2 and then Category 1 storm, the hurricane did notably significant damage even when it was a tropical storm in states like New Jersey and New York. Due to the vulnerability of the urban areas in these two states to flooding,

they felt some of the most detrimental impacts of the storm. After wreaking havoc in the Northeast, the storm became extratropical as it moved past Maine and crossed in Canada and diminished in the Northern Atlantic Ocean (Pasch et al. 1999).

Hurricane Ida formed in the Caribbean Sea and officially became a hurricane right off the coast of Cuba, where it made its first landfall. The storm passed over Cuba and became a Category 3 storm before strengthening to a Category 4 storm and landfalling in Port Fourchon, Louisiana. However, Hurricane Ida's power did not diminish at precedented levels. In fact, the storm continued as a tropical depression over numerous Eastern and Midwestern states before its remnants wreaked havoc on New York, New Jersey, and other Northeastern states. This hurricane is an example of how Gulf Coast hurricane landfalls can still be an issue for Northern states because the flooding that occurred in New Jersey and New York due to the *remains* of the storm were extremely alarming and unexpected (Weather Channel).

IV. Data, Indicators, and Limitations

There are limitations both in the number of states and hurricanes used in this thesis, owing to the lack of readily available data suitable for testing my hypothesis and the difficulty of compiling such data from secondary sources. The two hurricanes from each state are apart by at least 20 years. Ideally, it would be preferable to have a longer time gap between the hurricanes since infrastructural changes and adopting building codes to mitigate the impacts of strong hurricanes take time.

In addition, although I am analyzing local and state government reactions to these storms, some federal actions will also be involved because some local and state actions are only possible because of federal funding. Due to the nature of the bureaucracy of hurricane relief, it is difficult to separate some actions as strictly federal-, state-, or local.

In observing the selected hurricanes, I identified three indicators to assess proactive and reactive government actions: government communication and coordination, emergency supplies, and infrastructural integrity. For each state I used a variety of sources to gauge how each state performed before and after the hurricane on these three dimensions of responsiveness. Because of the nature of the differences between preventative and reactionary measures, each indicator for pre- and post- hurricane is within the same theme but changed slightly to fit the circumstance of the time difference.

These limitations will undoubtedly undermine the explanatory utility of the findings of the investigation. However, the thesis can still shed some preliminary light on the questions the thesis attempts to answer.

A. Response Indicators

Government communications and coordination. The first indicator I observe is government warning time. Before the hurricane, I observed how much time local and state officials like mayors and governors gave to their constituents to evacuate and declare a state of emergency. When harmful hurricanes come towards the coast, declaring a state of emergency in ample time and urging residents to evacuate can save lives. After the hurricane, this indicator appears slightly different. I examine what is done for residents after they are encouraged to leave their homes and their homes are destroyed. What does temporary housing look like? Is there enough of it? Is it accessible and are residents made aware of their resources? These are the questions I sought to answer with this indicator.

Emergency Supplies. The second indicator I analyze is emergency supplies. Before the hurricane, I observed what the supply stockpile looked like and if there was sufficient funding to provide food, water, and first aid kits to people in need after the storm hits. After the hurricane, I

observed if these supplies were effectively distributed to impacted communities. It is not a uniform indicator, considering different hurricanes impact different amounts of people and different areas. However, it is important to get a sense of how necessary supplies are prepared and distributed after these storms.

Infrastructural Integrity. The final indicator is infrastructural integrity. Before the hurricane, I note if cities and states are prepared for hurricane conditions regarding building codes, transportation, etc. Up-to-date building codes and sufficient transportation protection can mean the difference between life and death, so I deem it crucial to see if municipalities and states are taking the necessary steps before hurricanes hit to protect their communities from extreme structural damage. In terms of after the hurricane, I observe if changes to infrastructural integrity are prioritized and expedited once the damage is done in order to analyze if municipalities are learning their lessons to prepare for the next storm to come.

