Superstorm Sandy: Ten Years Later

2022 CONFERENCE PROCEEDINGS

FOR

THE 38TH ANNUAL MEETING

OF THE

GEOLOGICAL ASSOCIATION OF NEW JERSEY

October 28 & 29, 2022

Edited by

Alan I. Benimoff

College of Staten Island/CUNY

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Field Guides and Proceedings of Prior Annual Meetings

2021 XXXVII *Karst Geology of NJ: Revisited*, Michael Hozik

2019 XXXVI *Geology and Paleontology of Monmouth County*, James Brown and Tim Macaluso

2018 XXXV *Hydrology, Hydrodynamics, and Water Supply in New Jersey and the Delaware River Basin*, Tim Macaluso

2017 XXXIV *The Piedmont: Old Rocks, New Understandings*, Howell Bosbyshell

2016 XXXIII *Shallow Subsurface Geophysical Applications in Environmental Geology*, Michael Gagliano and Suzanne Macaoay Ferguson

2015 XXXII *Neotectonics of the New York Recess*, Gregory Herman and Suzanne Macaoay Ferguson

2014 XXXI *Global Environmental Issues and Local Consequences: Earth Processes and Urban Environmental Quality*, Nurdan Duzgoren-Aydin

2013 XXX *Igneous Processes During the Assembly and Break-up of Pangaea: Northern New Jersey and New York City*, Alan Benimoff

2012 XXIX *Geology and Public Lands*, Jane Alexander

2011 XXIII *Environmental Geology of Central New Jersey*, Emma Rainforth and Alan Uminski

2010 XXVII *Geology of the Greater Trenton Area and Its Impact on the Capital City*, Pierre Lacombe

2009 XXVI *New Jersey Coastal Plain Stratigraphy and Coastal Processes*, Deborah Freile

2008 XXV *Environmental and Engineering Geology of Northeastern New Jersey*, Matthew Gorring

2007 XXIV *Contributions to the Paleontology of New Jersey 2*, Emma Rainforth

2006 XXIII *Environmental Geology of the Highlands*, Suzanne Macaoay and William Montgomery

2005 XXII *Newark Basin - View from the 21st Century*, Alexander Gates

2004 XXI *Proterozoic, Paleozoic, and Mesozoic Mafic Intrusions of Northern New Jersey and Southeastern New York*, John Puffer and Richard Volkert

2003 XX *Periglacial Features of Southern New Jersey and Adjacent Areas*, Michael Hozik and Mark Mihalsky

2002 XIX *Geology of the Delaware Water Gap Area*, Dana D'Amato

2001 XVIII *Geology in the Service of Public Health*, Pierre Lacombe and Gregory Herman

2000 XVII *Glacial Geology of New Jersey*, David Harper and Fred Goldstein

1999 XVI *New Jersey Beaches and Coastal Processes from Geologic and Environmental Perspectives*, John Puffer

1998 XV *The Economic Geology of Central New Jersey*, John Puffer

1997 XIV	*The Economic Geology of Northern New Jersey*, Alan Benimoff and John Puffer
1996 XIII	*Karst Geology of New Jersey and Vicinity*, Richard Dalton and James Brown
1995 XII	*Contributions to the Paleontology of New Jersey 1*, John Baker
1994 XI	*Geology of Staten Island*, Alan Benimoff
1993 X	*Geologic Traverse Across the Precambrian Rocks of the New Jersey Highlands*, John Puffer
1992 IX	*Environmental Geology of the Raritan River Basin*, Gail Ashley and Susan Halsey
1991 VIII	*Evolution and Assembly of the Pennsylvania-Delaware Piedmont*, Maria and William Crawford
1990 VII	*Aspects of Groundwater in New Jersey*, James Brown and Richard Kroll
1989 VI	*Paleozoic Geology of the Kittatinny Valley and Southwest Highlands Area, New Jersey*, Irvin Grossman
1988 V	*Geology of the Central Newark Basin*, Jonathan Husch and Michael Hozik
1987 IV	*Paleontology and Stratigraphy of Lower Paleozoic Deposits of the Delaware Water Gap*, William Gallagher
1986 III	*Geology of the New Jersey Highlands and Radon in New Jersey*, Jonathan Husch and Fred Goldstein
1985 II	*Geological Investigation of the Coastal Plain of Southern New Jersey*, Ray Talkington and Claude Epstein
1984 I	*Igneous Rocks of the Newark Basin: Petrology, Mineralogy, and Ore Deposits*, John Puffer


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In Memoria

Suzanne M. Macaoay, PG
Vice President
1963 – 2022

Suzanne was the long standing Membership Secretary of GANJ (1997-1999 and 2005-2022), Councilor-at-Large (2003-2004), editor of the field books, and herder of cats on the field trips. Sometimes, the cats herded her, too. Her association with GANJ was one of the things she was most proud of in her distinguished career.
She was well loved and will be missed.

Geological Association of New Jersey Memorial to Suzanne Macaoay Ferguson

Our dear friend, geologist, Membership Secretary, and thrice co-editor of proceedings of the Geological Association of New Jersey (GANJ) passed away August 20, 2022. Suzanne was a kind, smart, and professional, member of GANJ for nearly 25 years.

Suzanne started her journey as a geologist after graduating from Westfield High school just south of the Watchung Mountains. Suzanne was proud of her community college roots, paying her own way as a commuter student at Union County College and then Rutgers University Newark, where she earned her bachelor's degree in Geology. She then obtained a Master's Degree in Geology from Princeton University, while working as a teaching assistant.

She worked for more than 25 years as a professional environmental scientist involved in all facets of geologic work including data collection, technical writing and reviewing, as well as office management and project supervision. Her more recent project work involved remedial investigations and solid waste management. Her skills proved valuable for litigation support, expert testimony, and as a geologic expert for Planning Board testimony.

As a longtime member of GANJ, Suzanne was Membership Secretary of GANJ from 1997-1999. Suzanne served as Councilor-at-Large from 2003-2004 and returned to her position as Membership Secretary from 2005 until her passing. Her GANJ activities also allowed her to retain an interest in geoscience education, and students recall positive interactions with her at the annual meetings and field trips. Suzanne was the type of person who brought reason and common sense to bear in major decisions of the GANJ Board's. She was important to our society in her ability to maintain the stability of GANJ for more than two decades.

Suzanne was co-editor of three GANJ Proceedings of Annual Meetings with Field Guides:

2016 GANJ—Shallow Subsurface Geophysical Applications in Environmental Geology, --co-edited with Michael Gagliano

2015 GANJ—Neotectonics of the New York Recess—co-edited with Greg Herman

2006 GANJ—Environmental Geology of the Highlands—co-edited with William Montgomery

Suzanne worked as Vice President of Special Projects for Sadat Associates in Trenton, NJ for 24 years. Most recently, Suzanne was Vice President of PennJersey Environmental Consulting in Milford, NJ. She also served on the Franklin Township Open Space Committee in Warren County, NJ, for many years. Suzanne was a member of the New Jersey Licensed Site Remediation Professional Association where she also served on the Finance Committee.

When Suzanne was not engaged with her passion for geology, she spent her time with her husband Rodger Ferguson; five children: Mitchell, Allan, Erin, Miguel, and Marion; mother: Sarah Ann O'Malley; sisters: Cecelia, Amy, and Sarah; and grandchildren: Atlas and Auria. She sang in the choir at church in Washington, NJ, and taught 6th grade Sunday School for many years.

SCHEDULE

<u>Friday, October 28, 2022</u>

1:00 pm Opening Remarks—Alan I. Benimoff

1:10 pm Climate Change Issues and Regional Flooding in New Jersey and New York by Jonathan Peters

1:30 pm Coastal Management Response to Superstorm Sandy (2012), Rockaway Beach Queens, New York by Sam Epstein, Peggy Epstein and Roger Sassen

1:50 pm Hurricane Sandy was a Wake-up Call & NJ Listened by Stewart Farrell

2:10 pm Business Meeting
State of GANJ
Treasurer's Report
Election of new
officers Other
business

2:30 pm Ida: another one-hundred-year hurricane nine years after Sandy: Random or consistent with a global warming trend? by John H. Puffer

2:50 pm Understanding the Vulnerability of Staten Island's Eastern Coastline from a Beach Morphology Perspective by Jane Alexander, Amaury Acevedo and Jacklyn Reiszel

3:10 pm Looking at the changes now made to protect the East Coast of New York and New Jersey from Future Storms since Hurricane Sandy by Dennis Askins

3:30 pm Break

3:45 pm Using a Hedonic Modeling Approach to Evaluate the Long-Term Benefits of Engineered Berm-Dunes along Long Beach Island, New Jersey By Jesse Kolodin

4:05 pm Keynote Address-- Learning from the impact of Superstorm Sandy: A review by Alan Benimoff

Revised 10.27.22

Saturday, October 29, 2022 Field Trip

The bus will depart from Parking Lot 1 Brookdale Community College at 8:00AM

Stop 1: Long Branch, NJ

Stop 2: Sandy Hook, NJ

Stop 3: Pleasant Plains, Staten Island, NY

Stop 4: Midland Beach, Staten Island, NY

Return to parking lot 1 Brookdale Community College

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Ida: another one-hundred-year hurricane nine years after Sandy: Random or consistent with a global warming trend?

John H. Puffer

Professor, Emeritus, Rutgers Univ. Dept. of Earth & Environmental Sciences, Newark, NJ 07102.

ABSTRACT

It is an undisputed scientific fact that hydrocarbon combustion yields H_2O plus CO_2 as major emissions and that CO_2 absorbs atmospheric heat. Heat is energy and atmospheric increases translate into stronger winds, more extreme weather events, as well as increased temperatures. However, the concept that global warming is largely due to anthropogenic factors is disputed by about 60 % of the US population as of 2021. This report describes several weather events that have taken place since Hurricane Sandy and attempts to place them in the context of fact based trends. In keeping with the theme of this conference, a hurricane event, Hurricane Ida, will be focused on but other evidence of trends in weather event severity will be examined. All post Sandy evidence examined is consistent with the continuation of a trend toward a higher energy climate and increasingly severe weather events. To avoid bias interpretations and opinions will be held to a minimum; just the facts, you decide.

INTRODUCTION

This paper accepts the word "fact" as "a thing that was done" in keeping with the long held legal definition derived from the Latin word for an action. Facts are unique. There can't be one fact that contradicts another. Opinions are much different. Some are based on a comprehensive set of facts while others may be based in part on mistaken beliefs or assumptions. Therefore, many interpretations and opinions are flawed and will be excluded from this paper except when clearly identified as such. This paper is not intended to be "balanced" with equal time given to climate deniers. It is simply a presentation of data, with a focus on Ida. Again; it is largely restricted to recent environmental data gathered from credible news coverage: Associated Press, Reuters, The Star Ledger, NOAA, Science, Nature, etc., that have provided first-hand accounts of Ida and other trend setting environmental events during the last few years up until the August 1 deadline for manuscript submission to the 2022 GANJ guidebook.

HURRICANE IDA

Here are a few basic statistics pertaining to Hurricane Ida that were conveniently accumulated by Wikipedia:

Formed - August 26, 2021
Dissipated - September 4, 2021
Highest Winds – One minute sustained: 150 mph (240 km/hr)
Lowest Pressure - 929 mbar
Fatalities – 115
Damage - $65.25 billion (sixth-costliest on record)

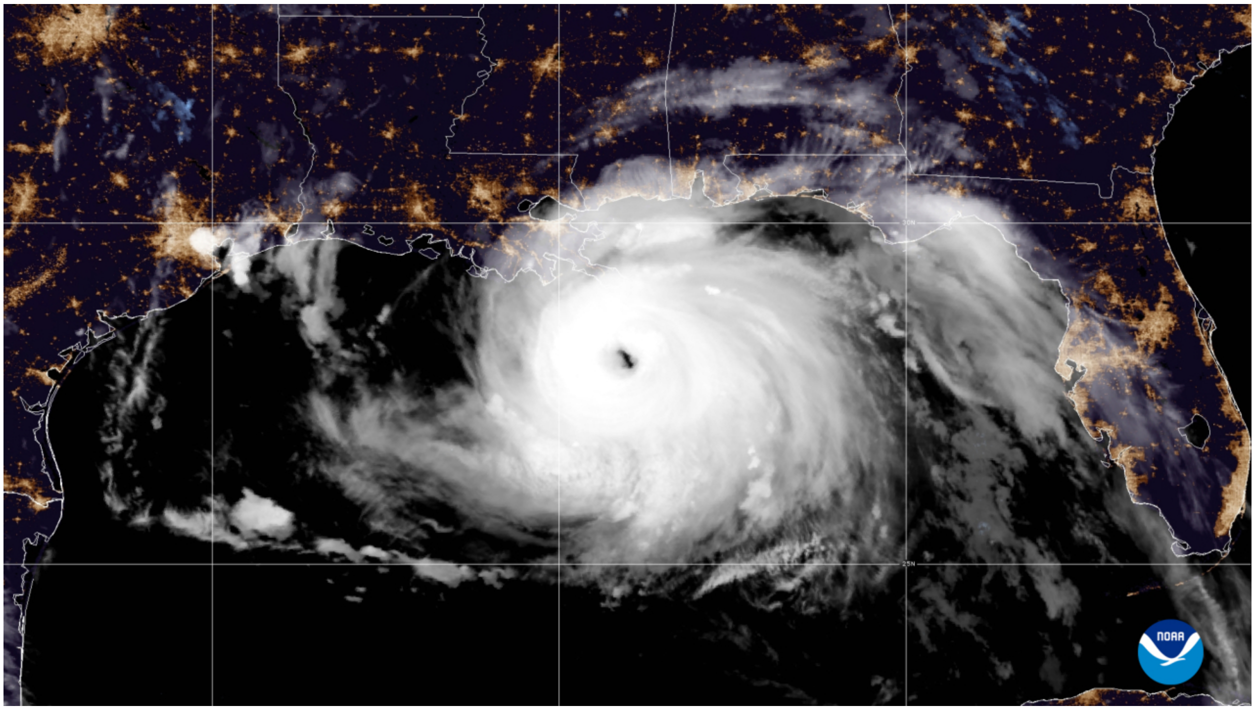

Fig. 1. *A visible satellite image of Hurricane Ida approaching land in the Gulf of Mexico taken by NOAA's GOES-16 (GOES East) satellite at 4:10 am (EDT) on August 29, 2021. (NOAA, 2022a)*

The impact of Ida on New Jersey

Since this paper is being submitted to a geological association located in New Jersey the membership may be particularly interested in the local impact of Hurricane Ida.

