Sea Level Rise Projection for 2100: Florida

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Abstract

Since 1900, global sea levels have risen between roughly 13 and 20 centimeters, and most research suggests that sea levels will continue to rise, but for how long and at rate is unknown. As a result, many sea level rise projections have been constructed both on local and global scales in order to provide insight into what might occur in the coming decades and centuries. This particular projection takes a more elementary approach without the involvement of a computer-based model and considers the historical contribution of primary sea level rise factors on the state of Florida in the year 2100, and provides three unique scenarios: "Best-Case" (1 m), "Median-Case" (3 m), and "Worst-Case" (5 m). In each of the three cases, the entirety of the Florida coastline will likely flood and face further consequences from tropical storm surges. The effects of the "Median-Case" and "Worst-Case" scenarios will obviously cause more damage as water penetrates further inland, especially in the southern third of the state and the portion of the Intracoastal Waterway located in Florida.

Introduction

In the recent past, global sea levels have increased at staggering rates and have begun to wreak havoc across the globe due to more damaging storm surges, and sparked uncertainty throughout the science community about the future of sea levels and their effects on civilization. This sea level projection focuses on the state of Florida until the year 2100, and takes into account both the surface and deepwater thermal expansion of seawater and the melting of polar ice sheets and other glaciers, which have been the primary contributors to sea level rise. Sea level rise projections exist to provide insight into future coastal infrastructure, possible socioeconomic effects, and possible evacuation procedures.

Problem Statement

A projection of future sea levels along the Florida coastline provides insight into the future geography of the state, allowing officials to begin planning of coastal infrastructure, estimating economic loss, and considering evacuation procedures.

Effects of Melting Polar Regions on Sea Level Rise

For at least the past century, average global sea levels have been rising at an alarming rate. Due entirely to global climate change, sea levels have risen due to polar ice sheet melting and the expansion of water due to heat. Therefore, if global temperatures continue to rise, sea levels will follow a similar trend as well.

As mentioned previously, elevated sea levels are driven by climate change, which is suspected to continue warming for decades and possibly even centuries, visible in **Figure 1**.

Projected Global Temperature Increase (°C)

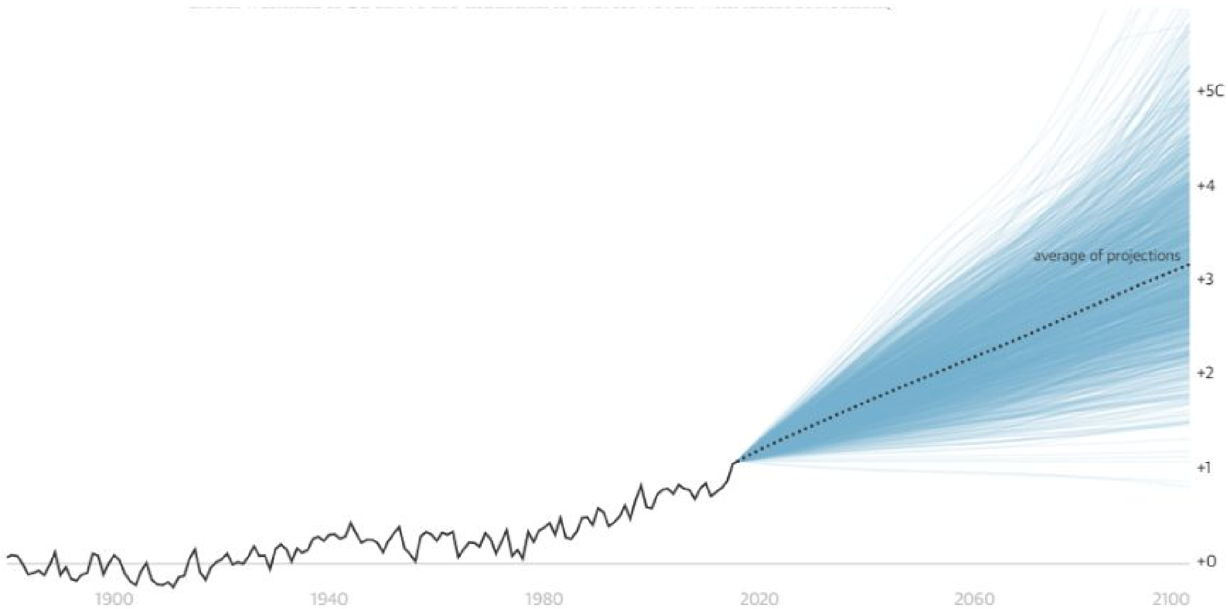

Figure 1. Projected Global Temperature Increase (°C)
Source: Holder, Kommenda, and Watts, 2017.

Rising sea levels can be attributed entirely to climate change, as increased global air temperatures have lead to increased sea surface temperatures and glacial melt, which are both primary contributors to sea level rise. Factors that influence climate change include changes in atmospheric composition (primarily the introduction of greenhouse gases), solar luminosity, products of volcanic eruptions, and orbital changes (Hunt and Scott, 2013). Rising global temperatures cause polar ice sheets, specifically the Greenland Ice Sheet (GIS) and Antarctic Ice Sheet (AIS), to slowly melt away, resulting in elevated sea levels. Currently, the GIS is melting more quickly than the AIS as a whole, as the WAIS is melting considerably faster than the EAIS, likely due to warmer deep ocean water temperatures (National Snow and Ice Data Center, n.d.). However, this process is not always so uniform on both a mechanical and temporal spectrum, and does not result in linear loss, but rather exponential rates of loss. For example, researchers at University of California-Irvine concluded that the WAIS had been collapsing into the Amundsen

Sea at a rate nearly three times faster between 2003 and 2009 than between 1992 and 2013 (Sutterly, *et al.*, 2014). Glacial meltwater and precipitation does not always drain directly into the ocean, but often into crevasses, resulting in vertical fractures which weaken the ice sheet, making it more susceptible to large scale glacial loss in the future. With a weakened structure, heavy ice near the top of the sheet can break apart, shearing off large chunks, resulting in an even weaker ice sheet (Pollard, DeConto, and Alley, 112-121). Furthermore, the rate of fracture is set to occur at a faster rate in the future as precipitation could increase by up to 400 mm per year (Lee, *et al.*, 2017). The recent discovery of these melting mechanisms helps to explain the elevated sea levels at polar regions during the warm periods of the last 25 million years.