B. Classifying State and Local Responses

To classify how states and municipalities perform on each indicator, I utilized an ordinal scale of low, moderate, and high, representing poor, average and good performance ratings, respectively. I assessed the preparedness and responsiveness of local and state governments against each indicator by assigning low, moderate or high ratings both for before and after hurricane occurrences. Despite their noted limitations, the data are reasonably comparable across time and space. This allows me to compare government preparedness and responsiveness across states.

Some of the main data sources I used are task force reports and storm reports from the National Hurricane Center, the National Oceanic and Atmospheric Association, local

newspapers, and state or local websites that detailed government preparation and reactions to these storms. In addition, news articles from local publishing companies like the New York Times, Miami Herald, Houston Chronicle, etc. aided me in retrieving information that was not necessarily organized and standardized, but still provided reasonably sufficient information to assess government coordination and communication as well as detailed information on emergency supplies availability. For emergency supplies, some information was retrieved from local food banks' websites, Feeding America, and the Red Cross.

Some information on building codes and other indicators of infrastructural integrity come from a platform called Municode, that details building codes, sewage system status, etc. for municipalities all over the United States. This source allowed me to corroborate some of the information I was seeing in news articles and other local sources to ensure this information was translated accurately.

Government Coordination and Communication.

A low score for government communication is assigned to local or state governments that do not give their residents adequate time to evacuate or not declaring a state of emergency when needed. Post-hurricane, this indicator's conditions change given the time conditions of this study. A low score would be earned by inadequate communication to residents on resources, lack of these resources, etc. Communication and coordination are particularly crucial after a hurricane because residents need to be aware of the housing and financial assistance programs to receive assistance after a storm. People rely on their local and state government to tell them what to do and where to go in a time of crisis like this when, in many cases, their lives have been swept away.

A moderate score for pre-hurricane performance in government communication and coordination is assigned if local and state governments took necessary steps to address the impending danger but could have implemented stronger regulations to warn people about the damage to come. For post-hurricane responsiveness, a moderate grade was assigned for government communication and coordination that were notable but failed to meet expectations. For example, a moderate grade for providing housing assistance signifies not having adequate facilities to accommodate all families affected by the storm.

Pre-hurricane high scores for government communication and coordination would mean the state or municipality gave ample warning time for evacuation, widespread declarations of emergency when needed, etc. Lastly, high scores for post-hurricane government communication and coordination were assigned where people are given proper guidance to relief sources, such as housing, and there is enough space to take all those people.

Emergency Supplies.

Low performance pre-hurricane for emergency supplies was assigned where the state or local government failed to prepare the necessary supplies beforehand or failed to ensure the necessary tools are available to deliver these supplies to residents in need. Post-hurricane, a low score would be assigned for state or local governments who failed to prepare the necessary emergency supplies or lacked proper distribution systems. Overall, a low grade signifies inadequate assistance for emergency needs.

For emergency supplies pre-hurricane, a moderate score is given to state or local governments who have organized food, water, and other necessary supplies on hand, but faced obstacles in terms of ensuring effective resource distribution to struggling populations.

For emergency supplies, high scores mean not only having adequate resources ready but also demonstrating efficient distribution systems to reach all citizens in need of emergency assistance. For emergency supplies post-hurricane, a high score signifies meeting expectations both in terms of having adequate emergency supplies and well organized and efficient distribution plan and mechanisms.

Infrastructural Preparedness.

Grading infrastructural integrity, I looked not only at how governments prepared themselves both on a state level and a local level before the hurricane, but how they managed to deal with structural, bureaucratic, and economic issues exposed by the storm. For example, if the state or local government learns that their building codes are not strong enough to handle flooding and wind from a storm, what measures are taken to prevent this from happening in the future? Is a task force created to address the issue or is it left up to a larger body of government that will not treat it as a priority?

For the low classification, attention has been brought to a failure made, but nothing is done about it or there is no clear or straight answer as to what precautions would be taken moving forward.