"The remnants of Hurricane Ida unleashed catastrophic and deadly damage across New Jersey on Wednesday night, (Sept 3, 2021) overwhelming areas with massive flooding in the northern parts of the state and in its southern half spawning tornadoes that destroyed at least 20 houses" (Mueller, 2021). The majority of the dead drowned in their cars due to rising floodwaters.

NJ Transit rail service was suspended for Thursday Sept 4 due to floodwaters 4 to 5 feet high. Holy Name Medical Center in Teaneck closed its emergency room after waters gushed into it like a river and traveled 200 feet into the building. More than 60,000 people remained without power as of midday Thursday (Mueller, 2021).

The National Weather Service reported at least three tornadoes touched down in New Jersey including one that damaged about 100 homes. More than a dozen houses in a Mullica Hill neighborhood were torn to shred by one of the tornadoes with winds as strong as 136 to 165 mph (Melisurgo, 2021a). Four other tornadoes were confirmed in eastern Pennsylvania (Mueller, 2021).

Newark was drenched with 8.41 inches of rain on the Wednesday portion of Hurricane Ida. This was the most rain ever recorded on any single day since records began in 1931. Ida arrived after Newark had its third wettest summer on record, and the fourth wettest September on record (Melisurgo, 2021b).

Shortly after Hurricane Ida's historic flooding in New Jersey, Star Ledger reporter Payton Guion (Guion, 2021) asked climate experts what's going on in New Jersey and if storms like this are what we can expect in the future. Kate Marvel, a climate scientist at NASA answered basic physics says that when air warms up, it can hold more water. The earth right now is 1.2 degrees Celsius warmer than before the Industrial Revolution. As a result, we've seen an increase in very heavy rainfalls, especially in the Midwest and on the East Coast. Rising temperatures mean air holds more water, so more gets dumped on us". **Pankaj Lal, a professor of earth and environmental studies at Montclair State University** answered "These types of events are going to keep happening. The infrastructure is not ready in New York, New Jersey, and Connecticut. We have some of the oldest infrastructure. We are not ready." **Andra Gardner, a professor of environmental science at Rowan University** said "We need to rethink the likelihood of such storms. We're making that type of event more likely and more intense when it does occur. This was probably the one in 100 years or one in 500 years event. It was likely true historically, but I don't know it's true going forward. Weather similar to what Ida brought will occur more frequently, and we as a society need to be thinking about what we can do to limit the impact. We have a society we've built around a really stable climate, and we're entering a period where climate is changing really rapidly. We need to be thinking about our infrastructure. Not only how do we mitigate climate change ... but also how we adapt our current infrastructure?"

Ida storm damage closed 21 schools in New Jersey and as of Nov 22, three months after the storm four still remained closed (Roman, 2021). Ida ripped through New Jersey turning roads into wild rivers caused unprecedented flooding. Thirty people in New Jersey were killed and thousands of children lost their schools. Some school buildings suffered catastrophic damage (Roman, 2021a). One parent complained "I'm just frustrated. My kid is suffering" The damage to one school (Cresskill High School) totaled $19 million but since the school is in a flood zone insurance will cover only $2 million of damage (Roman, 2021b). Hurricane Ida caused at least $83.6 million of damage to the New Jersey school system as of Nov. 17, 2021 (Roman, 2021c). New Jersey finally received $228 million in federal funds in 2020 to rebuild after Hurricane Ida (Salant, 2020).

IS THE TIMING AND SEVERITY OF IDA CONSISTENT WITH POST-SANDY GLOBAL WARMING OR NOT? YOU DECIDE:

Temperature trends

The Intergovernmental Panel on Climate Change revealed a litany of broken climate promises in an April 4, 2020 report. Governments agreed in the 2015 Paris accord to keep global warming well below a 3.6 degree Fahrenheit, (ideally no more than 2.7 degrees Fahrenheit or 1.5 degrees C) increase this century. However, temperatures have already increased by over 2 degrees Fahrenheit resulting in measurable increases in flooding, droughts, hurricanes, wildfires, and dangerous heat waves (Jordans and Borenstein, 2020). To keep the 1.5- degree limit we need to cut global greenhouse emissions by 45% this decade but current climate pledges would result in a 14% increase in emissions (Jordans and Borenstein, 2020). "We are on a pathway to global warming of more than double the 1.5-C limit agreed in Paris. Some governments and business leaders are saying one thing – but doing another. Simply put, they are lying." said Antonio Guterres the U.N. Secretary General. He went on to say that the planet is moving "Perilously close to tipping points that could lead to cascading and irreversible impacts" (Jordans and Borenstein, 2020).

According to the EU's Copernicus Climate Change Service, (Rostonm, 2022), the last seven years rank as the hottest on record, and 21 of the 22 warmest years have occurred since 2000. The data indicates (Fig. 2) that the post Sandy global warming trend is clearly worsening; that is not an opinion; that is a fact.

In addition, a global consortium of climate scientists backed by the United Nations concluded with "unequivocal" confidence in an August 2021 report that human-made air pollution, particularly fossil-fuel combustion is causing the warming trend. Atmospheric methane increased to a new record of 1,876 ppb during 2021 with 80 times the warming impact of carbon dioxide (Rostonm, 2022).

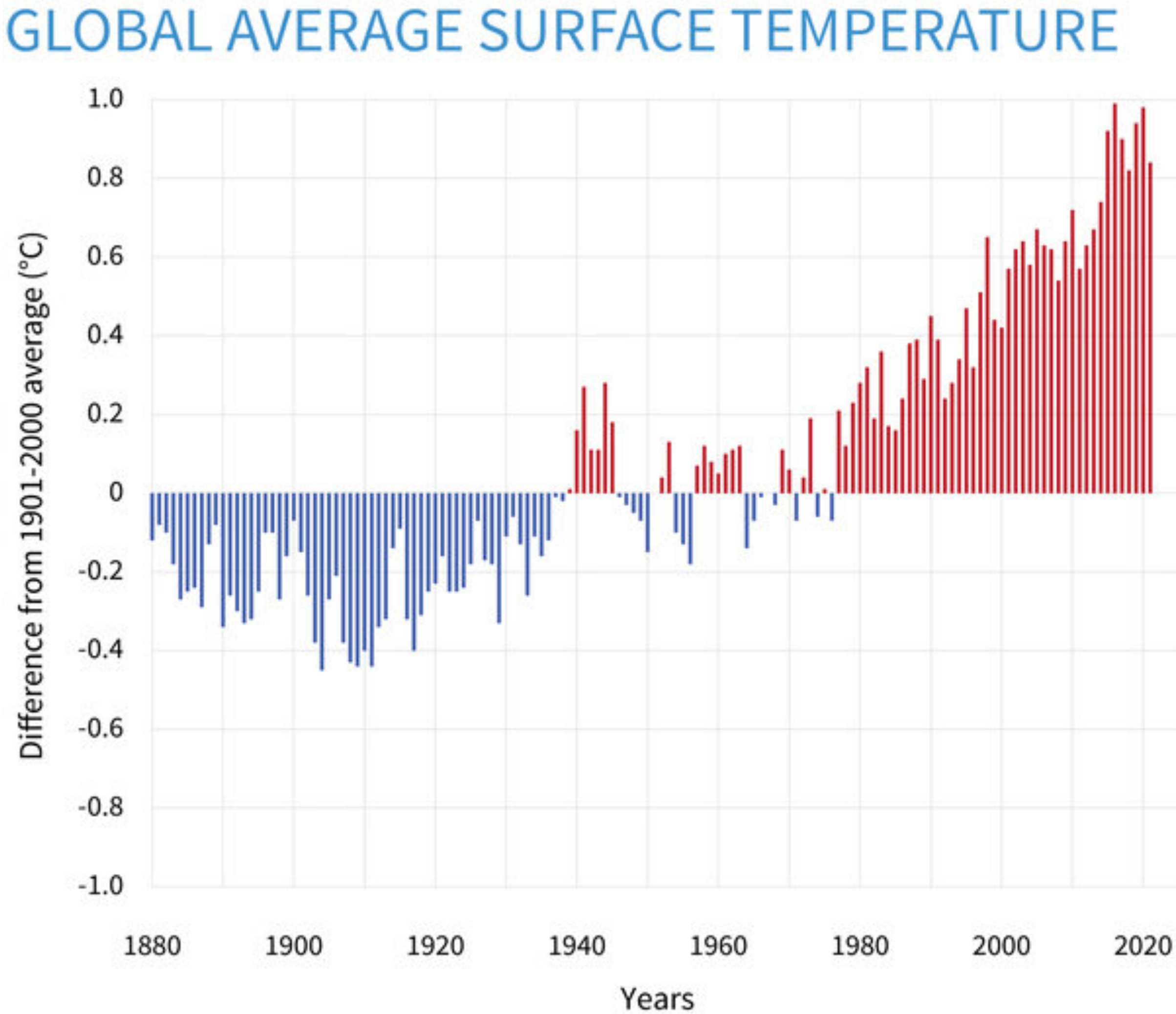

Fig. 2. *Yearly global temperatures from 1880-2021 compared to the twentieth-century average. The Global average surface temperature has risen 0.14 degrees Fahrenheit per decade since 1880. The rate of warming has more than doubled since 1981 (NOAA and NCEI).*

Figure 3 plots the same data in fahrenheit units and separates the components of the trend into: human-caused (largely hydrocarbon fuel combustion), natural varability, Solar (sun spot cycles), and volcanic emmisions. Volcanic events correlate with three 2-year negative anomalies in the temperature trend with amplitudes of as much as -0.6 F°. The brief influence of volcanic activity is related to the ability of weather systems to wash out the particulates and sulfur gasses that have a cooling effect. The global temperature influence of the August 1883 eruption of Krakatoa, a volcanic island in Indonesia located 100 miles west of Indonesia is clearly depicted on Fig 3. The eruption killed more than 36,000 people making it one of the most devastating volcanic eruptions in human history. The eruption of Mount Pinatuba, April 2, 1991, is also clearly indicated on Fig. 3 as a negative 0.5 °F anomaly (temporarely –0.9 °F). The eruption killed 847 people, left 10,000 people homeless, and released 17 megatons of sulfur dioxide into the atmosphere. Far more people would have been killed if it were not for accurate warnings by volcanologists.