As mentioned before, glacial loss does not occur at a linear rate, but rather an exponential rate, as prior events greatly affect future events. To explain, the melting of polar regions due to elevated global temperatures results in an increased rate of glacial loss due to the altered ice-albedo feedback. When ice sheets lose mass, less incident light is reflected away from the surface, resulting in more solar absorption at the surface, leading to even greater air temperatures and higher melting rates. And though not a current problem concerning the AIS, but rather the GIS, exposed bedrock in ice-free areas again contributes to an increased rate of glacial loss due to the reduced reflectivity of the exposed bedrock. Just as global warming influences polar ice loss, the same polar loss influences changes in global and regional climates. For example, an altered ice-albedo feedback due to glacial melt would likely result in a regionalized climate change for countries located in the North Atlantic, including the surface temperature of Greenland, due to freshwater influxes from the Greenland ice sheets altering the oceanic structure (Goelzer, *et. al*, 1006). These ice-climate interactions is critical to understanding future glacial melt projections.

Using temperature-index melt models from the Intergovernmental Panel on Climate Change (IPCC), the impact of climate change on ice-free areas can be quantified. The most extreme scenario produced by the IPCC models predicts a 25% increase in global ice-free areas before the turn of the century, which equates to roughly 17000 square kilometers. The majority of this ice-free expansion is set to occur in the Antarctic Peninsula (WAIS), where a potential threefold local increase in ice-free areas would drastically increase the amount of glacial meltwater flowing into the ocean, attributed to a potential loss of up to five meters of ice by the end of the 21st century, as opposed to approximately one meter across the rest of the continent (Lee, *et al.*, 2017). Considering all of the aforementioned statistics and projections, **Figure 2** displays the severe warming and resulting melting crisis occurring across the Antarctic coastline, specifically the Antarctic Peninsula of the WAIS.

Changes in Antarctic Climate and Physical Geography

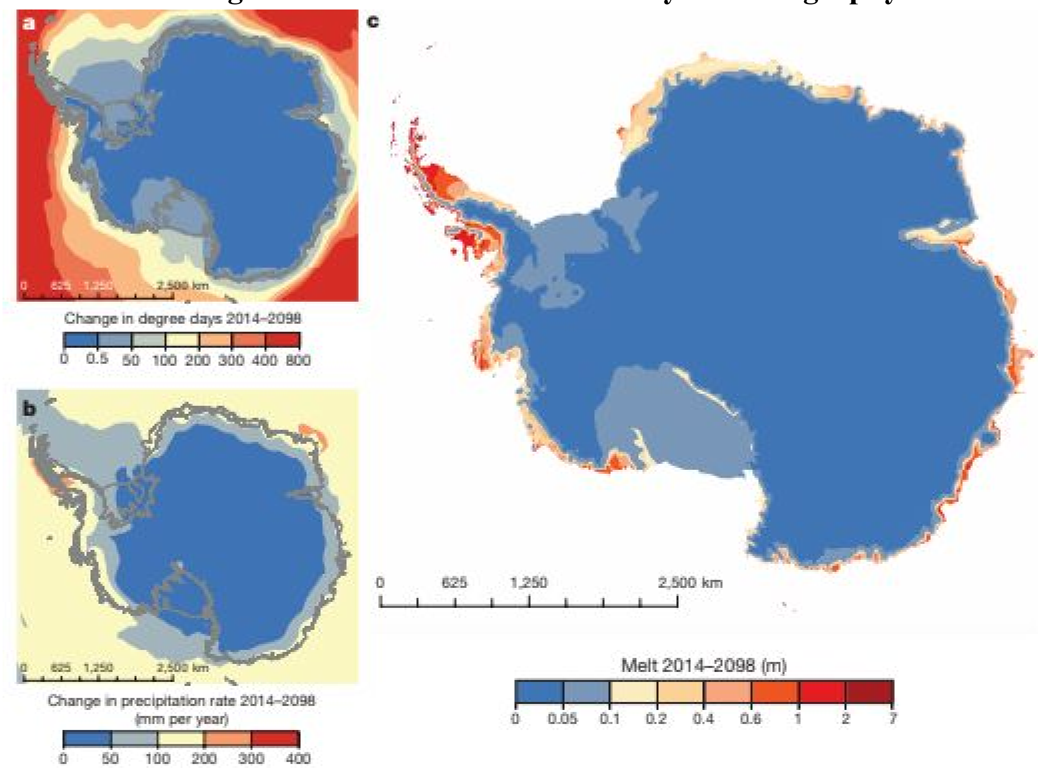

Figure 2(a). Projected change in degree days from 2014-2098. Figure 2(b). Projected change in precipitation rate from 2014-2098. Figure 2(c). Glacial melt projection from 2014-2098. Source: Lee, *et al.*, 2017.

As seen in **Figure 1**, melt projections driven by altered temperature and increased precipitation suggest that the Antarctic Peninsula may lose several meters of ice by the turn of the century. Consequently, glacial loss of this magnitude would likely leave many low-lying coastal areas submerged and uninhabitable due to resulting sea level rise.

