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Studying the Effects of Sea Level Rise on Coastal Flooding in Southern New Jersey

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Introduction

Climate change's far-reaching consequences disproportionately affect certain geographical locations, increasing the possibility for a greater frequency of coastal flooding events occurring in areas along the Eastern Seaboard. With increased global temperatures and continued sea level rise, coastal vulnerability is a serious concern among policymakers and residents alike. Negative impacts to real estate, tourism, and hospitality industries, as well as the maritime sector, threaten economic sustainability in these regions, and adversely affect coastal communities as a whole. The damage to critical ecosystems from continued storm effects decreases resiliency and increases the probability for future flooding events to have greater impact. This investigation into the relationships between sea level rise and coastal flooding event frequency and severity highlights the need for further mitigation and adaptation practices.

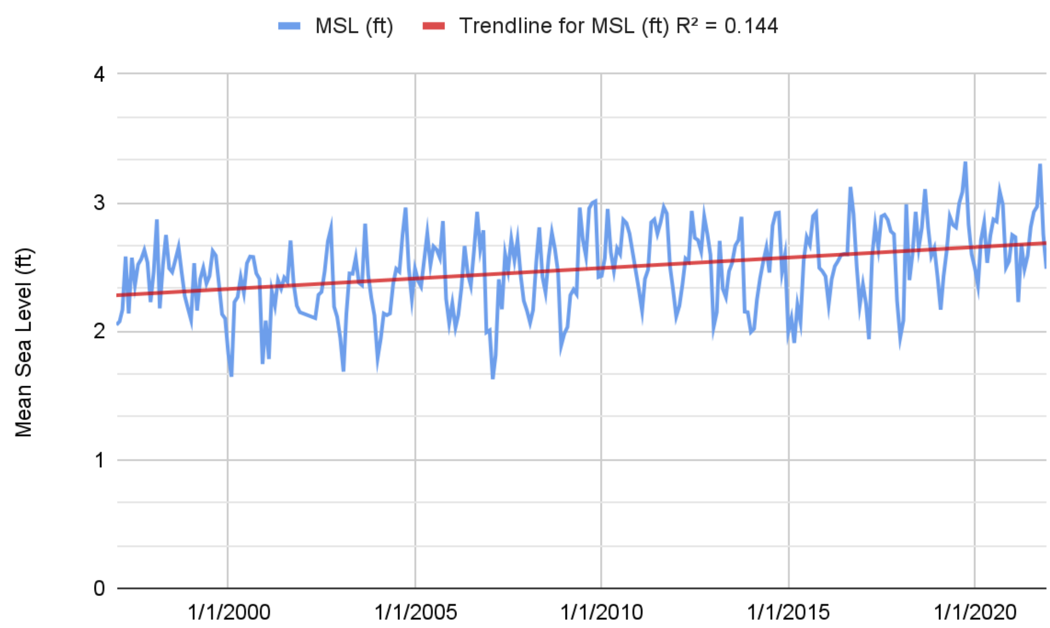
Sea Level Rise

Global sea level rise resulting from climate change has the potential for serious physical impacts on the environment, as well as costly economic impacts from remediation efforts and the loss of economic activity due to inundation. The majority of direct physical impacts from sea level rise include beach erosion, delta inundation, flooding, increases in salinity, and the loss of marshes and wetlands (Neumann et al., 2000). Other possible physical impacts include changes of streamflow into coastal waters, variations in the abundance of fish and shellfish (Najjar et al., 2000), modifications to shorelines or tidal flats, the distribution of coastal wetlands, and alterations in estuarine habitats (Cooper et al., 2008). Many of these impacts also have compounding effects that can worsen local vulnerability to flooding due to the destruction of natural habitats that function to protect coastal regions. Issues associated with inland storms such as increased precipitation and riverine flooding can also worsen the effects of coastal flooding and intensify storm event damage to estuaries, vital ecosystems where freshwater systems meet ocean water, and wetlands (Wu et al., 2002).