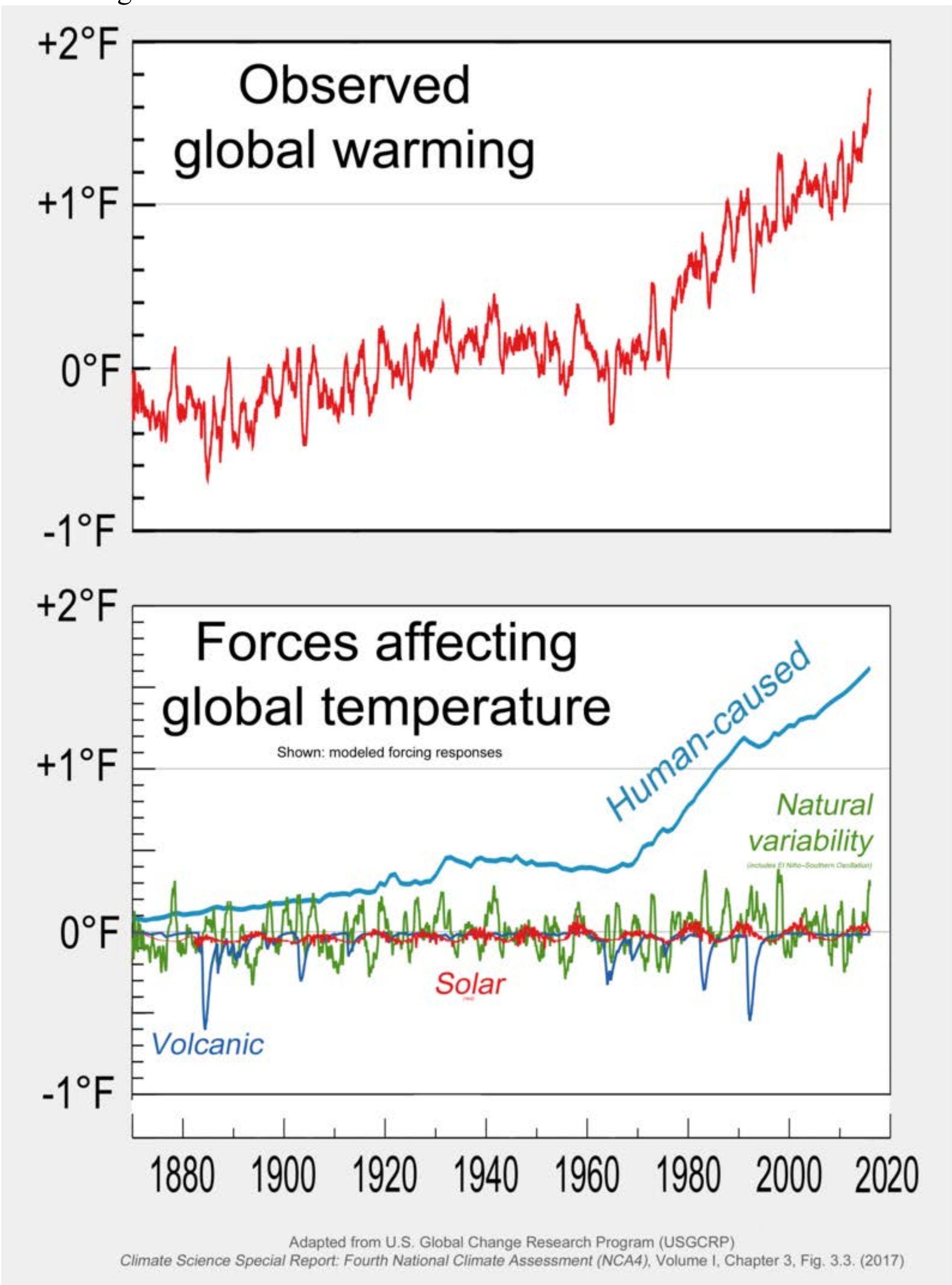

Fig. 3. *Illustrates how human factors—not various natural factors are the predominant cause of observed global warming. (USGCRP, 2017). This is the most important chart of this chapter and is based on very credible sources. Please feel free to show it to all your students and acquaintances!*

Some climate deniers allege that water vapor is a significant greenhouse gas, and is left out of many climate models. It is true that water vapor is a greenhouse gas but it's short atmospheric lifetime (about 10 days) compared to that of CO_2 (hundreds of years) means that CO_2 is the primary driver of increasing temperatures; water vapor acts as a feedback, not a forcing mechanism. Water vapor actually has been incorporated into climate models since their inception in the late 1800s (USGCRP).

Droughts

The Great Salt Lake was 3,300 square miles in the 1980's; as of Sunday July 10, 2022 it covers less than 1,000 square miles (Leffer, 2022). It is now at its record low. According to the National Drought Monitor, 83% of Utah is experiencing extreme drought and 100% of Utah is in a state of drought. The Great Salt Lake is now at the lowest level than at any other time in the past 1,200 years (Leffer, 2022). As the lake bed dries up toxic dust storms are becoming common. The arsenic content of the dust is particularly troublesome with the potential to cause skin, and lung cancer. A similar problem occurred in the Aral Sea in Uzbekistan and Kazakhstan when water was diverted to agricultural irrigation starting in the 1040s leaving only a toxic desert with dust that poisons the area inhabitants. The surrounding population is suffering "... unusual high rates of cancer, kidney disease, and infant mortality" (Leffer, 2022).

Lake Mead is a reservoir that supplies electricity to 350,000 homes and irrigation and drinking water to about 25 million people (Zeleb, 2022). It has as of 7/12/2022 reached record low water levels and if the trend continues will become a "dead pool" when the water levels become too low to flow downstream from Hover Dam. According to the US Bureau of Reclamation the water level at Lake Mead is at the lowest level since being filled in 1937 after the construction of Hover Dam. Artifacts, including human remains and boats, are currently being found on the dried lake floor that were formerly sunk into 200 feet of water (Zeleb, 2022). The Southern Nevada Water Authority on April 2022 observed that "The Colorado River Basin is experiencing the worst drought in recorded history".

As of April 27, 2022, water levels at Lake Mead were a third of its capacity, while 95% of California was experiencing extreme drought and statewide snowpack was only 35% of normal. The results of paleoclimate research conducted by Williams et al (2020) have shown that the last 22 year period since 2000 have been the driest in 1200 years and can be factually linked to human caused climate change. Williams et al. (2020) used a combination of hydrological modeling and tree-ring reconstructions of summer soil moisture to show that the period from 2000 to 2018 was the driest 19 year span since the late 1500s and the second driest since 800 CE. Anthropogenic trends in temperature, humidity, and rainfall measured from 31 climate models account for 46% of the drought severity pushing an otherwise moderate drought into the second worst southwest North American mega drought since 800 (Williams et al. 2020). Since publication of the 2020 Williams et al. paper in Science which was based, on data collected up to 2018, the drought has gotten significantly worse. Extremely dry conditions over the past three years have persisted and are projected to be the driest in California history (Patel and Samenow, 2022).

The current mega-drought is not confined to the western U.S.A. (Fig, 3). 96% of Portugal at the end of June 2022 was classified as being either in "extreme" or "severe" drought (Alves and Wilson).

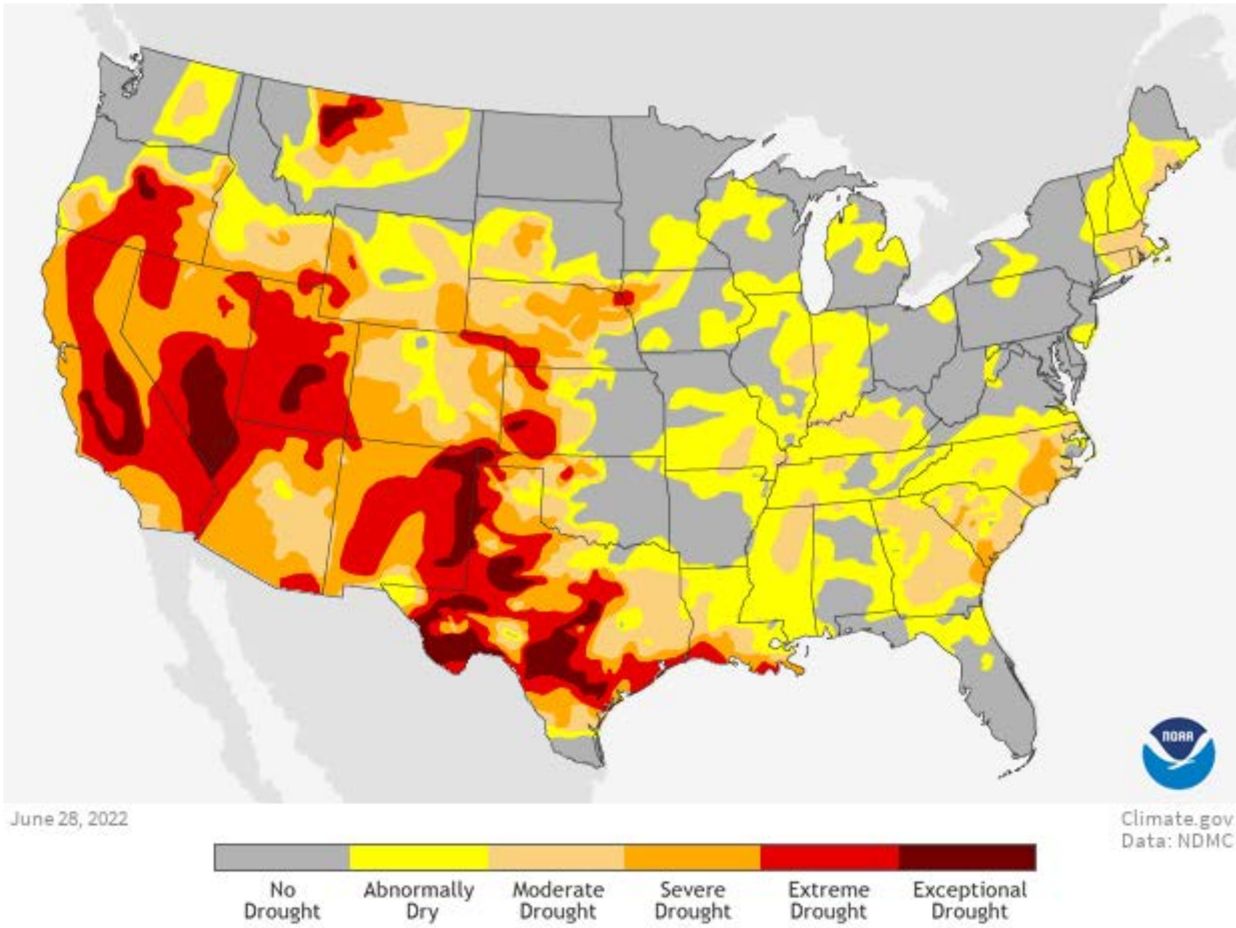

Fig. 4. *As of June 28, 2022 over half of the original United States was experiencing abnormal dry to exceptional drought conditions (Climate.gov). Tan areas are experiencing Moderate Drought: water supplies may be low and damage may occur to crops and pastures. Orange areas are in Severe Drought: water shortages are common and crop and pasture losses are likely. Red areas are experiencing Extreme Drought. Areas in this category may experience widespread water shortages and major losses of crops and pastures; forests in these areas become dry and susceptible to fire. Dark red areas are in Exceptional Drought. Shortages of water in streams, reservoirs, and wells in these areas can lead to water emergencies. Failed crops, barren pastures, and tinder-dry forests may be widespread across these areas.*

Wildfires

As of July 14, 2022, Portugal, Spain, and southern France were experiencing out of control wildfires amid one of the worst heat waves in 200 years. Over 400 people were evacuated because of wildfire that consumed 8,600 acres in western Spain (Alves and Wilson, 2022).

As of 7/11/2022 the Washburn wildfire burning the southern edge of Yosemite National Park has destroyed 3,200 acres of redwood trees after nearly a week as 550 firefighters fight to protect the historic Mariposa Grove and the 500 giant sequoias in the park (Parker, 2022). The grove includes the 209-foot tall Grizzly Giant. Several of the groves trees were hit by fire with 70-foot high scars on their trunks. So far none of the giant sequoias in Mariposa have been killed but the fire is only 22% contained (Parker, 2022). These special trees commonly live 2,000 years and have lived up to 3000 years. Will they finally die on our watch?

Dangerous Heat Waves

Columbia University's climate school recently found that exposure to extreme heat (dangerous heat waves) tripled between 1983 and 2016 and now effects over a quarter of the world's population Costley and Forster, 2021). In 2016, almost 1.7 billion people lived in areas with an increasing extreme heat trend. The most affected area was southern Asia where India accounted for 37% of the population experiencing an increasing exposure to extreme heat capable of causing rashes, cramps, and heat stroke (Costley and Forster, 2021). This extreme heating is consistent with Fig. 5. As of July 14, 2022 Portugal was experiencing record high temperatures, with the central Alentejo region reaching 46°C (115°F) on July 13 and Spain experiencing 43°C (109.4°F) on July 12. (Aleves and Wilson, 2022).

As I finish writing this paper today (7/17/2022) Kirka (2022) reports that the British government held an emergency meeting to plan for record high temperatures tomorrow and issued their first-ever "red" warning for extreme heat forecast to reach 40 degrees Celsius (104 Fahrenheit) for the first time. The British heat record is 101.7 °F set in 2019. They are particularly worried about rail tracks expanding and derailing train service.