A pre-hurricane infrastructure preparedness moderate score would be classified as the state taking small measures to prepare their communities for hurricanes, but falling short in some areas including widespread implementation, proper inspection protocol, etc. Lastly, A post-hurricane infrastructure preparedness moderate score is classified as the state taking some action to address weakness in hurricane resilience, but not necessarily addressing the problem fully. A high score in infrastructure preparedness signifies having infrastructure that is already resilient to hurricanes, meets building codes, and passes inspection tests. Lastly, a high score can be earned on infrastructure preparedness after the storm by taking the necessary steps to address all the

systems that failed to protect residents, weather that be an aged sewage system, poor infrastructure for public transportation, etc.

C. Composite Index

Inspired by the methodology that the NOAA's Climate Prediction Center used to calculate a composite index for Accumulated Cyclone Energy, I calculated a composite index to capture a summary of state responses to hurricanes by taking the average of the grades assigned for the three indicators. I assigned 3 for “High”, 2 for “Moderate” and 1 for “Low” and divided the sum by 3. If I have data for only two indicators, I calculated their average based on two indicators. If data is available for only one indicator, I did not calculate a summary score. Scores were calculated separately for each hurricane and each time period.

V. Results

This section contains the summarized findings for my comparative case study analysis. I analyze the meaning of the scores behind the numbers at the end of this section, after detailing the reasoning for each score, state, and hurricane.

Table 3: Texas' Pre- and Post-Hurricane Response Findings

Texas				
State Response	Hurricane Alicia 1983 (Category 3)		Hurricane Harvey 2017 (Category 4)	
	PRE	POST	PRE	POST
Communication and coordination	Low	Moderate	Low	Low
Emergency food, water, and supplies	High	High	High	Low
Infrastructure preparedness	Low	Low	Low	High
Composite Index	1.67	2.0	1.67	1.67

A. Texas: Hurricane Alicia (1983), Category 3

Hurricane Alicia was a category 3 hurricane that lasted from August 14-22, 198, and was the first hurricane to hit the Continental United States since 1980. Galveston and Houston experienced the brunt of this storm. Government preparedness as measured by communication and coordination efficiency was low. Galveston Mayor E. Gus Manuel decided to evacuate low-lying areas, while ignoring the advice of Governor Mark White who suggested 60,000 residents be evacuated in the city (Time Magazine). This proved to be the wrong decision because, once

the mayor decided to extend the evacuation notice, the bridge from Galveston to the mainland was uncrossable and it was too late (Time Magazine).

Emergency supplies was organized in a better way, and I graded the effort as high. Red Cross played a large role in this by dispatching disaster equipment paid for by the federal government before landfall in Texas (Hurricane Alicia-Prediction, Damage, and Recovery Efforts). This made it easier to get these resources to residents after the storm. Lastly, I rated "Infrastructure Preparedness" as low because there was a serious issue in Galveston and Houston with building code non-compliance. Mayor Manuel admitted to Galveston buildings' lack of proper structural components for hurricanes, such as roofs secured with inadequate staples (Hurricane Alicia-Prediction, Damage, and Recovery Efforts). The overall composite score was 1.67, mainly being lifted by the preparedness of food, water, and other emergency supplies.

The post-hurricane response had a high composite score of 2.0 because there was a major improvement in government communication and coordination, moving from a low to moderate score. This was partly due to how FEMA coordinated with local officials to provide displaced residents with temporary housing units (Hurricane Alicia-Prediction, Damage, and Recovery Efforts). However, it was not quite enough to make it high because many residents were in public shelters for a long time before receiving any private temporary residency. Food distribution and infrastructure preparedness kept their scores post hurricane. Red Cross successfully distributed their resources including 400,000 meals (Hurricane Alicia-Prediction, Damage, and Recovery Efforts). For infrastructure preparedness, there was little information on the state or local county websites regarding what was done to fix the weakness of infrastructure in these cities (Committee on Natural Disasters).