Impacts of Sea Level Rise

If sea levels continue to rise at alarming rates, many coastal areas worldwide will likely experience severe flooding and possible inundation. As a result, nearly 40% of the global population, which lives within 100 km of a coastline, may be forced to retreat as more damaging storm surges cause coastal infrastructure to collapse and decimate major cities (United Nations, 2007). In regards to the eastern seaboard of the United States, roughly 60% of the land below 1 m is expected to be developed further (Titus, *et al.*, 2009). Elevated sea levels will enable storm surges to penetrate further inland, resulting in more widespread damage, especially in low-lying areas such as the eastern seaboard of the United States. Furthermore, the continued increase in frequency and intensity of Atlantic hurricanes, which has been linked to increased sea surface temperatures, will only worsen the impact of tropical storms as Category 4 and Category 5 storms cause more regional flooding due to heavy rainfall and powerful storm surges (Anderson, *et al.*, 1). Conversely, higher sea levels may also act as an elevated seaward barrier, inhibiting the retreat of of flood waters back into the sea (Walsh, *et al.*, 2004). The combination of elevated sea levels and increases in both frequency and intensity of Atlantic storms will likely overwhelm low-lying areas along the east coast, especially Florida. In **Figure 3**, the Union of Concerned Scientists projects that a significant portion of coastal Japan, along with many other cities worldwide, would be left underwater with a global temperature increase of 3℃, forcing millions to relocate and economies to crumble (Holder, Kommenda, and Watts, 2017).

Sea Level Rise Projection for Major Coastal Regions

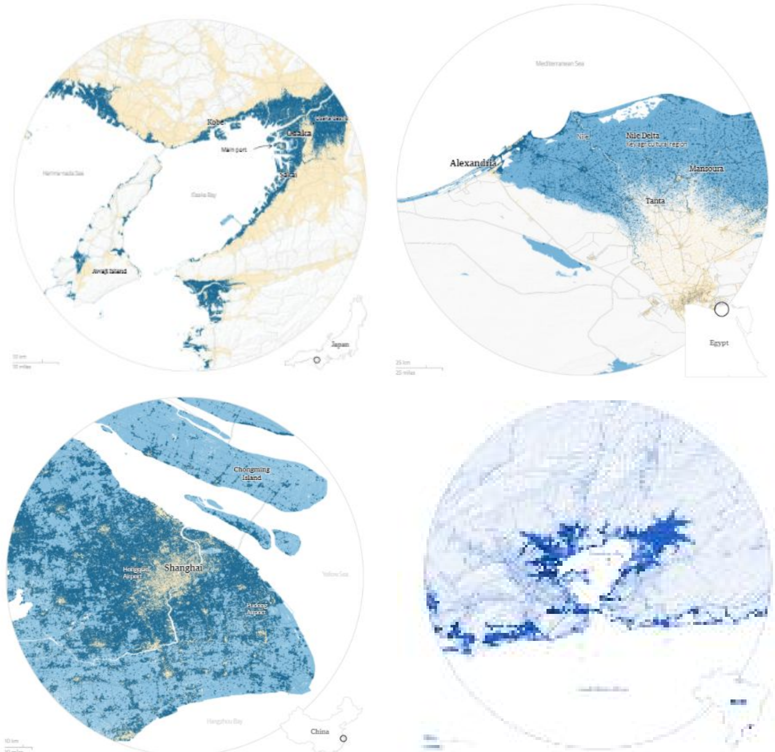

Figure 3. The Union of Concerned Scientists projects that a global temperature increase of 3℃ would result in the decimation of major cities worldwide. Picture above in clockwise order are the coastal regions of Osaka, Japan, the Nile Delta, Shanghai, China, and Rio de Janeiro, Brazil. Source: Holder, Kommenda, and Watts, 2017.

Unfortunately, these grim sea level projections are relatively consistent across the globe. In reference to Florida, just a 2℃ global temperature increase could result in the bottom third of the state becoming uninhabitable. The city of Miami is most at risk from rising sea levels as a global analysis of vulnerable coastal assets in 2070 ranks it at the top of the list, with a projected $3.5 trillion worth of financial assets at risk (Anderson, *et al.*, 5). The city of half a million people will likely collapse both physically and financially, displayed by a flooding projection in **Figure 4**.

Sea Level Projection for Miami, Florida

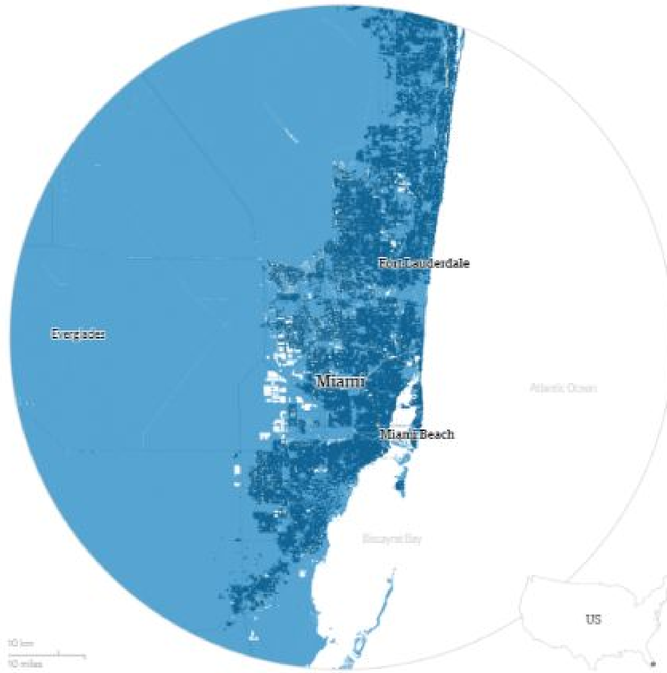

Figure 4. A global temperature increase of 3℃ would theoretically eliminate the city of Miami and surrounding metropolitan area.
Source: Holder, Kommenda, and Watts, 2017.

In the United States, many major metropolitan areas lie on coastlines, especially on the Atlantic Ocean and Gulf of Mexico, which are the two most at-risk regions in the United States for sea level rise. Because of this, many cities such as Boston, New York, and Louisiana also face imminent threats like Miami, which include countless socioeconomic and environmental issues. Potential socioeconomic effects include altered domestic and international trade, a housing crisis, and the loss of trillions of dollars in assets worldwide. Assuming that sea levels continue to rise, large coastal ports and hubs that once served as the foundation for international trade will be ravaged by powerful storm surges, forcing nations to seek new coastal ports that were once considered inland. Consequently, the coastal retreat of millions would create new metropolitan areas, resulting in a housing crisis for the millions who were forced to flee their homes. Furthermore, economies will struggle as trillions of dollars of coastal assets are lost worldwide, possibly shifting the financial balance of power worldwide. As the natural environment responds to warming temperatures and melting glaciers, the consequential rising sea levels will also wreak havoc on coastal ecosystems.