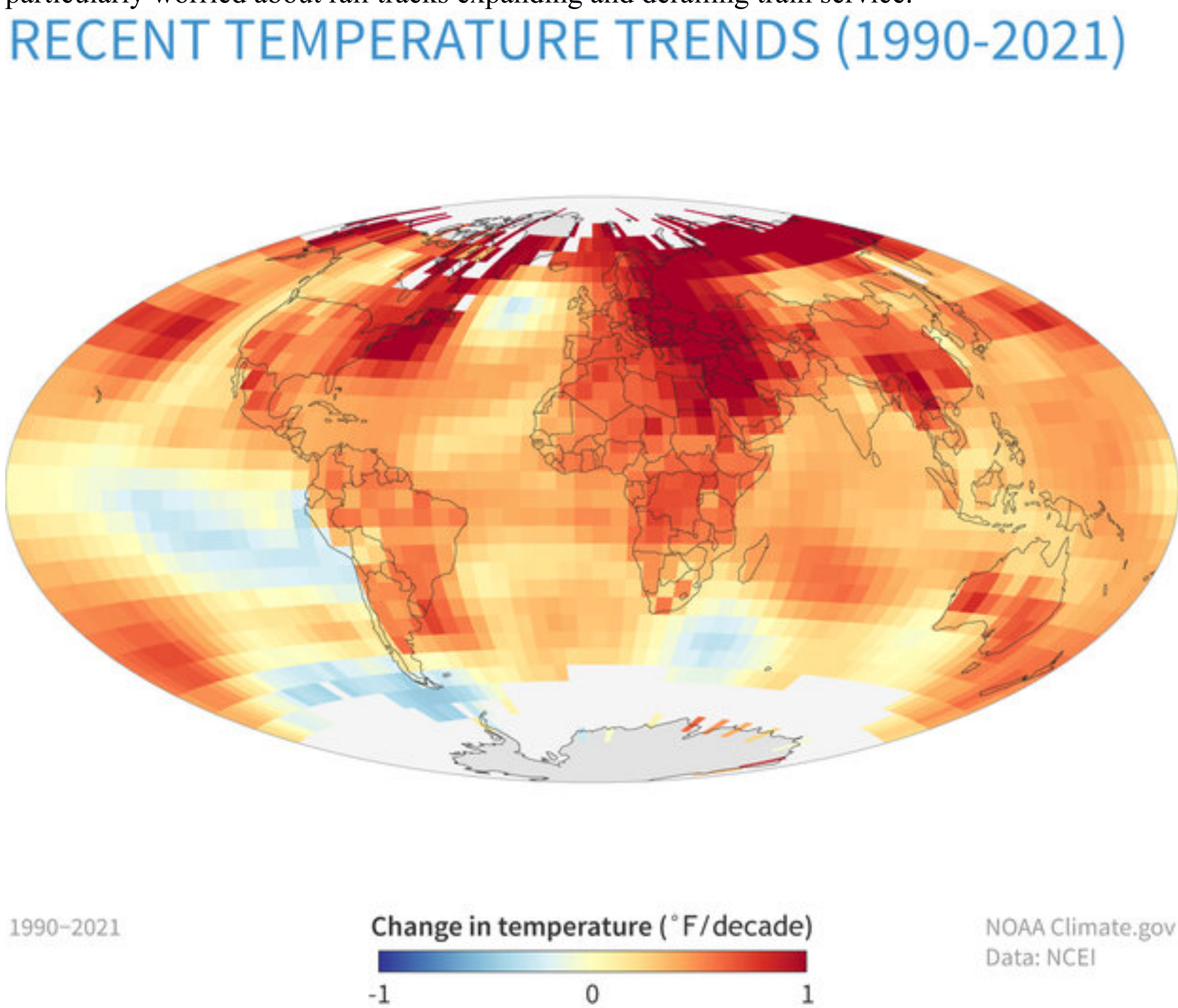

Fig. 5. *Trends in average surface temperature from 1990-2021. Overall, land areas warmed faster than oceans. The most extreme warming (darkest red) was in the northern high latitudes, and parts of Eurasia and the Middle East. Data from NOAA NCEI.*

Water Quality

Water temperatures on all of the five Great Lakes reached record-high autumn 2021 levels about 6 degrees above average (Patel, 2021). Sapna Sharma, a professor at York University, a lake water expert, said that each of 60 studied lakes in the Northern Hemisphere have warmed six times as fast in the past 25 years compared with any other period in the past century. On average the lakes are freezing about 11 days later and thawing about seven days earlier. The Great Lakes are among the fastest warming lakes in the study. Less ice means even more water will evaporate, concentrating pollutants, and allowing more algal blooms that diminish the water quality (Patel, 2021).

Infrastructure

Power outages from severe weather have doubled over the past 20 years according to an Associated Press analysis of government data (Brown et al., 2022). Main, Louisiana and California have each experienced a 50% increase in outage duration over the past few years. "Driving the increasingly commonplace blackouts are weather disasters now rolling across the country with seasonal consistency" (Brown et al., 2022). "The electrical grid is our early warning. Climate change is here and we're feeling real effects." Said Alexandra von Meier from U.C. Berkeley.

Fish and Wildlife

Researchers from the Univ. of British Columbia estimated that seabird populations have fallen 70% since the mid-20th century due to a reduction of plankton and small fish in cold northern waters (Whittle, 2021a). Warming waters deprive the birds of the sardines and anchovies they feed on. For example nearly 8000 dead birds washed up on a single beach in Alaska in the mid-2010s. Their death was due to a marine heat wave known as "the blob". In addition rising sea levels have destroyed the low-lying coastal habitats of Albatross colonies in the central Pacific (Whittle, 2021a).

New England's shrimp fishery was shut down because of concerns about the health of the shrimp population due to warming ocean temperatures (Whittle, 2021b). Warming water deprives aquatic life including shrimp of oxygen. Their health is, therefore, imperiled by the warming of the ocean off New England. There have been seven consecutive years of low abundance. Main fishermen harvested more than 10 million pounds of shrimp per as recently as 2011. Then the catch fell to less than 5 million pounds in 2012 and less than 0.6 million pounds in 2013, the first year of a fishing ban (Whittle, 2021b).

Sea Level Changes

The NSF is funding Columbia University's new five year "Learning the Earth with AI and Physics" (LEAP) project that is developing improved climate change models through the use of new technologies (Irvin and Hoff, 2021). Current projections show that sea levels will rise anywhere from half a meter to two meters in the next few decades.

An ice shelf about 460 square miles, the size of New York City collapsed in East

Antarctica, March 2020, making it the first time in human history that Antarctica had an ice shelf collapse (Borenstein, 2020). Temperatures were more than 70º warmer than normal during mid-March. Peter Neff, an ice scientist at the Univ. of Minnesota said he worries that previous assumptions about East Antarctica's stability may not be correct. That is important because if all the water frozen in East Antarctica completely melted it would raise seas across the globe about 160 feet (Borenstein, 2020). Although very unlikely within the next few hundred years, if all land ice melted, sea levels would rise 70 meters (230 feet), (NSIPC, 2022).

Hurricanes

A growing body of fact based research indicates that hurricanes are growing stronger and faster (Harris, 2021). As we enter the 2022 hurricane season the 2021 hurricane season was the sixth season in a row with above average activity as accurately predicted by NOAA. Last year was the third year ever to exhaust the list of storm names. The 2021 hurricane accumulated cyclonic energy (ACE), a mixture of a storm's power and longevity, was distinctly above average (Harris, 2021). A worsening hurricane trend, particularly post-Sandy, is becoming apparent.

However, since 2014 when NOAA stopped publishing annual trend charts, reliable hurricane trend charts are difficult to access. Instead, a variety of conflicting charts from questionable sources have recently been published. Nevertheless, making the safe assumption that NOAA data is reliable; the NOAA data supports a distinctly post Sandy upward trend. The 1950 to 2013 data (Fig. 6) shows no increase in hurricane activity between 1950 through 1995. But in 1995 hurricane activity starts to increase, particularly if uncharted 2014 through 2021 data were included. Based on the most recent 30-year climate record NOAA has recently recalculated the "average" Atlantic hurricane season to reflect more storms (NOAA, 2021). Beginning in 2021 NOAA's Climate Prediction Center (CPC) will use 1991-2020 as the new 30-year period of record as their new definition of "average". The new average compared with the old "average" based on 1981-2010 data increases the number of named storms from 12 to 14 and the number of hurricanes from 6 to 7. The update "...reflects a very busy period over the last 30 years, which includes many years of a positive Atlantic Multi-decadal Oscillation, which can increase Atlantic hurricane activity. These updated averages better reflect our collective experience of the past 10 years, which included some very active hurricane seasons. NOAA scientists have evaluated the impact of climate change on tropical cyclones and determined that it can influence storm intensity." (NOAA, 2021).

Since the deadline for submission of manuscripts to GANJ was Aug. 1, it is impossible to comment of this year's hurricane season. However it will be interesting to compare the actual hurricane data during the October mid-hurricane-season GANJ conference with the NOAA predictions made May 24 of this year (2022). NOAA predicts an above average 2022 hurricane season based on ongoing La Nina above-average Atlantic temperatures (NOAA, 2022a). NOAA has calculated a 65% chance that 2022 will have an above normal hurricane season with 14-21 named storms, 6-10 hurricanes, and 3-6 major hurricanes. NOAA Administrator Rick Spinrad said "... past storms such as Superstorm Sandy, wish devastated the New York metro area ten years ago – remind us that the impacts of one storm can be felt for years. Since Sandy, NOAA's forecasting accuracy has continued to improve... "(NOAA, 2022a). On June 28, 2022 NOAA introduced the nation's newest weather and climate supercomputers. Twin supercomputers became operational named Dogwood and Cactus. Each supercomputer operates at a speed of 12.1 petaflops – three times faster than NOAA's former system (NOAA, 2022a).

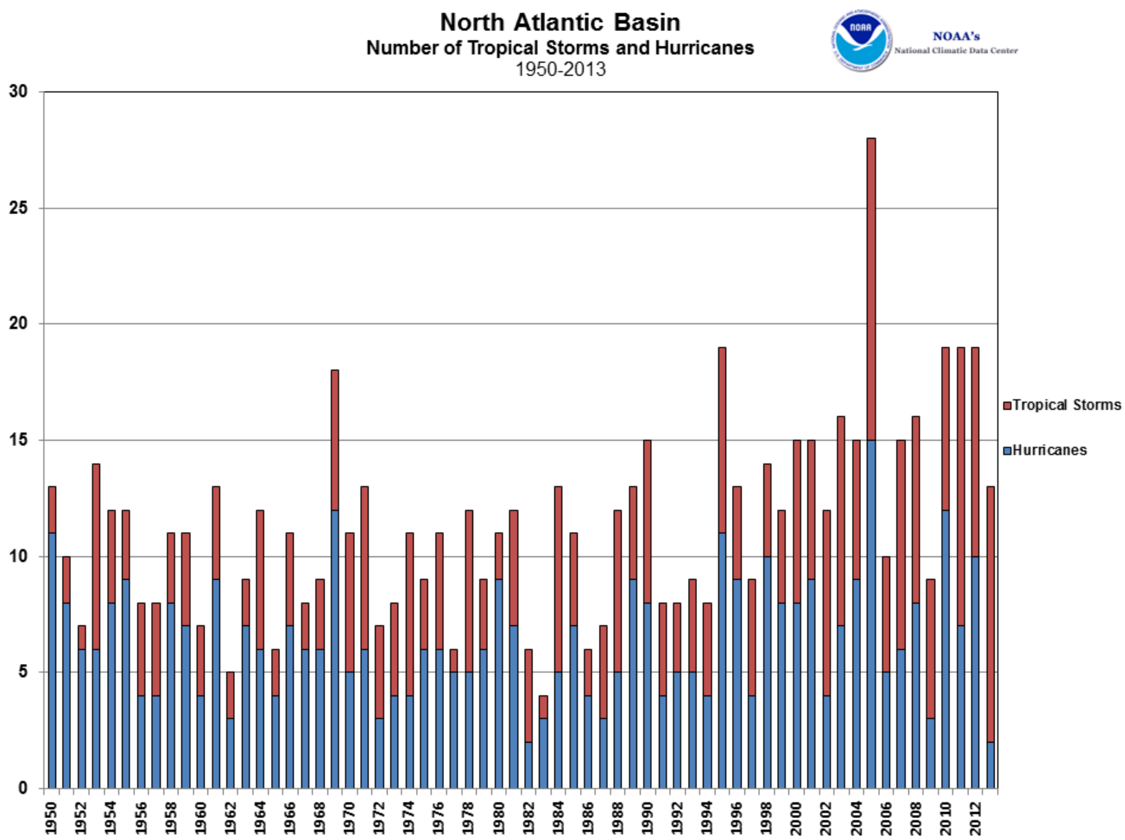

Fig. 6. *Bar chart of the number of Tropical Stormes and Hurricanes between 1950 and 2013 (NOAA).*

Tornadoes

Tornadoes caused catastrophic damage across six states on Dec 10, 2021 killing dozens. One of the tornados broke a 100-year old record for how long a tornado stayed on the ground in a path of destruction (Naishadham and Borenstein, 2021). Atmospheric conditions that give rise to tornado outbreaks are intensifying in the winter as the planet warms. Tornado alley is shifting farther east away from the Kansas-Oklahoma area. In 2019 tornado activity increased in the Midwest and Southeast. (Naishadham and Borenstein, 2021).

More than 100 people were killed during the Friday Dec 10, 2021 tornado making it the deadliest December tornado on record. It carved a 250-mile course through Arkansas, southeast Missouri, northern Tennessee and western Kentucky with winds of 190 to 205 mph. Radar data detected debris above 30,000 feet; a very rare occurrence (Samenow J. 2021). 163 tornados were confirmed last December, the most on record for Dec. by far (Samenow J. 2021).