B. Texas: Hurricane Harvey (2017), Category 4

Hurricane Harvey was a Category 4 storm that made landfall along the Middle TX Coast. The composite score for government communication and coordination before the hurricane made landfall was 1.67. Government communication and coordination earned a low score due to the governor's reaction to the incoming storm. The evacuation notices from Governor Greg Abbott that came two days before landfall and was declared for 30 counties (ABC News) was considered a "mere suggestion" (Texas Tribune). Because it was not mandatory, people did not take it seriously, evacuated late, and the roads were extremely congested. For emergency supplies, FEMA pre-positioned supplies and personnel in the state before the storm hit with the help of the Texas Division of Emergency management, faith-based organizations, local agencies, non-profits, and the private sector (FEMA). Lastly, for infrastructure preparedness, there were unsuitable building codes and new developments stopped floodplains from serving as a sponge (Spokesman). This earned the state a high score and aided in lifting the entire pre-hurricane assistance score from a 1.0 to the currently held 1.67.

After the hurricane, the overall composite score was also a 1.67. Communication and coordination remained low, as over 40,000 people asked for some form of short-term housing assistance and only 900 families were assisted by the General Land Office (Texas Tribune). There is little information on what ended up happening to those individuals and families. This time, emergency supplies distribution received a low score after the hurricane as opposed to its high score before the hurricane made landfall (Texas Tribune). This is due to volunteer organizations' role in distributing resources, with little to no help from the local or state government (FEMA). Lastly, the infrastructure preparedness for after the hurricane was high, as counties and the city of Houston began making changes to building codes in order to mitigate

flood impacts (Municode). For example, in Harris County, structure elevation was moved from 18 inches off the ground to 36 inches (Jones Carter). A similar change in election was made to buildings in the City of Houston as suggested by the newly formed Redevelopment and Drainage Task Force (Jones Carter).

Table 4: Florida's Pre- and Post-Hurricane Response Findings

Florida				
State Response	Hurricane Andrew 1992 (Category 5)		Hurricane Irma 2017 (Category 5)	
	PRE	POST	PRE	POST
Communication and coordination	Low	Moderate	Moderate	High
Emergency food, water, and supplies	..	Low	High	Moderate
Infrastructure preparedness	Low	High	High	High
Composite Index	1.0	2.0	2.67	2.67

B. Florida: Hurricane Andrew (1992), Category 4

Hurricane Andrew was a Category 4 storm that hit South Florida in 1992, causing an estimated $26 billion in damage. The composite score for pre-hurricane preparedness was 1.0, solely based on information compiled for communication and coordination as well as infrastructure preparedness. The state scored low on the communication and coordination indicator. This was due to the short amount of time Governor Lawton Chiles gave for residents to evacuate their homes (NOAA). The hurricane made landfall on August 24th, and a state of

emergency was declared on August 23rd (NHC). This short notice led to the worst traffic jam seen in Florida's history (NOAA). There was no concrete, uniform information on emergency supplies availability for before the hurricane's landfall. For infrastructure preparedness, the state scored low as well, due to the lack of strong building materials caused by the population boom of the 70s and 80s. As a result, 60% of buildings erected during this time did not pass inspections (Washington Post).

After the hurricane, the overall hurricane preparedness received a composite score of 2.0. Post-hurricane government communication and coordination scored moderately, as relocation checks were provided to residents by the state government (New York Times). However, the temporary housing situation was in adequate with tent communities being prominent rather than secure housing provided by the local and state government (New York Times). Emergency supplies scored low after the storm because there were numerous obstacles to getting people needed food, water, and aid supplies (New York Times). This included blocked roads, bureaucratic issues, and loss of power which all made it difficult to communicate needs. Even staged areas for supplies pick up did not do their necessary job because there was no formal disclosure of how many there were, their locations, etc (New York Times). Lastly, infrastructure preparedness after the storm scored high, as two years after the storm, South Florida released a new building code manual with improved roof standards and other hurricane-resilient infrastructure (ABC News).