Sea level rise also increases the severity of storm aftermath, particularly in the amount of coastal flooding and inundation that occurs. Rising seas affect storm surge levels by moving greater amounts of water inland, thereby threatening coastal infrastructure. Modest estimates of sea level rise have the potential to multiply flood frequencies in certain coastal areas by a factor of 100, or in some areas by as much as 1,000 (IPCC, 2013). Along the northeastern coast of the United States, sea level rise has been observed to be even more accelerated at a rate of roughly three to four times greater than global averages (Sallenger et al., 2012). Moreover, dynamic sea level along the northeast region has been observed to be particularly sensitive to increases in greenhouse gas concentration (Jianjun et al., 2009). These regional concerns of flooding and high storm surges are further complicated by the fact that many coastal regions in New Jersey, particularly the barrier islands, are not much higher than mean sea levels.

One tool used to record the history of sea level off the coast of southern New Jersey are tidal gauges. Tidal gauges measure changes in sea level relative to a specific height reference, or datum. These gauges take into consideration global thermal expansion of the ocean and glacial melting, as well as regional vertical land movements as a result of tectonic activity (Najjar et al., 2000). The National Oceanic and Atmospheric Administration maintains an oceanic monitoring station in Atlantic City, New Jersey, with a tidal gauge that observes and records water levels every six minutes. In Figure 1, these frequent measurements are averaged together to create monthly means that are plotted from the years 1996-2020. The trendline for mean sea level (MSL) rise suggests an overall increase in sea level during this time, according to measurements obtained by the Atlantic City tidal gauge. This trend has been observed in various research, and has proven to be exacerbated in the northeast coastal regions of the United States (Stanley et al., 2004; IPCC, 2007; Jianjun et al., 2009; Sallenger et al., 2012).

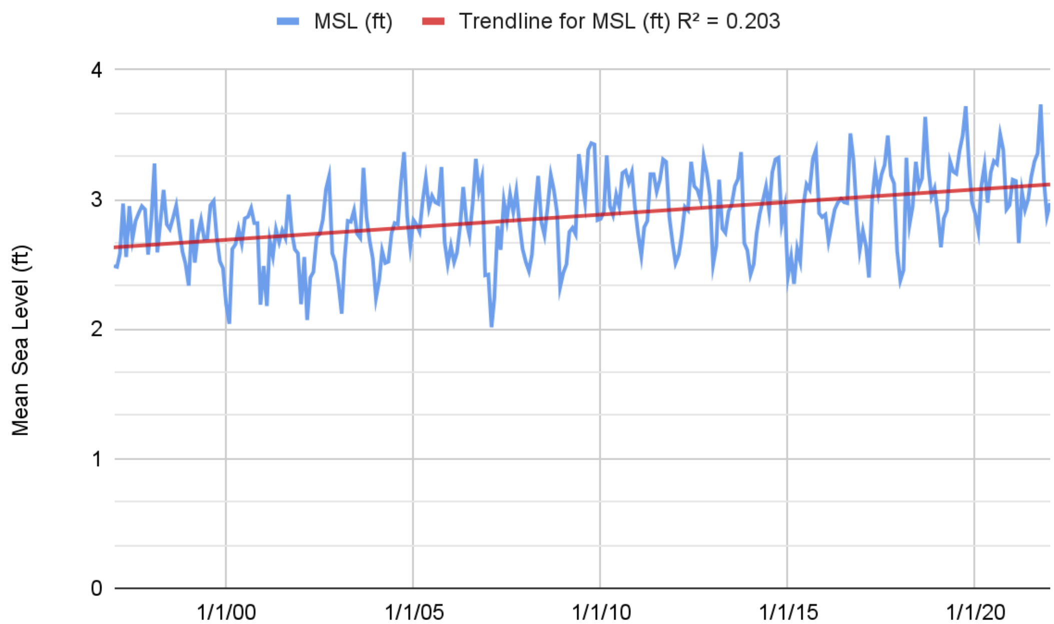
Figure 1: Monthly Mean Sea Level, Atlantic City New Jersey (1996-2020)



Source: NOAA, Tides & Currents Station #853470

Figure 2 shows sea level data from another tidal gauge located on the bay side of the southernmost point of Cape May, New Jersey. Similar to Figure 1, frequent measurements are averaged together in Figure 2 to create monthly means that are plotted from the years 1997-2021. The trendline for mean sea level rise based on measurements from the Cape May tidal gauge also suggests an overall increase in sea level during this time period.