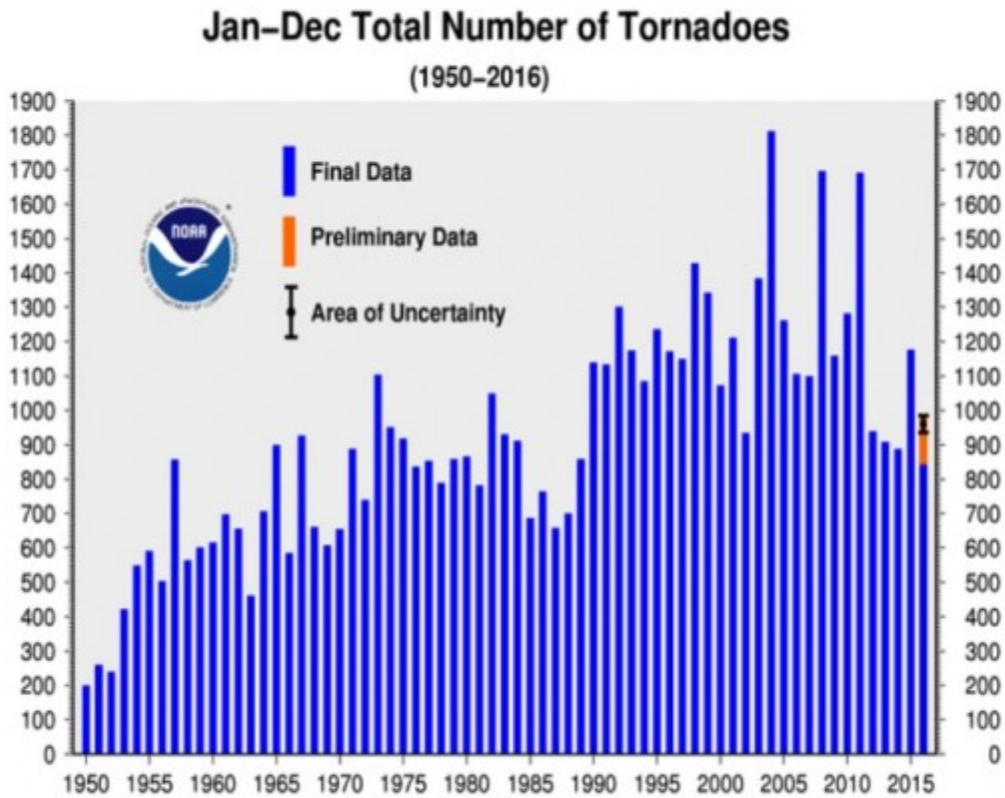

Fig. 7. *Bar chart of the total number of tornadoes between 1950 and 2016 (NOAA).*

Glacial Retreat

Glacial retreat is particularly acute for South America, where several artificial lakes used for drinking water are filled almost exclusively by glacial melt originating in the Andes Mountains (BBC News, 2003). Asian countries including India and China also depend on the seasonal glacier melt water for irrigation and drinking supplies from glaciers in the Himalayas and in the Pacific Northwest of North America, glacier runoff is important for hydropower. Currently, nearly all glaciers have a negative mass balance (Fig. 8) measured in meters of water equivalent which is a measure of the thickness lost (or gained) from the surface of the glacier. In addition to the loss of potential water supplies for drinking, irrigation, recreation, and hydroelectric power, glacial water drainage into the world's oceans are contributing to increasing sea levels. It is important to note the steepening trend line of Fig. 8, particularly the post Sandy portion of the curve. Since Sandy the glacial retreat trend has been speeding up.

Figure 9 presents comparative photographs of the Muir Glacier, Alaska. I (the author) was one month old on August, 1941 when the first photograph was taken (Fig. 9a). As a boy and teenager I spent several summers on camping trips at Glacier Park, Montana or Banff National Park, British Columbia hiking through the glaciers. Most of the Glacier Park glaciers are currently gone or almost gone. The esthetic loss of glaciers is hard to quantify but the trend is clear; quite sad (an opinion).

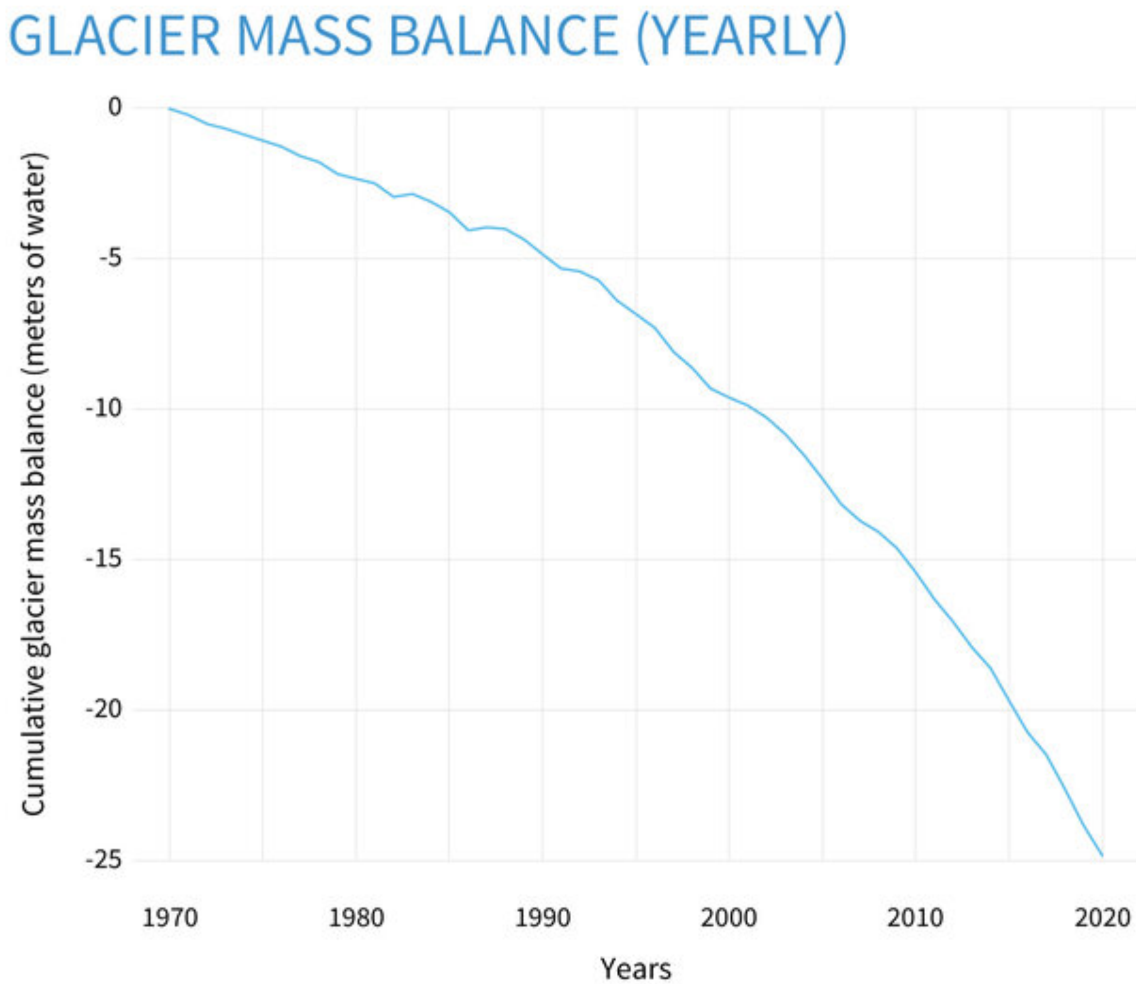

Fig. 8. Ice loss relative to 1970 for the glaciers in the World Glacier Monitoring Service's climate reference network. Including the preliminary values for 2019-2020, these glaciers have lost a thickness of ice equivalent to about 27.5 meters (90 feet) of water spread out over each glacier. Data from WGMS reported by NOAA Climate.gov

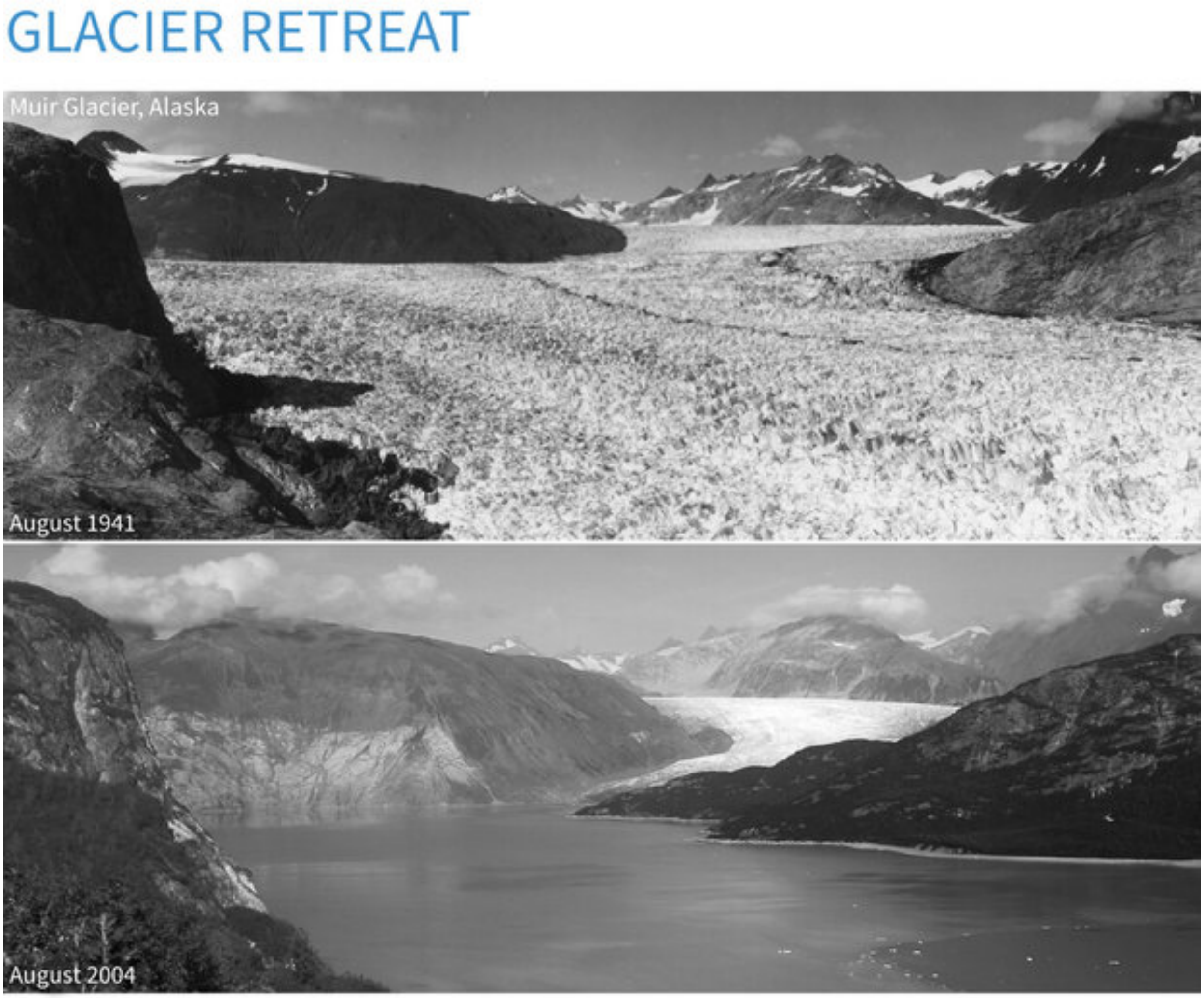

Fig. 9. Retreat of Alaska's Muir Glacier between August 1941 and August 2004. In the six decades between the photos, the glacier has retreated far into the mountains. Photos from the National Snow and Ice Data Center.

Atmospheric CO2 trends

About half of the CO_2 emitted since 1850 remains in the atmosphere while the other half is dissolved in the world's oceans. The biosphere is also a sink for CO_2 but deforestation and forest fires cancel the terrestrial uptake (Friedlingstein et al. 2019). Carbon dioxide and other greenhouse gases absorb heat and release it gradually over time. Without this greenhouse effect the Earth's average temperature would be below freezing instead of close to 60ºF (NOAA, Climate.gov).

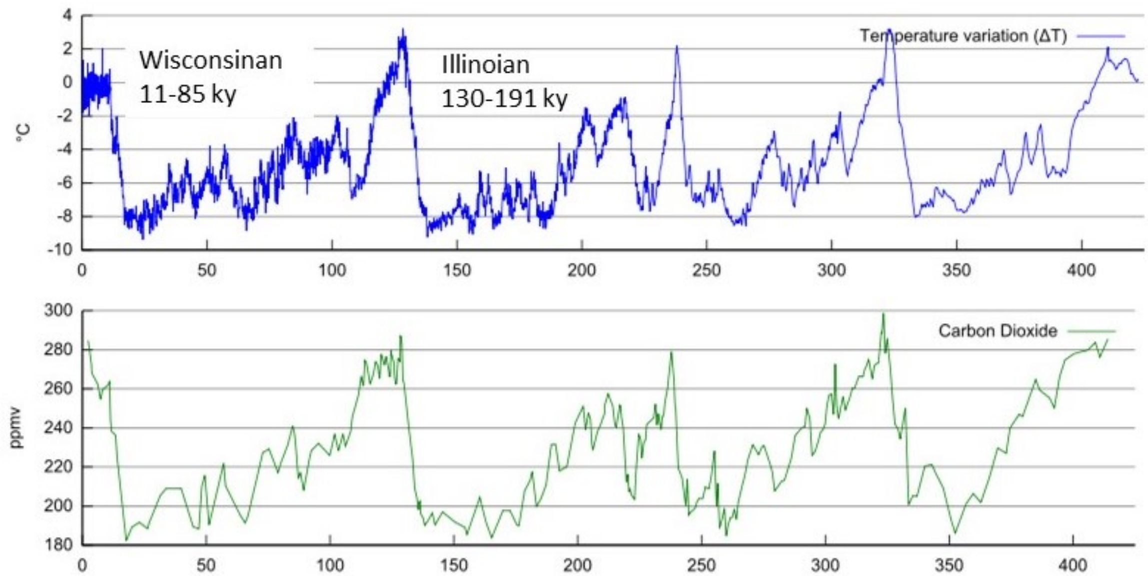

Fig. 10. *The CO_2 and Temp. data is based on is based on ice core data from the Vostak ice cores (Petit et al, 1999) going back to 420,000 thousand years before present. Note the very close correlation between T and CO_2 content.*

Fig. 10 shows that we are currently in an interglacial interval based on data collected from the Vostok, East Antarctica Ice Cores published by Petit et al. (1999). A variety of data collected from the 3623 m thick ice cores, including oxygen isotopes, provides direct evidence of temperatures back to 420,000 years before present. Ironically, however the cores do not provide good data on the most recent 100 years or so. In May 2013, it was reported that atmospheric readings for CO_2 surpassed 400 ppm for the first time.