C. Florida: Hurricane Irma (2017), Category 5

Hurricane Irma was a Category 5 storm that hit Florida in 2017 and lasted from August 30-September 14. Before the hurricane hit, the state scored an overall composite score of 2.67. Government coordination and communication scored moderately. Governor Rick Scott declared

a state of emergency six days before the hurricane made landfall, allowing ample time for people to evacuate (My Florida House). However, with 54/67 Florida counties ordering evacuations, most of them did not declare mandatory evacuations until the day before the hurricane made landfall (Florida Counties). Preparations for emergency supplies scored high, as Feeding South Florida's food bank (a main provider of food and water), had roughly 2 million pounds of food on hand before the storm hit (Feeding South Florida). Lastly, the state scored high on infrastructure preparedness because of changes made after Hurricane Andrew to strengthen the state's hurricane resilience. This was the first test of the revised building codes and reinforcements.

After the hurricane, the overall composite score for hurricane preparedness was 2.67. Government communication and coordination scored high, as there was a designated temporary housing program in Florida after Irma, and over 27,000 household participated in this program (Naples News). Emergency supplies distribution received a moderate score because there were resources for citizens to utilize, but obstacles to getting to them. An example of this was in Broward County, where they had Points of Distribution (PODS) that were supposed to be a type of "self-service" location where residents could receive the supplies they needed. However, this resource was not erected until five days after landfall and there was no clear information on where they were located, their hours, etc (Sun Sentinel). Lastly, infrastructure preparedness scored high as well because of the concrete plans the state took to ensure they did not experience the detrimental impacts of a storm like Irma again. An example of this was the Rebuild Florida Program, started by the Florida Department of Economic Opportunity, that allotted $100 million dollars towards infrastructural improvements and hardening projects to increase resilience (CBS Miami).

Table 5: New Jersey's Pre- and Post-Hurricane Response Findings

New Jersey				
State Response	Hurricane Floyd 1999 (Category 4)		Hurricane Ida 2021 (Category 4)	
	PRE	POST	PRE	POST
Communication and coordination	Low	Low	Low	Low
Emergency food, water, and supplies	…	…	…	…
Infrastructure preparedness	Low	High	Low	High
Composite Index	1.0	2.0	1.0	2.0

D. Hurricane Floyd (1999), Category 2

Hurricane Floyd was a Category 4 hurricane. Pre-landfall, the state earned a score of 1.0 on the composite scale. This was because of the low scores earned in both government communication and coordination as well as infrastructure preparedness. Governor Chris Christie did not declare a state of emergency until after the hurricane hit (NCDC). However, the storm was strong enough to shut down Amtrak services for days and Transit Lines for almost a week (NCDC). There was not sufficient information on emergency supplies security before the storm. However, New Jersey lacked resilient infrastructure before the storm because the state still had intensive developments on floodplains that are meant to mitigate flooding (New York Times). For example, Bound Brook severely flooded because of increased run-off (New York Times). This was an issue numerous counties and boroughs faced.

After the hurricane, the state scored a 2.0 on the composite scale. Government communication and coordination was low because of the lack of temporary housing provided,

leaving over 1,000 people homeless after the storm hit (New York Times). There is little to no information on what happened to those individuals and families. Changes were made to infrastructure in certain impacted communities in this case were Bound Brook and Manville and these towns created walls and levees to prevent extreme flooding in the future, strengthened their communication/alarm systems for emergencies, and received better equipment to navigate through floodwaters (NJ: True Jersey).

E. Hurricane Ida (2021), Category 4

The pre-landfall the composite index was 1.0, owing to poor performance both on government communication and coordination as well as infrastructure preparedness sides. Governor Phil Murphy failed to declare state of emergency before the hurricane hit (State of New Jersey). Furthermore, the day the storms remnant hits, all 27 counties were urged to stay off the roads. On infrastructure preparedness side poor design of stormwater systems and aged sewage systems contributed for the "Low" rating (Politico).