Figure 2: Monthly Mean Sea Level, Cape May New Jersey (1997-2021)



Source: NOAA, Tides & Currents Station #8536110

Coastal Flooding

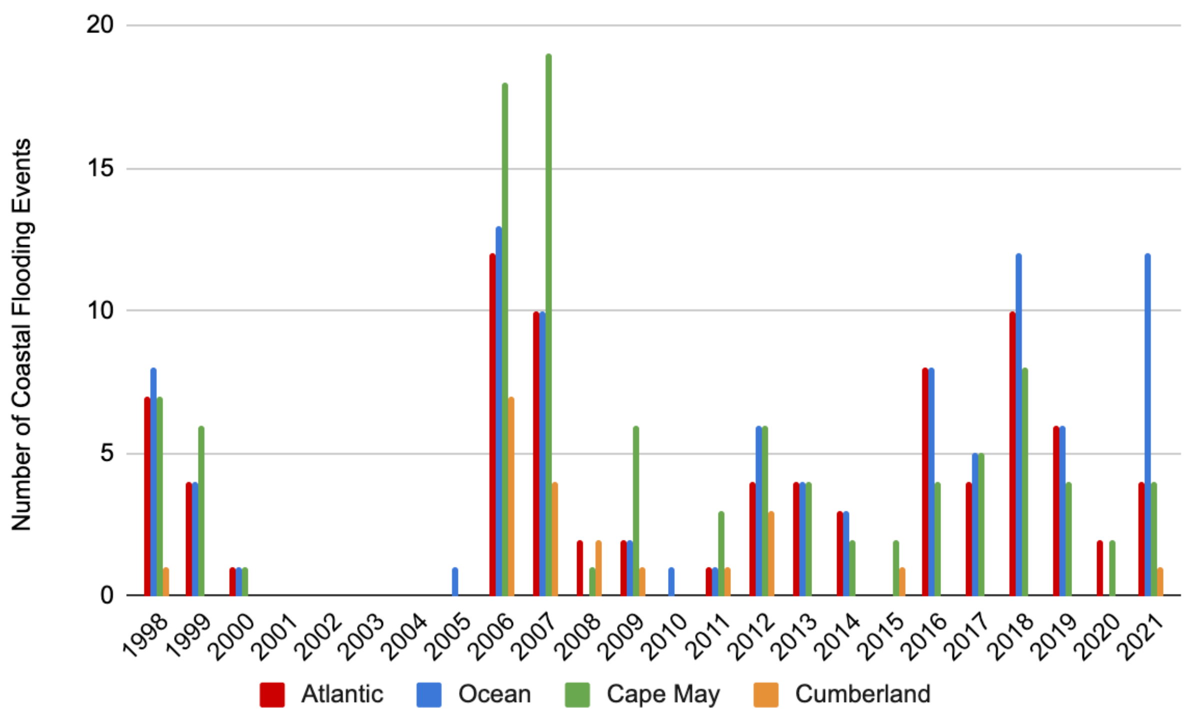
As mean sea levels rise, the potential for coastal flooding events increases, threatening coastal infrastructure. The extent of damage as a result of storm-related coastal flooding events depends on tidal and wave effects, particularly storm event duration and onshore wind speeds (Kirshen et al., 2008). Sea level rise increases the height of storm surges, which are predicted to significantly increase along the entire eastern seaboard by 2050 (Kirshen et al., 2008). In New Jersey, the current 100-year flood water level will be exceeded three to four times more frequently as a result of a 0.61 meter rise in sea level (Cooper et al., 2008). The current 100-year flood water level would otherwise have a 1% chance of being exceeded in a given year. With this 0.61 meter rise, approximately 9% of the state's total land area would be impacted by episodic flooding (Cooper et al., 2008). This issue is compounded in areas with inland waterways, where riverine flooding is also a concern in storm events and can amplify the effects of coastal flooding caused by surges (Wu et al., 2002).