As storm surges overtake entire cities and creep further inland, the natural environment will also suffer immensely. Potential environmental risks in Florida include further beach erosion, fresh water table contamination, and damaged wildlife habitats. Beach erosion is a widespread occurrence that affects nearly every coastal region. In Florida, the state must work constantly to replace sand in order to protect the tourism industry, so much so that state officials have spent nearly $400 million on sand replacement in the last decade (Holder, Kommender, and Watts, 2017). Storm surges which push further inland will contaminate freshwater aquifers used for agriculture and drinking water. Lastly, wildlife habitats could be destroyed as wetland area decreases due to overwhelming amounts of flooding and some marine species may be forced to migrate north to colder waters as southern coastal waters continue to warm. These combination of risks places Florida the most at risk along the eastern US seaboard.

Projections for Sea Level Rise

Over the course of the past century, the global average sea level has risen at a steady rate and is projected to continue increasing, but at what rate is uncertain (Anderson, *et al.*, 1). Most data models involve projections until the year 2100, and the model results vary due to different methodologies and climate assumptions. Most models project an average global sea level rise between 0.2 m and 2.0 m, with outliers on either side of that same range (Melillo, *et al.*, 2014). The difficulty of projecting future sea level rise lies in the uncertainty of climate warming and consequential ice sheet melting. Additionally, little is known about glacial melt and how significant of a role it will play in elevated sea levels. And though sea levels have risen significantly in the past century, historical trends will likely not continue at an identical rate in the future, and should only serve as a reference for what the future might hold. And as mentioned previously, the rate of sea level rise is currently uncertain, but most climate scientists agree that the rate will likely increase in the coming years as the effects of a warming climate intensify.

Impacts of Variables on Projections

Global sea level rise can largely be attributed to the increased average global temperature. However, the increased global temperature results in several factors directly impacting sea levels, as mentioned previously. Specifically, the main contributors to sea level rise include the thermal expansion of both ocean surface water and deep ocean water, melting of polar ice sheets along with other smaller glaciers and ice caps, and terrestrial storage, visible in **Figure 5**.

Variable Contribution to Sea Level Rise (1960-2005)

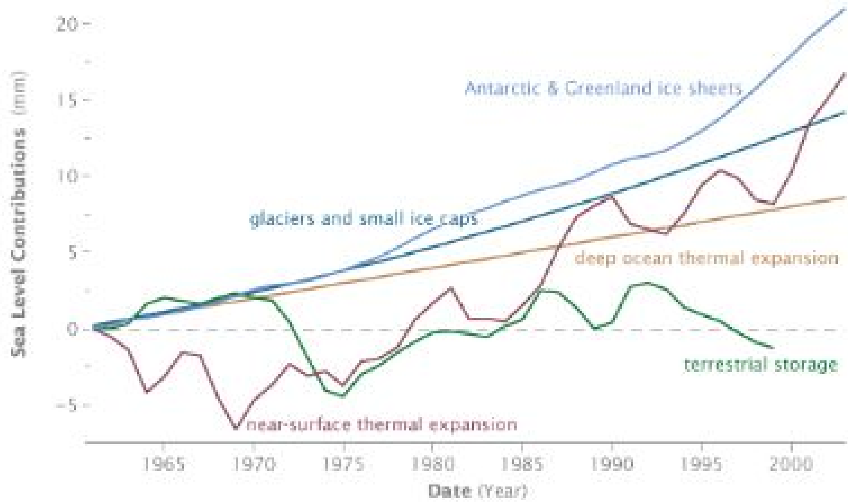

Figure 5. Over the course of the last half century, the melting of polar ice sheets and near-surface thermal expansion have been the driving forces behind eustatic sea level rise.
Source: NASA Earth Observatory, 2014.

In order to comprehend the details of sea level rise, it is imperative that one understands the driving forces behind it. Each of the variables displayed in the graph are explained below.

Thermal Expansion of Surface Water

The thermal expansion of seawater can be attributed to two factors: water temperature and salinity. As water temperature increases, the volume of water increases due to a decreased water density. In terms of seawater, increasing regional surface temperatures have resulted in increased water volume and subsequently, elevated sea levels in regions with increased water temperatures. Conversely, increased salinity values result in an increased density of water, leading to less thermal expansion. In more recent history, the thermal expansion of seawater has been a driving force behind rising global sea levels, contributing more than 20 mm in the past half century (NASA Earth Observatory, 2008).

Thermal Expansion of Deepwater

In addition to horizontal oceanic zones which vary in temperature and salinity with changes in both latitude and longitude, vertical stratification exists where varying temperatures and salinity values create layers at multiple depths as the result of differing densities. Thus, deep ocean water does not expand due to thermal influence quite as much as surface water due to decreased temperatures and salinity values. In the last fifty years, the thermal expansion of deep seawater has increased at a near consistent rate, and has contributed roughly 8 mm to eustatic sea level rise (NASA Earth Observatory, 2008).

Melting of Polar Ice Sheets

As mentioned previously, the Greenland and Antarctic Ice Sheets are melting at a exponential rate due to elevated global and regional temperatures. Historically, the GIS has experienced a greater loss in total mass in comparison to the AIS. However, the melting of the AIS will have a far greater future impact on sea level rise given that it accounts for roughly 90% of all ice on the planet (). The direct input of glacial runoff and fractures has historically accounted for roughly 50% of sea level rise in the previous half century (Bindoff et al., 2007). Interestingly enough, glacial meltwater and fracture input has a greater impact on sea levels elsewhere rather than regional sea level at the poles, as the loss of glacial mass reduces the gravitational pull of the ice sheet, allowing seawater to migrate away (Brennan, 2016). Lastly, glacial meltwater input can also affect the salinity of seawater, altering global ocean currents and heat budgets, further perpetuating climate change and ultimately sea level rise ().