The post-landfall the composite index was 1.5, due to "Low" rating for government communication and coordination, and "Moderate" rating for infrastructure preparedness. Unmet promises contributed for the "Low" rating for communication and coordination. Tenants registered complaints that they were charged rent for rental units that were damaged by the hurricane, and they were not given timeline when their complaints would be addressed (ABC7NY). Though housing vouchers were provided, it was not enough to meet the demand for them (ABC7NY). The "Moderate" rating for post-landfall infrastructure preparedness was justified by a $1 billion infrastructure bill. The bill provided for any eligible Clean Water State Revolving Fund project and other emerging concern in wastewater (State of New Jersey).

Table 6: New York's Pre- and Post-Hurricane Response Findings

New York				
State Response	Hurricane Floyd 1999 (Category 4)		Hurricane Ida 2021 (Category 4)	
	PRE	POST	PRE	POST
Communication and coordination	Low	…	Low	Moderate
Emergency food, water, and supplies	..	…	…	…
Infrastructure preparedness	Low	…	Low	High
Composite Index	1.0	…	1.0	2.5

F. New York: Hurricane Floyd (1999), Category 2

Hurricane Floyd was a category 4 hurricane. Pre-landfall government preparedness was "low" for both communication and coordination as well as infrastructure preparedness. Communication and coordination was poor because the mayor of New York City never declared a state of emergency; instead, businesses were told to close early and non-emergency city workers were told to leave work slightly early (Independent). Infrastructure preparedness was lacking as well due to a lack of preventative measures for flooding.

E. New York: Hurricane Ida (2021), Category 4

Hurricane Ida was a category 4 hurricane. As with Hurricane Floyd, pre-landfall government preparedness was "low" for both communication and coordination as well as infrastructure preparedness. In terms of communication to the public, the disaster notification system lacked language diversity (Reuters); additionally, by the time the state of emergency was declared, rainfall had already begun (CBS News). However, there were some improvements in

the post-storm response after Hurricane Ida. The temporary government assistance is graded as "moderate" and the changes to infrastructure after the storm are graded as "high". On the government assistance, the city helped some displaced families find temporary housing, although there were some unsafe conditions in some hotels (NY Spectrum News). Additionally, major changes were made to the disaster notification system. The Reuters article notes, "New York City Mayor Bill de Blasio on Friday announced a series of initiatives to tackle extreme weather events, including a more aggressive use of travel bans to get residents off the street ahead of a storm and evacuations to help people living in vulnerable spaces like basement apartments." On the changes to infrastructure, a task force was created to evaluate the response and come up with measures to address the city's shortcomings (Reuters). It is too early to tell whether the changes will have a lasting long-term impact on storm preparedness but there are promising signals from the city's work after the storm.

VI. Analysis

Table 7: Summary of State Responses to Major Hurricanes

Texas				
State Response	Hurricane Alicia 1983 (Category 3)		Hurricane Harvey 2017 (Category 4)	
	PRE	POST	PRE	POST
Communication and coordination	Low	Moderate	Low	Low
Emergency food, water, and supplies	High	High	High	Low
Infrastructure preparedness	Low	Low	Low	High
Composite Index	1.67	2.0	1.67	1.67

Florida				
State Response	Hurricane Andrew 1992 (Category 5)		Hurricane Irma 2017 (Category 5)	
	PRE	POST	PRE	POST
Communication and coordination	Low	Moderate	Moderate	High
Emergency food, water, and supplies	..	Low	High	Moderate
Infrastructure preparedness	Low	High	High	High
Composite Index	1.0	2.0	2.67	2.67

New Jersey				
State Response	Hurricane Floyd 1999 (Category 4)		Hurricane Ida 2021 (Category 4)	
	PRE	POST	PRE	POST
Communication and coordination	Low	Low	Low	Low
Emergency food, water, and supplies	…	…	…	…
Infrastructure preparedness	Low	High	Low	High
Composite Index	1.0	2.0	1.0	2.0