Fig. 11 goes still further back in time based on the Antarctic ice core data of Lüthi, D. et al, (2008). On this time scale, the increase to 2021's 414.7 ppm looks practically instantaneous. As of June 2022 the global atmospheric CO_2 content has increased still further to a record 419 ppm CO_2 (NASA, 2022).

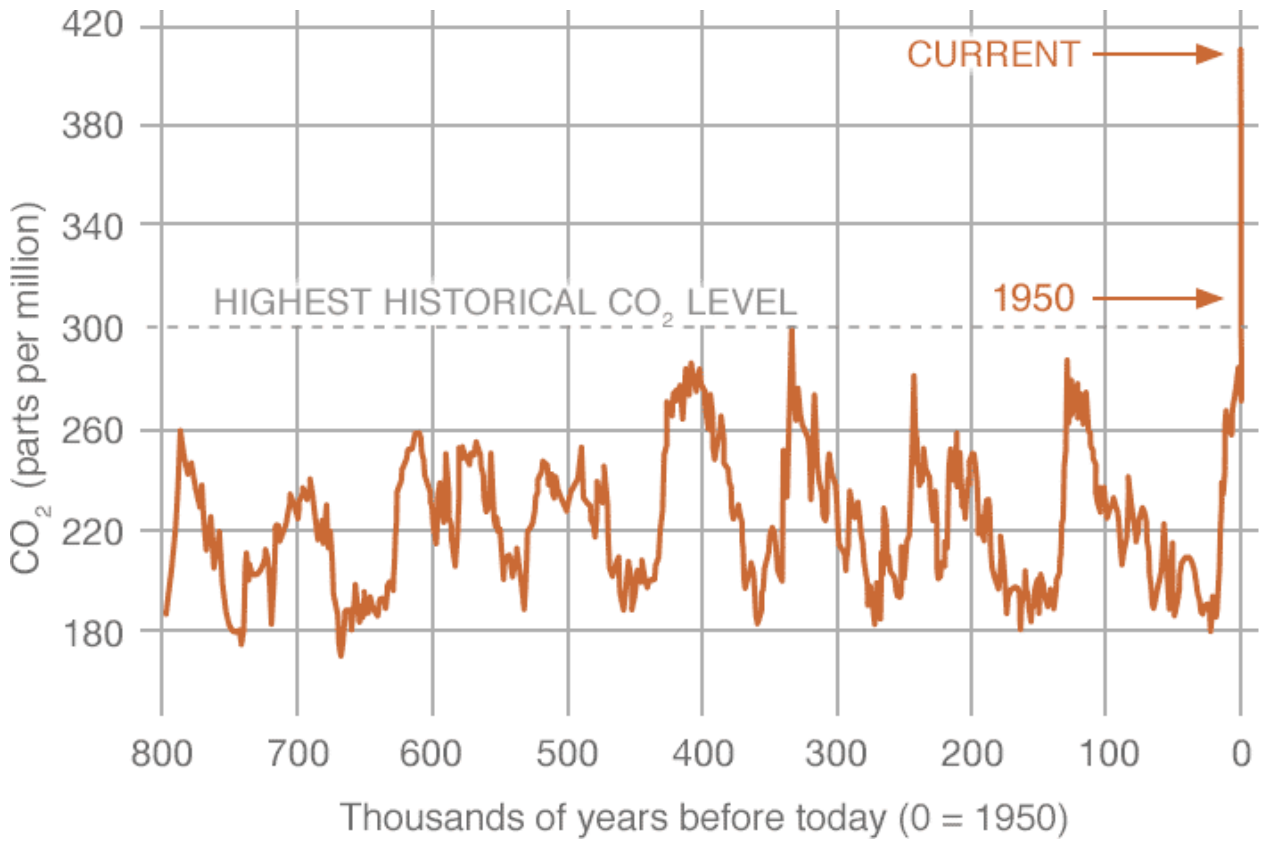

Fig. 11. *The amount of carbon dioxide in the atmosphere during ice ages and warm periods over the past 800,000 years, based on Antarctic ice core data (Lüthi, D. et al, 2008). Source is NOAA, Climate.gov accessed 7-17-2022.*

Figure 12 is a graph that shows the monthly mean atmospheric carbon dioxide measured at Mauna Loa Observatory, Hawaii. An important aspect is the fact that the trend is not linear but is accelerating. Note the relative position of Hurricanes Sandy and Ida. A continuation of an increasing CO_2 level since Hurricane Sandy is absolutely clear (Fig. 12) together with global warming implications. Figure 12 is absolutely factual and helps answer the original question posed in the title of this chapter. Another fact is that greenhouse gas buildup forces global warming (Fig. 3). If you, dear reader, conclude that global warming (a higher energy atmosphere) is or even potentially could be dangerous to humanity. You have the obligation as a responsible human to act accordingly. For suggestions pertaining to appropriate actions that you should take, I refer you to a recent book by Michael Mann titled "The New Climate War: The Fight to Take Back Our Planet" (Mann, 2021).

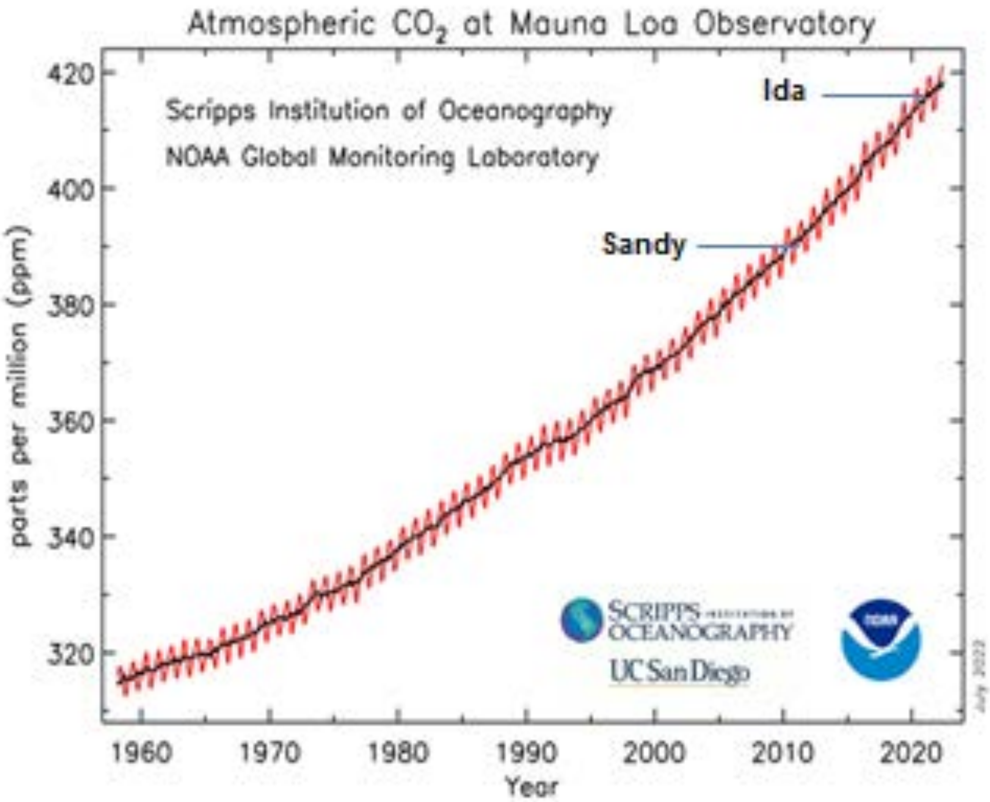

Figure 12. *The graphs show monthly mean carbon dioxide measured at Mauna Loa Observatory, Hawaii. The carbon dioxide data on Mauna Loa constitute the longest record of direct measurements of CO_2 in the atmosphere. They were started by C. David Keeling of the Scripps Institution of Oceanography in March of 1958 at a facility of the National Oceanic and Atmospheric Administration [Keeling, 1976]. NOAA started its own CO_2 measurements in May of 1974, and they have run in parallel with those made by Scripps since then [Thoning, 1989]. The data for Figure 12 extends up to July 2022. The relative time positions of Hurricanes Sandy and Ida are added for comparison.*

CONCLUSIONS

It could be argued that I have presented only negative aspects of weather events cherry picked from the literature. It is true that I may have missed an important post Ida tornado, or drought event during this last year that actually benefited the effected community, but I doubt it, and I actually would have included it if I had seen such a report. However, even if all the destructive weather events included in this report are discounted, one trend remains (Fig. 11 together with Fig. 12) that is so important that in my opinion it should be presented in all science classes beginning in first grade. Any objective person cannot seriously look at Figures 11 and 12 without concluding that something potentially very dangerous to humanity is occurring. If temperatures (Fig. 10a) start catching up with CO_2 levels (Fig 10b, 11 and 12) as they always have (Fig 10) we are in for some problems that we should take very seriously.

The fact that 60 percent of Americans according to the Yale Program on Climate Change Communication (Leiserowitz, et el. 2021) are either "climate deniers" or totally misinformed about climate science (Figure 13) indicates to me that Science teachers and Earth Science professors (including myself) have failed miserably to teach the importance of greenhouse gas emission and ought to treat the subject with the importance that it deserves. That is my concluding opinion.

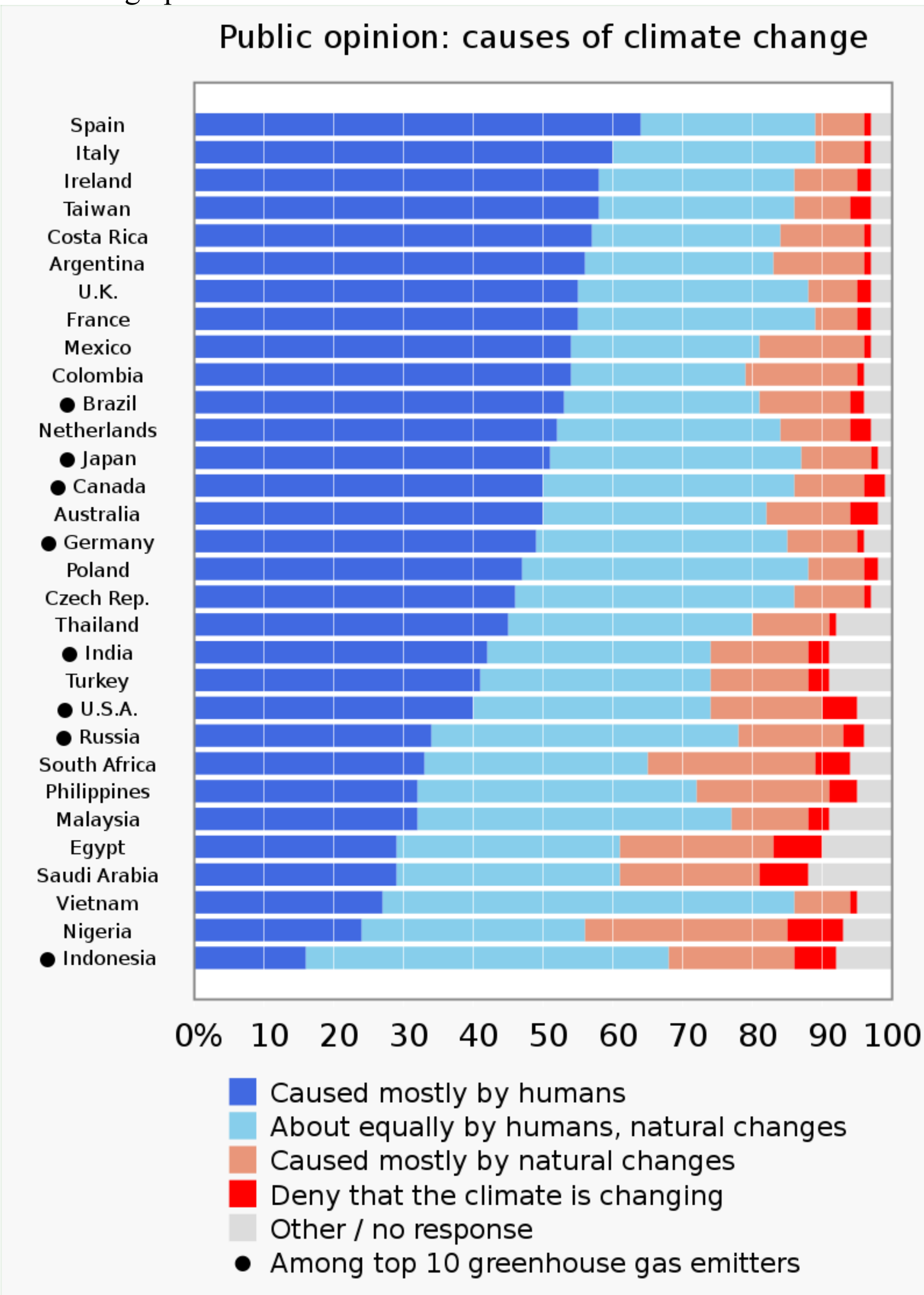

Fig. 13. *Bar chart showing public opinion on causes of climate change as reported by Yale Program on Climate Change Communication.* ***If there is any doubt about the actual cause of climate change see Figure 3****. Source: Leiserowitz, et al. (2021).*

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Understanding the Vulnerability of Staten Island's Eastern Coastline from a Beach Morphology Perspective

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Introduction

Staten Island's beaches were shown to be vulnerable to storm surge during Hurricane Sandy, with severe inundation into neighborhoods along the eastern shoreline; the area chosen for this study (Figure 1), and the area in which the Army Corps of Engineers plan to start constructing a seawall. A preliminary survey in summer 2018 (Alexander and Avilla Sanchez, 2019) suggested that this shoreline is reflective - i.e., one that changes little over the course of a year, but which is vulnerable to erosion during major storm events (Short, 1999). The current work is designed to test the hypothesis that this is a reflective shoreline by completing regular field surveys over the course of a year and using the data collected to make predictions about future shoreline responses to storm events and sea level rise.