Melting of Glaciers and Small Ice Caps

The melting of mountain glaciers and other small ice caps has increased greatly in recent years, and those glaciers are melting more quickly than the GIS and WIS, primarily the glaciers found in the mid-latitudes and tropics, given that the melt rate is greater than the rate of snowfall (Rising Sea Level, n.d.). Contrary to melting polar regions, meltwater from mountain glaciers enters the ocean through streams and rivers flowing away from mountains, rather than directly into the ocean. However, the input of mountain glacial meltwater also affects ocean salinity, much like polar meltwater.

Terrestrial Storage

Terrestrial water storage sources such as soil and groundwater/aquifers, snowpack and permafrost, and surface water bodies (lakes and rivers) often lose water due to both natural mechanisms and human interaction. This net loss of terrestrial water generally results in a net gain of ocean water, leading to elevated sea levels, albeit the smallest major contributor to sea level rise, accounting for less than ten percent of sea level rise from 1961 to 1992, and from 1993 to 2003, where it accounted for less than the previous period (Bindoff et al., 2007). The contribution of terrestrial water storage to sea level rise has been incredibly minimal, and as a result, was not considered in this projection.

Methodology

Thermal Expansion of Surface Water

Thermal expansion of surface water can be calculated using the following equation:

$$dV = V_0\beta(t_1 - t_0)$$

Where dV = $V_1 - V_0$ (change in volume)

β = volumetric temperature expansion coefficient

t_1 = initial temperature (ºC)

t_0 = final temperature (ºC)

Source: The Engineering Toolbox

A rectangular study area was used on both the eastern and western coastlines of Florida, as Florida is surrounded by both the Gulf of Mexico and Atlantic Ocean. The study area covering the Gulf of Mexico spanned an area of $124,625\ km^2$ with a calculated volume of $201,269\ km^3$ using the equation: $V = A * h$, based on the average depth of the Gulf of Mexico. The study area covering the Atlantic Ocean spanned an area of $127,096\ km^2$ with a calculated volume of $424,374\ km^3$ using the same aforementioned volume equation.. To briefly explain the following calculations, the change in volume was calculated using the thermal expansion equation, and then substituted into the equation $h = \frac{V}{A}$, in which h was equal to the rise in sea level (m), V was equal to the calculated dV, and A = study area (km^2). The sea level rise calculations for each of the study areas were averaged to obtain the average contribution of thermal expansion to sea level rise. Multiple scenarios were calculated based on varying water temperatures, as seen below and in **Table 1**.

Best Case Scenario (0.5℃ SST increase by 2100)

Gulf of Mexico

$$dV = V_0\beta(t_1 - t_0)$$
$$dV = (201,269\ km^2)(.000255)(0.5\ ℃) = 25.6617975\ km^2$$

$$h = \frac{V}{A}$$
$$h = \frac{25.6617975\ km^2}{124,625\ km^2} = 0.00020591\ km^2$$
$$h = 0.00020591\ km^2 * 1000$$
$$h = 0.206\ m$$

Atlantic Ocean

$$dV = V_0\beta(t_1 - t_0)$$
$$dV = (424,374\ km^2)(.000255)(0.5\ ℃) = 54.107685\ km^2$$

$$h = \frac{V}{A}$$
$$h = \frac{54.107685\ km^2}{127,096\ km^2}$$
$$h = 0.00042572\ km^2 * 1000$$
$$h = 0.426\ m$$

Average $= (\frac{0.206 + 0.426}{2}) = 0.316\ m$

Sea Level Rise due to Thermal Expansion at Varying Water Temperatures

Temperature Increase in ℃ by 2100	Gulf SLR	Atlantic SLR	Average SLR
0.5 ℃ (Best Case Scenario)	0.206 m	0.426 m	0.316 m
2.0 ℃	0.820 m	1.700 m	1.260 m
4.01961 ℃ (Worst Case Scenario)	1.660 m	3.420 m	2.540 m

Table 1. The contribution of thermal expansion to sea level rise is displayed at varying water temperatures. The average SLR was used in the final projections.

Thermal Expansion of Deepwater

Given that the thermal expansion of deepwater has been nearly uniform for the previous 50 years, it was assumed that this trend would likely continue, resulting in a 0.328 m contribution to SLR by 2100.

Melting of Polar Ice Sheets

As mentioned previously, the majority of projections for polar ice loss display medium confidence due to the lack of knowledge about melting mechanisms and the inability to accurately quantify the resulting ice loss due to warming air and sea temperatures. As a result, this projection for the year 2100 assumed the historical trend of polar ice loss, in which the melting of polar ice sheets has accounted for roughly one-third of the historical sea level rise. Thus, the sum of the other three contributing factors to sea level rise were equal to two-thirds of the total sum of sea level rise in this projection. And though this contradicts an earlier statement explaining that future trends will likely vary in rate from historical trends, the assumption in this projection which assumed historical trends will experience little variance before the coming century, appeared to be the most logical way to proceed given the lack of glacial knowledge.

Melting of Glaciers and Small Ice Caps

Given that the melting of glaciers and small ice caps has been nearly uniform for the past 50 years, it was assumed that this trend would likely continue, resulting in a 0.205 m contribution to SLR by 2100.

After accounting for the four major variables, the following projections were made by summing each of the factor contributions for a total, which can be seen below in **Table 2**.

Sea Level Rise Scenarios Breakdown

	Surface Expansion	Deepwater Expansion	Polar Sheet Melting	Small Glacier Melting	Total
Best-Case	0.316 m	0.328 m	0.425 m	0.205 m	1.274 m
Mean	1.260 m	0.328 m	0.897 m	0.205 m	2.690 m
Worst-Case	2.540 m	0.328 m	1.537 m	0.205 m	4.610 m

Table 2. The table shows the contribution of each factor to sea level rise and the total sea level rise.

Sea Level Rise Maps

Using a digital elevation model (DEM), obtained from Florida Disaster: Emergency Management Division, and ArcMap 10.6, several maps were created which displayed the effects of 1 m, 3 m, and 5 m sea level rise in Florida. The results from the "Total" column of **Table 2** (above) were rounded to the nearest whole number, as the DEM only presented elevation values by whole numbers.