New York				
State Response	Hurricane Floyd 1999 (Category 4)		Hurricane Ida 2021 (Category 4)	
	PRE	POST	PRE	POST
Communication and coordination	Low	…	Low	Moderate
Emergency food, water, and supplies	..	…	…	…
Infrastructure preparedness	Low	…	Low	High
Composite Index	1.0	…	1.0	2.5

A. General Assessment

The study found southern states are better prepared for hurricanes (Table 7). For both Hurricane Alicia (1983) and Hurricane Andrew (2017), Texas scored 1.67 for pre-landfall composite index. Florida scored 1.5 for Andrew (1992) and 2.67 for Irma. As these scores correspond with higher levels of government response, they display the differences between how state and local governments reacted to these storms. Both Texas and Florida performed well in

post-landfall responsiveness. Florida scored slightly better with 2.0 for Andrew and 2.67 for Irma. The corresponding figures for Texas were 2.0 and 1.67, respectively.

On the other hand, than both New Jersey and New York scored 1.0 across the board for all hurricanes for pre-landfall preparedness. Data was not available for post-landfall responsiveness for Hurricane Floyd for New York. For Hurricane Ida New Jersey scored 2.0. The corresponding figure for New York was 2.5.

B. Reactionary Measures

One of the strongest generalizations that can be made was that states are better at responding to hurricanes rather than preparing for them. For every hurricane, the composite score was higher post-hurricane than it was pre-hurricane. This represents a higher number of reactionary actions, rather than preventative. It is especially crucial to note this trend for Southern states, who usually experience multiple hurricanes in one season, do not seem to improve on their hurricane preparedness in terms of ensuring there are more preventative measures over time.

C. Comparisons of Northern and Southern State Reactions

My corollary hypothesis seems to be disproven according to the available data points. Overall, the Northern states performed poorly compared to the two Southern states. Two factors make the finding concerning. Northern states have relatively more time after hurricane landfall and this should help them prepare better, but this does not show in the study results. Second, the two Northern states have significantly higher GDP per capita. New York has the highest at $75,131 followed by New Jersey at $71,467 (BEA). By comparison, Florida is the lowest with $51,518. Texas has $63,588. One would expect states with relatively higher income levels will have the resources necessary to be more responsive, but this is not what the results show. One

possible explanation is that adopting for hurricanes takes a long period of time. Northern states where hurricanes are a relatively new phenomenon may need more time to adopt.

When comparing the composite scores of pre- and post-hurricane reactions for each storm, Southern states hold higher scores than Northern states for all but Hurricane Harvey (2017). Since Southern states experience hurricanes more often, this trend could be attributed to that, but there are also many ways for states in the North to learn from the mistakes of the Southern states. However, from what is presented here, that does not seem to be the case.

It is crucial to note that lack of data could contribute to this stark difference between reactions from both regions. For example, there was a strong lack of data for New York's Floyd response. This could be for many reasons, one of them being how long ago the storm was or a weak system of compiling this data over time. Regardless, this observation still holds some truth because of the long periods of time between each hurricane and the number of hurricanes Southern states experience each year.

D. New Jersey's Floyd Response: Government Communication and Coordination

Because of the difference in infrastructure between the Northern states and Southern states, it is difficult to simply assert that low scores in the North mean that Northern states are not taking the issues seriously. When there is a dense population of people in a small area, it can be difficult to prepare the population structurally for what is going to come. However, I think it is important to note how New Jersey's Floyd response can expose an issue in hurricane preparedness for this state.

If cities like Jersey City or Newark have dense populations and weak infrastructure, a strong system for evacuation or adequate warning/ emergency statements is crucial so that people can make sure they have enough time to make the decision that is right for them. As is

seen in the government communication and coordination section of the table for Floyd and Ida, the state scores low across the board. This not only means that there has not been an adequate response for this indicator, but also shows that the state had not made improvements in this indicator for over 22 years. Even with the lack of data for New York, a similar trend is present between Hurricane Floyd and Hurricane Ida.