Figure 1. Location of study area on the eastern shoreline of Staten Island

Methodology

During the summer of 2018, Alexander and Avilla Sanchez (2019) conducted a survey of 9 measured transects from the low tide mark to the base of the dunes (most of which are man-made structures). This original survey used simple equipment – a 2 m long builders' level and a cell phone clinometer. A second survey was completed in August 2022 at 8 of the original sites and an additional 4 (Figure 2), to provide better coverage of the entire shoreline. This second survey used ranging poles and a Brunton Axis Transit, for more accurate measurement of angles, but still used a 2 m interval for the survey. Using the angular slope measured at 2 m intervals and basic trigonometry, we plotted the transects in an Excel spreadsheet. All surveys were completed within an hour of low tide.

2018	I	H	G			E	D			C	B	A
2022	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	T11	T12

Figure 2. Locations and corresponding names of transects surveyed in 2018 and 2022

While measuring the transects samples were collected from the low tide ridge, the high tide mark, the top of the berm (where present; 2022 only) and the top of the beach, right before the start of dune vegetation or man-made dune structure. During the 2022 survey, an additional "offshore" sample was collected at a water depth of approximately 1 m. These samples were dried, and sieved into different grain size fractions. Size fractions were statistically analyzed using GRADISTAT (Blott and Pye, 2001), to identify any significant relationships between grain size characteristics and location on the beach. 2022 sample analysis is not yet complete at the time of writing.

Results

Beach morphology

Profiles from 2022 (blue) and 2018 (orange) are shown in
Figure 3. Transects from 2018 (orange) and 2022 (blue) and their locations on the beach
.
The beach profiles are all typical of a sandy, wave dominated beach. Variations along shore are partially the result of sand movement being restricted by groins, with a much wider overall beach profile being present where sand is accumulating on the up-current side of the structure (
Figure 3. Transects from 2018 (orange) and 2022 (blue) and their locations on the beach
and Figure 4). Despite this, the slope of the beach face (between low tide and high tide) does not vary much along the beach, and is between 4.7° and 8.5° (Figure 4). Slight changes between the 2018 and 2022 surveys are discussed below.

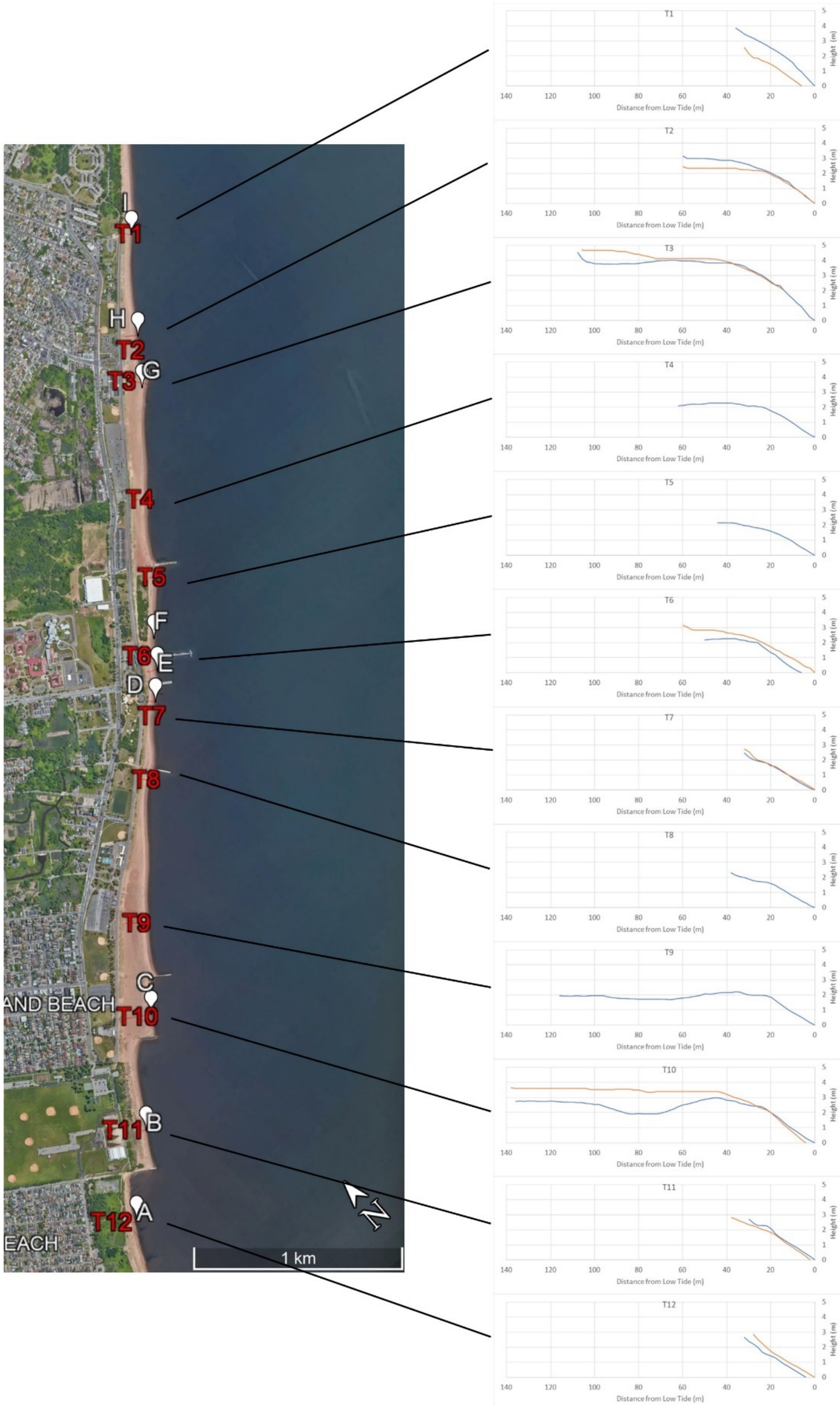

Figure 3. Transects from 2018 (orange) and 2022 (blue) and their locations on the beach

.

Location	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	T11	T12
Beach width (m)	36	60	108	62	44	50	32	38	116	136	30	28
Beach face slope (°)	8.5	6.0	8.1	5.2	4.9	5.6	4.8	4.7	5.2	5.7	6.0	5.2

Figure 4. Beach widths and beach face slopes recorded in 2022.

Sediment grain size analysis

The sediment grain size distributions for samples that have been analyzed so far are summarized in Figure 5, with 2022 samples plotted in blue and 2018 samples in orange. In general, sediments collected from the low tide ridge are the coarsest grained and most poorly sorted, being mostly sandy gravels (Figure 5 and
Figure 6. Summary of low tide sediment parameters calculated using GRADISTAT (Blott and Pye, 2001) with the parameters of Folk and Ward (1957)). The 2022 surveys took more care with timing close to low tide, and wading to find the ridge, which may explain the fact that these more recent samples seem to be coarser. The presence of a low tide ridge or step, composed of coarse sands and gravels is typical of a reflective beach (Short, 1999)

The samples taken from the most recent high tide mark are the most variable (Figure 5 and Figure 7). Most are sandy gravels or gravelly sands, and the distribution of gravel is most likely a result of deposition on the surface by waves at the most recent high tide. This is supported by the observation that the coarser samples are also the most poorly sorted and often show a bimodal distribution of grain sizes. So far, only three berm samples have been analyzed (blue triangles in Figure 5), but the expectation is that when all of the berm samples are analyzed they will be less variable than the high tide mark. However, not at all locations had a clear berm.

The samples from the top of the beach are the most consistent, both geographically and over time (Figure 5 and Figure 8). They are also the least coarse grained, and are all slightly gravelly sands with a mean grain size of medium sand. They are moderately to poorly sorted, although samples in the latter category have a sigma value only marginally greater than 1 (1.005 – 1.138). Outside of major storm events, these sediments are transported primarily by aeolian processes (Short and Jackson, 2013).

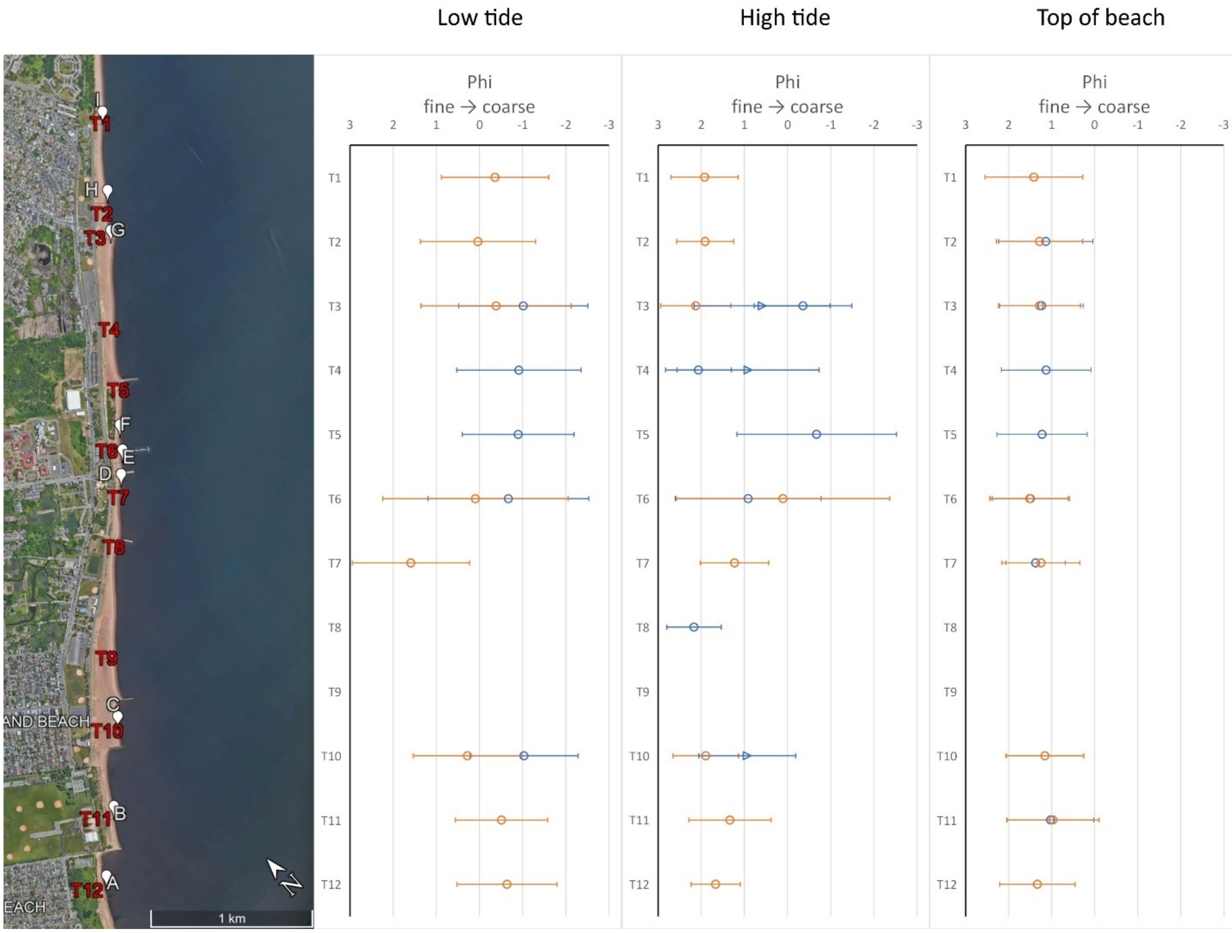

Figure 5. Distribution of mean grain size (circles) and sorting (error bars show σ) using the Folk and Ward (1957) method, as calculated using GRADISTAT (Blott and Pye, 2001). Data from the 2018 survey are shown in orange and from the 2022 survey in blue.