The DEM, contained within a geodatabase (flidar_mosaic_m.gdb), was added to a blank ArcMap document and using the "Select by Attributes" tool, the following query was entered:"Value <= 1", which selects all elevation values less than or equal to 1 m. Though most areas in the state with an elevation less than or equal to 1 m lie along the coastline, some areas existed in the central part of state with equivalent elevation values. Thus, the following geoprocessing tools were run to eliminate the low-lying non-coastal areas from the map.

The "Spatial Analyst" extension was turned on prior to running the following geoprocessing tools. The "Raster Calculator" tool, found within "Map Algebra" in the ArcToolbox, was run with the following Map Algebra expression: "flidar_mosaic_m <= 1" and output as “OutputRaster_1 m.” The Raster Calculator tool creates a boolean raster of values ‘0’ and ‘1’, where ‘0’ is equal to values that are not less than or equal to 1 m, and ‘1’ is equal to the values that are less than or equal to 1 m. Upon completion, the “Region Group” tool, found within “Generalization” in the ArcToolbox, was run using OutputRaster_1 m as the input raster, “EIGHT” number of neighbors to use, “WITHIN” as the zone grouping method, and an excluded value of ‘0.’ A link field was also added to the output raster “RegionGroup_1 m” so as to preserve the original values for each newly created zone. The Region Group tool creates a raster of regions within a zone, where each region is defined by cells of equal value, and each region is now a unique selectable region. The Region Group tool works by scanning every raster cell from top to bottom and left to right, grouping equal neighboring values together and breaking when the tool reaches a new value, assigning the new foreign value a different one than the previous region.

Following the Region Group tool, the “Extract by Attributes” tool was run to extract the coastal cells of the created raster using an SQL query. If the SQL query evaluated true for a particular cell, the original input value was returned for the cell location. If the query evaluated false for a particular cell, the cell was assigned “NoData.” Upon completion, the new attribute table displayed significantly less values given that a large portion of the cells evaluated false, triggering them to be assigned “NoData.”

The Extract by Attributes tool was followed by the final geoprocessing tool, the “Raster to Polygon” tool. The tool was run using the “Simplify” option, which required les processing time and simply just approximates edges instead of retaining the original raster shape. The completion of these four geoprocessing tools transformed a raster into a polygon, which was then overlaid with population data to quantify the amount of Floridians affected by various sea level rise scenarios.

Block group data from the 2010 Census was used to estimate the amount of Floridians affected by the varied sea level rise scenarios. *Note: The following data was obtained from the "2010 Census Complete Geodatabase."*

The national block group layer, "C10_bg," was overlaid against the resulting polygon from the previous steps and the "Select by Location" tool was utilized to determine which block groups intersected the resulting polygons of each sea level rise scenario and determine a rough estimate of the amount of affected citizens. Once the appropriate block groups were selected, a new layer was created from the selection: "BlockGroups_xM," where 'x' was equal to either 1M, 3M, or 5M depending on the scenario being run. The national block group layer was turned off to avoid clutter. A state border was added using "C10_st" from the Census database. A query was written in the "Select by Attributes" window: "NAME = 'Florida'" and a new layer was created from the selection in order to eliminate the other states from the data frame and final map document. The state background was colored a neutral tone and the affected block groups were displayed using graduated colors to differentiate between varying populations among the block groups. Each map was accompanied by a data legend, scale, and a north arrow for reference and saved as "Florida_xM_SLR," where 'x' was equal to the relative scenario.

Results

After observing the selected block groups, the following observations were made about the likely affected population in Florida as a result of rising sea levels, visible in **Table 3**.

Population Affected by Sea Level Rise

Sea Level Rise	Population Affected
1 Meters (Best-Case)	~2,817,070
3 Meters (Median)	~10,939,830
5 Meters (Worst-Case)	~10,993,135

Table 3. Block group data obtained from the 2010 Census helps quantify the impact of rising seas, as a significant amount of citizens are at risk in Florida.

In the event of a one meter sea level rise, every meter of Florida coastline would suffer immensely from eustatic rise in addition to the further damage caused by tropical storm damage such as storm surges and heavy flooding. And though a one meter sea level rise is quite significant, the damage caused by eustatic rise is limited mostly to the coastlines. Based on 2010 Census block group data, roughly 2,817,070 people would be affected by sea level rise, visible in **Figure 6**. However, this number has likely increased given that the Florida population has increased by over two million people since 2010.