Another type of hazardous coastal flooding is tidal flooding, often referred to as nuisance flooding or sunny day flooding. This type of flooding occurs in the absence of storm events, and results from exceptionally high tides. Low-lying areas such as roadways are inundated with relatively slow-moving oceanic water via piping systems. This causes transportation disruption and infrastructure strains. These events are often less damaging overall than large storm events, but are occurring at an increasingly greater frequency (NOAA, 2014). Sea level rise contributes to the increasing frequency of nuisance flooding, as the acceleration of sea level rise reduces the gap between regular high tides and flooding thresholds (Li et al., 2021). This acceleration is more pronounced along the Eastern Seaboard, where mean sea level has risen faster than in other parts of the country, (Pethick, 2001; Li et al., 2021). Nuisance flooding may not result in extensive property damage or threaten public safety, but it adds strain to critical infrastructure such as sewage systems and roadways (Jacobs et al., 2018). This can lead to loss of income or worsened public health risks (Moftakhari et al., 2018). These issues are magnified in urban areas and are a large concern for coastal communities in southern New Jersey, all of which are examined further

Event Frequency

Human interaction with the global environment has exacerbated the negative effects of climate change. The frequency of flooding events, storms, and hurricanes has increased as a result of climate change, with more than 90% of observed flood days occurring due to anthropogenic contributions to climate change (Strauss et al., 2016). In this most recent decade, there is greater than a 95% probability that more than half of observed flood days would not have occurred without the human contribution to global sea level increases (Strauss et al., 2016). The impacts of climate change occurring on a global scale are also observable along the eastern Seaboard. Since 1980, New Jersey coastal storm events have increased in both frequency and intensity (Psuty and Ofiara, 2002). Figure 3 shows the number of storm-related coastal flooding events recorded for each year from 1998-2021 in Atlantic, Ocean, Cape May, and Cumberland counties. There was a high frequency of storms in the years 2006-2007, particularly in Cape May County. During this time frame, the only large-scale storms that occurred were a nor'easter and Hurricane Ernesto. Most of these events were smaller storms with high amounts of precipitation lasting multiple days, and nearly all of the smaller-scale events in these two years were caused or worsened by tidal flooding.

Figure 3: Coastal Flooding Event Frequency (1998-2021)



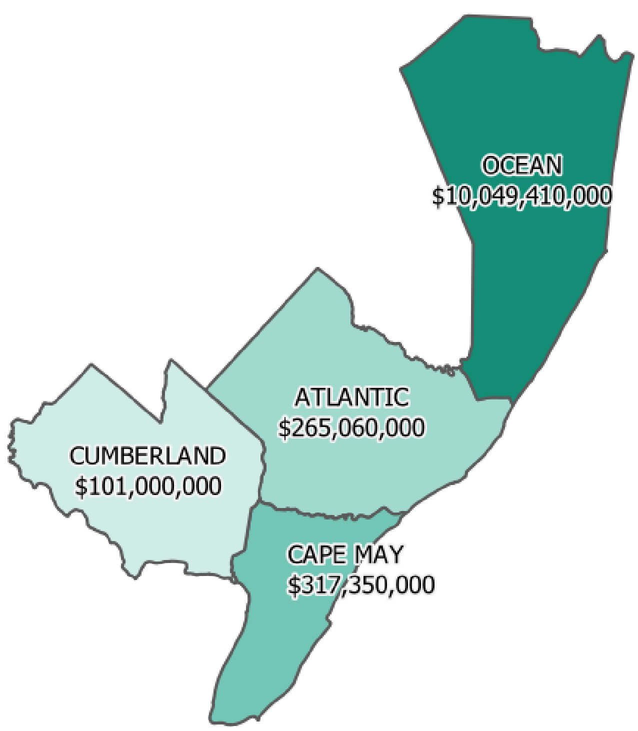
Source: NOAA, Storm Events Database

Property Damage & Economic Vulnerability

Historically, coastal ecosystems have been a desirable place for settlement due to resource prevalence, logistical options for trade and transport, and recreation (Neumann et al., 2000). Many of the most densely populated cities globally are located in coastal zones with increasingly prevalent coastal hazards. In southern New Jersey, coastal communities are vulnerable to risks associated with increased storm event frequency in terms of property damage, loss of economic activity, and mitigation costs. Increased sea level rise and regional subsidence alone will be responsible for the permanent inundation of some areas, resulting in land loss and economic disruption.