VII. Conclusion

The primary hypothesis the thesis tested was: The more that in-land communities that are impacted by destructive hurricanes, the more local, state, and federal governments react and take proactive and reactive government assistance and preventative actions, drawing from past experiences. To test the hypothesis, the thesis utilized two northern states (New York and New Jersey) and two southern states (Texas and Florida) and analyzed their hurricane preparedness and responsiveness over a 41-year span, using three indicators: (1) government communication and coordination; (2) immediate hurricane relief assistance for necessities such as food, water and other essentials, and (3) infrastructure stability to mitigate hurricane damages.

The findings of the study for Texas and Florida seem to reject the primary hypothesis. The two states have a long history of hurricanes and despite this, they continue to be ill-prepared for what impact hurricanes can have on their community. This is shown through the higher scores in reactionary measures for the hurricanes and lower scores in the preventative measures.

A corollary hypothesis the thesis tested was if northern states benefited from lessons learned in the South to mitigate the devastations of hurricanes and adopt their lifestyles as well as business and government practices as the new normal becomes normal. The findings of the study rejected the hypothesis.

It must be stressed that the paucity of readily available data and the difficulty of gathering data from disparate sources restricted the scope of the study and limited the utility of the outcome of the study. However, the study can serve as preliminary and encourage more in-depth investigation.

VIII. Further Research

A key further research area for investigation includes budget availability. Budgets and funding can contribute to differences in how states or municipalities react to certain storms. Northern states are richer in terms of GDP per capita, but do they allocate adequate resources for hurricanes is a key question to investigate. Another question is do Southern states receive more federal hurricane relief funding to address infrastructure integrity issues in comparison to a state like New York, that experiences hurricanes much less than the Gulf Coast states. This is important not only for infrastructure preparedness and responsiveness, but also for immediate hurricane relief efforts both before and after landfall.

Population density is also an important factor to evaluate government coordination pre- and post-landfall. As noted above, New Jersey/New York have very different landscapes from Texas/Florida. The former has most of their population living in vertical cities, where everyone is restricted to a smaller environment whereas the latter is more spaced out. It is extremely difficult to evacuate a city with so many people tightly packed together than it is for a city with a more widespread population. Even in the case of sprawled out populations, like seen with Florida's traffic jam, problems can still arise in preparedness.

From a policy making perspective, political orientation of government administrations in office as it relates to climate change should be investigated, as it may have notable influence in government preparedness and responsiveness. Another important area for future study is

coordination between federal, state, and local governments. Politics may have a role in coordination and response to hurricanes if federal, state, and local governments are from different parties.

Another factor to consider in this study is how the frequency of hurricanes impacts the results. As noted in the Data and Indicators section, Southern states experience more hurricanes than Northern states. It would be interesting to see how the fluctuation in frequency and how those changes over a longer period would influence the results of this study if it were replicated. In tandem, it would also be crucial to note how differences in category can influence what we view as "extreme damage" for a state. For example, in my study I note that New York's and New Jersey's densely populated areas also have aged sewage systems and building structures that allow more flooding to occur. If this is the case, would a lower category storm have a similar impact in these areas to that of a high category storm in Southern states with more sprawl?

Lastly, one of the key findings of this study is that states tend to perform better post-hurricane than they do pre-hurricane for many indicators. Future research could further analyze how some indicators may be prioritized in for different storms that different points in those storms. For example, I found that temporary housing was an area were many states and municipalities failed to provide for their residents. However, it is important to note that this does not mean the area completely ignored the need for temporary housing but may have prioritized resources for other more time-sensitive indicators.

When pursuing a research topic like that of this study, there are many nuances to keep in mind in order to note attribute lack of action on certain issues as pure abandonment or neglect. There is a plethora of factors that go into how states prepare and react to hurricanes. However, as climate change worsens and storm decay slows, it is crucial that states that are most vulnerable to

these impacts have curated plans to confront these issues over time. This study can shine preliminary light on the importance of paying attention to an issue that will only worsen as years pass, making it serve as a warning to states to act now or suffer the consequences later.

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