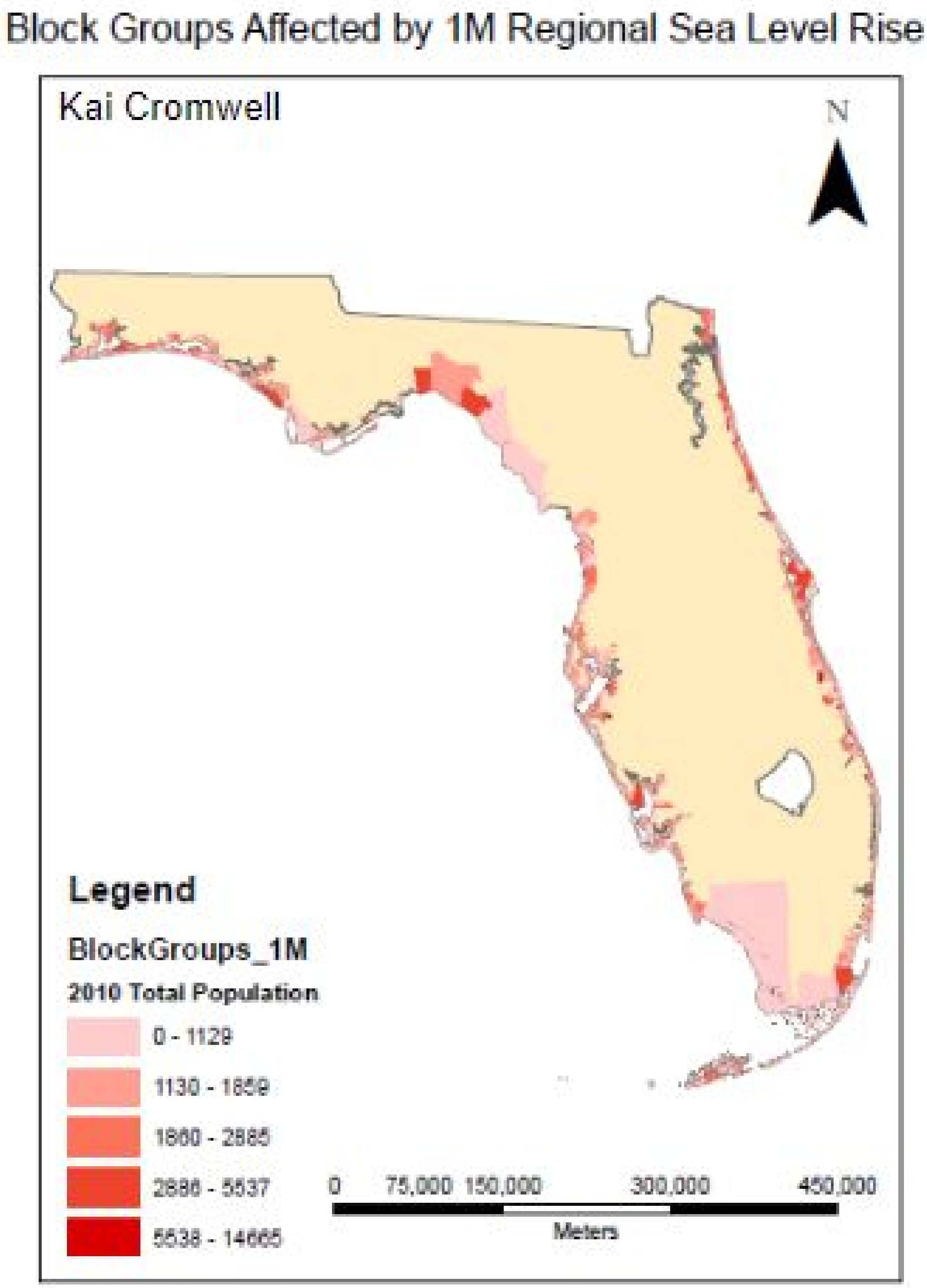

Figure 6. Block groups in Florida affected by a 1 m sea level rise.

In the event of a three meter sea level rise, the entirety of the Florida coastline would likely be submerged and water levels would penetrate further inland on both the Gulf and Atlantic coasts, potentially even threatening citizens directly to the southeast of Lake Okeechobee. The damage caused by three meter sea level rise would likely endanger roughly 10,939,830 people, visible in **Figure 7**.

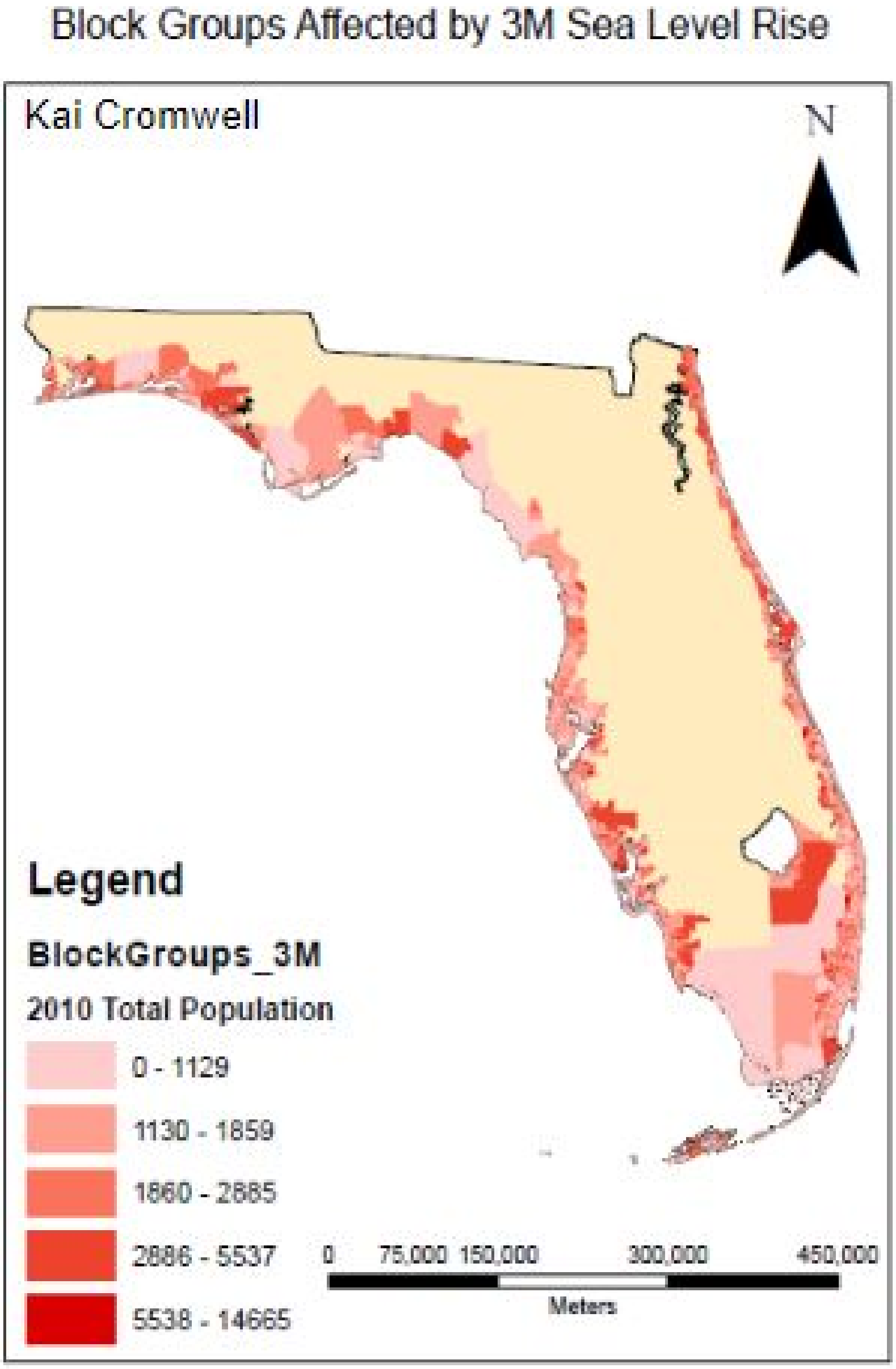

Figure 7. Block groups in Florida affected by a 3 m sea level rise.