Figure 4 shows the total cost of property damage associated with coastal flooding events for each year from 1998-2021 in Atlantic, Ocean, Cape May, and Cumberland counties.

Figure 4: Property Damage Associated with Coastal Flooding Events (1998-2021)



Source: NOAA Storm Events Database

There is also the possibility for ecosystem damage from sea level rise and flooding events, particularly to coastal wetlands, bays, and estuaries. Coastal wetlands are vulnerable to the effects of sea level rise and coastal flooding, and their damage could result in other compounded ecological implications (Nicholls et al., 1999; McLean et al., 2001; Cooper et al., 2008). Storm surges from Hurricane Sandy alone resulted in severe long-term degradation of coastal wetlands in New Jersey, and the loss of ecosystem services from this damage was quantified monetarily at nearly $4.5 billion (Hauser et al., 2015). These ecosystems in New Jersey provide vital habitats for migrating shorebirds, horseshoe crabs, and many other species of birds, fish, and shellfish. The threat of sea level rise may cause coastal wetlands to move further inland, eroding current coastal saline marshes, as well as changing brackish wetlands to saline marshes (Najjar et al., 2000; Cooper et al., 2008). Oceanic waters encroaching inland also may cause significant negative impacts on drinking water quality, with some estimates of impact becoming apparent within the 21st century (Hull and Titus, 1986; Najjar et al., 2000).

Damage to Critical Infrastructure

Sea level rise and the increased frequency of coastal flooding also threatens various critical infrastructure locations in coastal regions. Transportation delays resulting from roadway inundation alone will continue to increase throughout the 21st century (Kirshen et al., 2004), and is especially concerning for emergency response services. Energy transmission is also vulnerable to certain storm events, where high winds, heavy precipitation, and flooding can damage power lines and flood equipment. Repeated occurrences of flooding on roadways strains sewage infrastructure through the management of storm runoff and tidal flooding, and there is often a potential for sewage overflow as a result of storm surge flooding. During Hurricane Sandy, New Jersey and New York experienced roughly 3.45 billion gallons of untreated raw sewage overflow due to damage caused by coastal flooding (Kenward et al., 2013). The flooding of known contaminated sites is also a concern, particularly in those located in coastal communities. In Atlantic City alone, a 100-year flood will submerge 18 Superfund sites, locations designated by the U.S. Environmental Protection Agency as hazardous and needing long-term cleanup, and nearly 150 known contaminated sites (Lathrop, 2017). Incidents like these are detrimental to public health and the environment and are extremely costly to remediate.

Mitigation and Adaptation

With increasing sea levels exacerbated regionally on the Eastern Seaboard and projected increases in tidal flooding occurrences (Sweet et al., 2020), coastal communities in southern New Jersey are at risk. These threats highlight the importance of concentrated effort toward climate action by regional and local policymakers and emergency planners. Practical adaptation strategies for extreme weather events include the formation of contingency plans for public transportation (Clark et al., 1998), increased wetlands preservation for flooding mitigation purposes (Kirshen et al., 2008), increased land use regulations (Kirshen et al., 2004), greater coastal zone management (Burger et al., 2017), and increased resiliency of water management facilities (Kirshen et al., 2004; Kenward et al., 2013). There must also be increased education on flooding risks, as well as perceptions between sea level rise, severe storms, climate change, and ecological barriers. Polling in New Jersey environmental justice communities has shown a lack of understanding in the role of ecological structures and their functions, particularly in protecting coastal communities (Burger et al., 2017). Greater public awareness of these issues is essential in creating meaningful policy solutions to protect coastal communities into the future.

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