In the event of a five meter sea level rise, though unlikely by 2100, the damage is quite similar to the possible damage from a three meter rise, in addition to slightly further penetration inwards in the northeast, southeast, and Panhandle regions of Florida. The affected area would endanger roughly 10,993,135 people, which is nearly half of the current population of Florida. This drastic change in sea level would entirely submerge the bottom third of Florida and likely cause additional flooding as Lake Okeechobee water levels experience resulting rise, causing more widespread damage, visible in **Figure 8**.

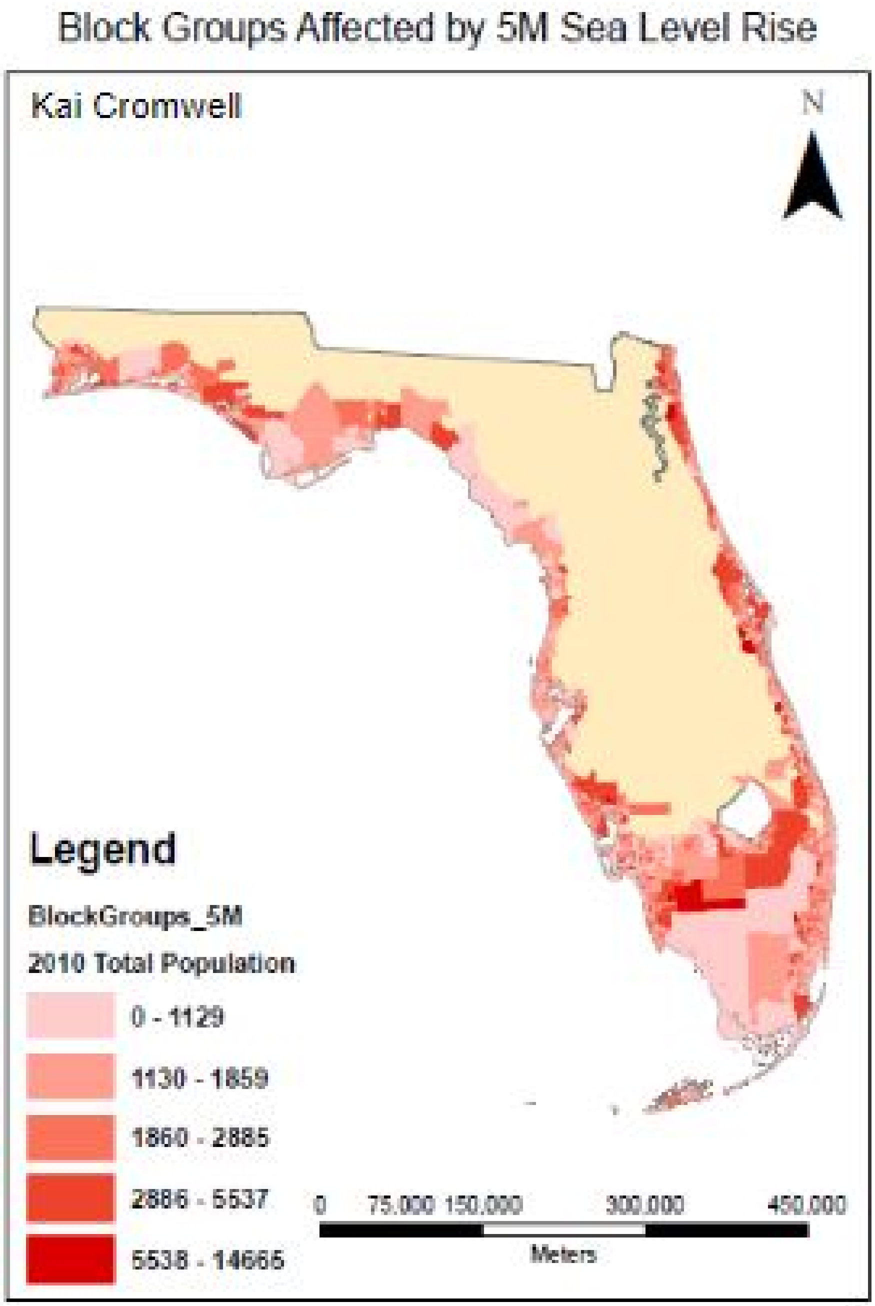

Figure 8. Block groups in Florida affected by a 5 m sea level rise.

Conclusion

The devastating effects of climate change on the planet have already begun to damage the coastal communities of Florida as the increase in both frequency and intensity of tropical storms has been linked to warming climates. Unfortunately, rising sea levels will not only continue to increase the flooding and inundation associated with tropical storms but create other unique socioeconomic and environmental issues which will likely plague the citizens of Florida for decades and even centuries to come. The affected coastline will create both statewide and nationwide housing and financial crises, in addition to the possible contamination of the fresh water table and damaged wildlife habitats. With millions of Floridians at risk from just a one meter sea level rise, the projection highlights the most "at-risk" areas so that both local and federal governments and agencies can begin preparing for the projected rise scenarios. And though coastal infrastructure may be able to withstand rising seas for a few more decades, the most economically feasible option is coastal retreat so as to protect citizens and some of their financial assets (Pikey and Young, 2011). The projections calculated in this study are only projections, and are likely subject to change depending on both global and regional climates such as varied air and sea surface temperatures affecting primarily thermal expansion and polar ice sheet melting. It is entirely possible that both of the previously mentioned variables may contribute more or less to sea level rise in the future, but will ultimately be governed by changes in climate.

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