Location	2018 Low tide			2022 Low tide		
	Textural group	Mean grain size	Sorting	Textural group	Mean grain size	Sorting
T1	Gravelly sand	V. coarse sand	Poorly sorted			
T2	Gravelly sand	Coarse sand	Poorly sorted			
T3	Sandy gravel	V. coarse sand	Poorly sorted	Sandy gravel	V. fine gravel	Poorly sorted
T4				Sandy gravel	V. coarse sand	Poorly sorted
T5				Sandy gravel	V. coarse sand	Poorly sorted
T6	Sandy gravel	Coarse sand	V. poorly sorted	Sandy gravel	V. coarse sand	Poorly sorted
T7	Gravelly sand	Medium sand	Poorly sorted			
T8						
T9						
T10	Gravelly sand	Coarse sand	Poorly sorted	Sandy gravel	V. fine gravel	Poorly sorted
T11	Gravelly sand	V. coarse sand	Poorly sorted			
T12	Sandy gravel	V. coarse sand	Poorly sorted			

Figure 6. Summary of low tide sediment parameters calculated using GRADISTAT (Blott and Pye, 2001) with the parameters of Folk and Ward (1957)

Location	2018 High tide			2022 High tide		
	Textural group	Mean grain size	Sorting	Textural group	Mean grain size	Sorting
T1	Slightly gravelly sand	Medium sand	Moderately sorted			
T2	Slightly gravelly sand	Medium sand	Moderately well sorted			
T3	Slightly gravelly sand	Fine sand	Moderately sorted	Sandy gravel	V. coarse sand	Poorly sorted
T4				Slightly gravelly sand	Fine sand	Moderately sorted
T5				Sandy gravel	V. coarse sand	Poorly sorted
T6	Sandy gravel	Coarse sand	V. poorly sorted	Gravelly sand	Coarse sand	Poorly sorted
T7	Slightly gravelly sand	Medium sand	Moderately sorted			
T8				Slightly gravelly sand	Fine sand	Moderately well sorted
T9						
T10	Slightly gravelly sand	Medium sand	Moderately sorted			
T11	Slightly gravelly sand	Medium sand	Moderately sorted			
T12	Slightly gravelly sand	Medium sand	Moderately well sorted			

Figure 7. Summary of high tide sediment parameters calculated using GRADISTAT (Blott and Pye, 2001) with the parameters of Folk and Ward (1957)

Location	2018 Top of beach			2022 Top of beach		
	Textural group	Mean grain size	Sorting	Textural group	Mean grain size	Sorting
T1	Gravelly sand	Medium sand	Poorly sorted			
T2	Slightly gravelly sand	Medium sand	Poorly sorted	Slightly gravelly sand	Medium sand	Poorly sorted
T3	Slightly gravelly sand	Medium sand	Moderately sorted	Slightly gravelly sand	Medium sand	Moderately sorted
T4				Slightly gravelly sand	Medium sand	Poorly sorted
T5				Slightly gravelly sand	Medium sand	Poorly sorted
T6	Slightly gravelly sand	Medium sand	Moderately sorted	Slightly gravelly sand	Medium sand	Moderately sorted
T7	Slightly gravelly sand	Medium sand	Moderately sorted	Slightly gravelly sand	Medium sand	Moderately well sorted
T8						
T9						
T10	Slightly gravelly sand	Medium sand	Moderately sorted			
T11	Slightly gravelly sand	Coarse sand	Poorly sorted	Slightly gravelly sand	Medium sand	Poorly sorted
T12	Slightly gravelly sand	Medium sand	Moderately sorted			

Figure 8. Summary of top of beach sediment parameters calculated using GRADISTAT (Blott and Pye, 2001) with the parameters of Folk and Ward (1957)

Discussion

This part of the Hudson Estuary has a low tidal range, with a maximum of about 2 m during spring tides. Wave heights are also relatively low (< 1 m) in the sheltered estuary mouth location, except during major storms. The beaches are stabilized by a series of groins, making the direction of littoral drift easy to interpret (Figure 9). The current direction is towards the south, south of Ocean Breeze Fishing Pier, and towards the north to the north of the pier. All of these characteristics contribute to the beach morphology and grain size distributions measured in the surveys.

Figure 9. Longshore current directions.

Relationships among morphology, grain size and location

Overall, the mean grain sizes of sediments on the beach range from medium to very coarse sands, with moderate to poor sorting (Figure 5). Beach face slopes range from 4.7° to 8.5° (Figure 4). These characteristics are typical of a reflective shoreline in an area with a low tidal range. All transects had the presence of a ridge or step at the low tide mark containing the coarsest material. Such a feature forms only on reflective beaches, and results from wave action on the steep beach face slope (Short, 1999). Both the uprush and backwash of incoming waves deposit the coarser material at this location, in effect "trapping" it there. Immediately seaward of this we would expect the sediment to become finer again. The 2 offshore samples processed so far suggest that this is true, with mean grain sizes of -0.12 φ and -0.55 φ. While these characteristics are consistent across all surveyed locations, there are some other variations linked to the interactions of littoral drift and groins.

The transects that are on the up current sides of groins have the widest beaches, averaging 78.3 m (T1, T3, T5, T9, T10 and T11), as would be expected from the build-up of sand in these locations. However, there is no relationship between the slope of the beach face and the location or the width of the beach. Two of these surveyed transects (T5 and T11) measured as narrower; however, these locations have well-established dune vegetation that is much wider than on most of this shoreline. We did not continue surveying into sensitive vegetated areas of the dunes. While we might expect these areas of sand deposition to have finer sediments than elsewhere on the beach (as these grains are more easily transported) the samples measured so far do not support this hypothesis.

Three transects are in areas experiencing significant erosion (T6, T7 and T12). These transects have the narrowest beaches, averaging 36.7 m. T6 and T7 are at the location where the longshore currents are diverging, so only erosion takes place (Figure 9). T12 is located beyond a series of long groins, and therefore is cut off from the sediment supply of the littoral drift (
Figure 3. Transects from 2018 (orange) and 2022 (blue) and their locations on the beach
). Again, there is no relationship between the beach face slope and beach width. The initial 2018 survey found that low tide sediments were finer at T6 and T7 where the currents diverge, which is not what we would expect. It was hypothesized that this might be related to beach replenishment done in this area. We are awaiting the analysis of the 2022 samples from these locations to see if there have been any changes.

Temporal variations

When we compare the surveys from 2018 and 2022, we see that the position of the low tide line has moved in some locations. This is most common in the areas of erosion and deposition identified above. The change in the measured latitude and longitude of the low tide starting point for our transects was confirmed by comparison with historical Google Earth images (Figure 10 and Figure 11). It should be noted that the images from 2018 do not seem to represent as low a tide as those from 2022. This may be due to the survey taking place before or after low tide, or the difference between spring and neap tidal ranges.

Figure 10 shows the locations where the low tide line has expanded seaward due to the buildup of sand behind groins. T1 is at the northern end of South Beach, where the littoral drift is towards the northeast. The transect measurements and Google Earth images show that the low tide line has moved by approximately 7 m at this location. Despite this deposition, the beach face slope angle has remained unchanged. T10 and T11 are at the southern end of Midland Beach, where the littoral drift is towards the southwest. The low tide line has moved approximately 5 m and 2m at these locations respectively. Here, we see that there is a slight reduction in the beach face slope angle as the sand has built up. We will continue to monitor these slopes, to see if wave action causes them to steepen again. The measured transects from T11 would appear to show that the beach has narrowed, however this is the result of expanded dune vegetation.

Figure 11 shows the locations where erosion is taking place. T6 and T7 are at the location where the longshore currents diverge. At T6 the low tide line has moved approximately 7 m landward, and there has been a steepening of the beach face slope. T7 has not seen any beach face erosion, or changes to the low tide line, however there has been significant damage to the artificial dune structure at the top of the narrow beach, which is clearly visible in the Google Earth images. T12 is located on New Dorp Beach, beyond the southern end of a sequence of long groins, and so is starved of sand from littoral drift. It has experienced about 5 m of erosion, with the front of the dunes moving about the same distance as the low tide line, and the beach face slope angle being unchanged.

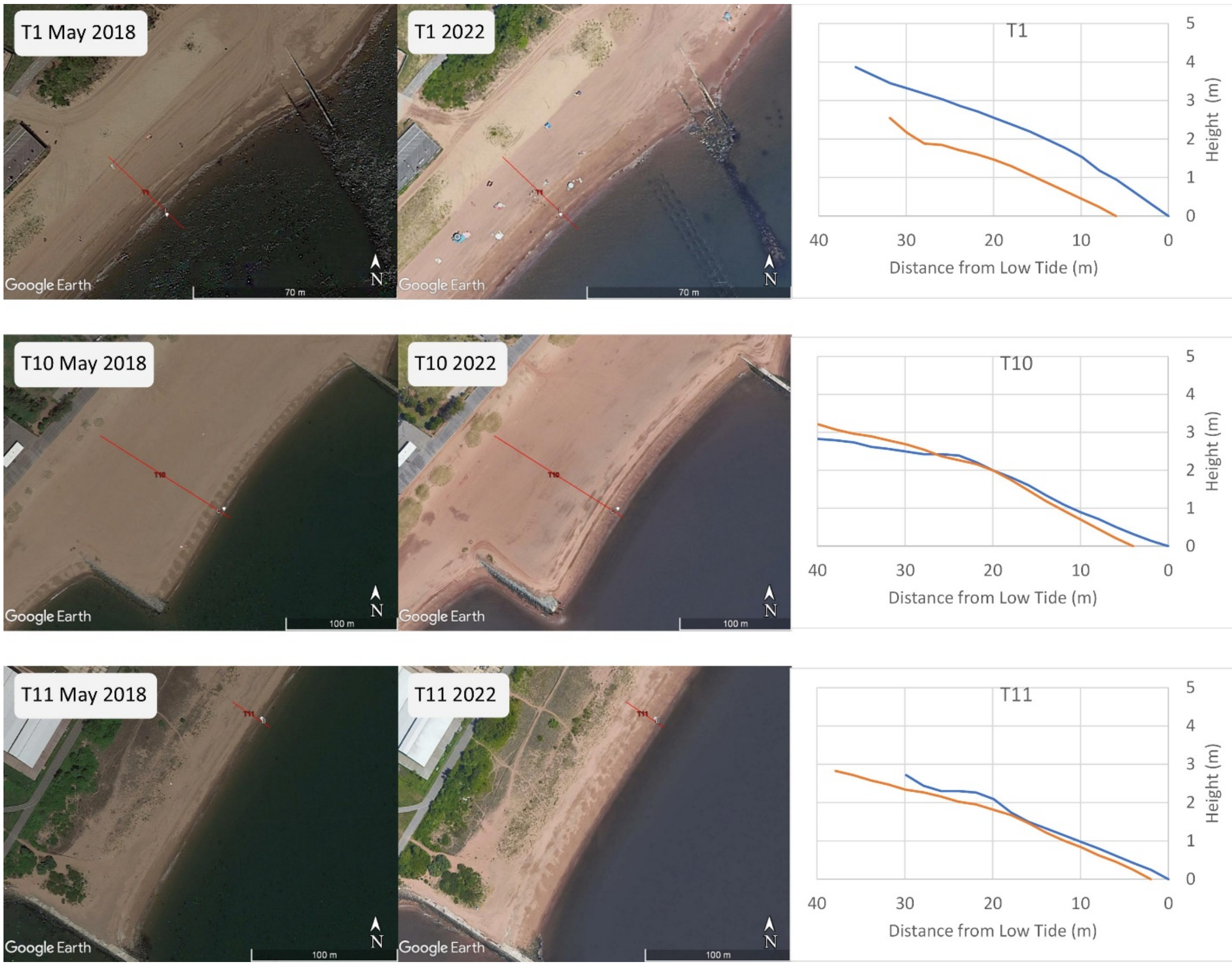

Figure 10. Google Earth images and measured transects showing areas where sand has built up behind groins (T1, T10 and T11). The white marks indicate the low tide point on the 2018 surveys, and the red lines mark the 2022 full transects from low tide to top of beach.

Implications for beach vulnerability

The natural beach morphology in this area, combined with high levels of human intervention that have led to the removal of any natural dune system, leave it highly vulnerable to erosion and inundation during storm events, such as Superstorm Sandy. Reflective shorelines are particularly at-risk during storms from the long period waves and storm surge that lead to overtopping and beach face slumping. Intermediate and dispersive beach morphologies are less susceptible to these processes (Short, 1999). Another feature of reflective shorelines is that there is little temporal variation in morphology, as this study so far has demonstrated. This feeds into a mentality that the beach is a permanent feature, and makes development in the area seem safe. This encourages construction in areas that are at risk when a major storm occurs.

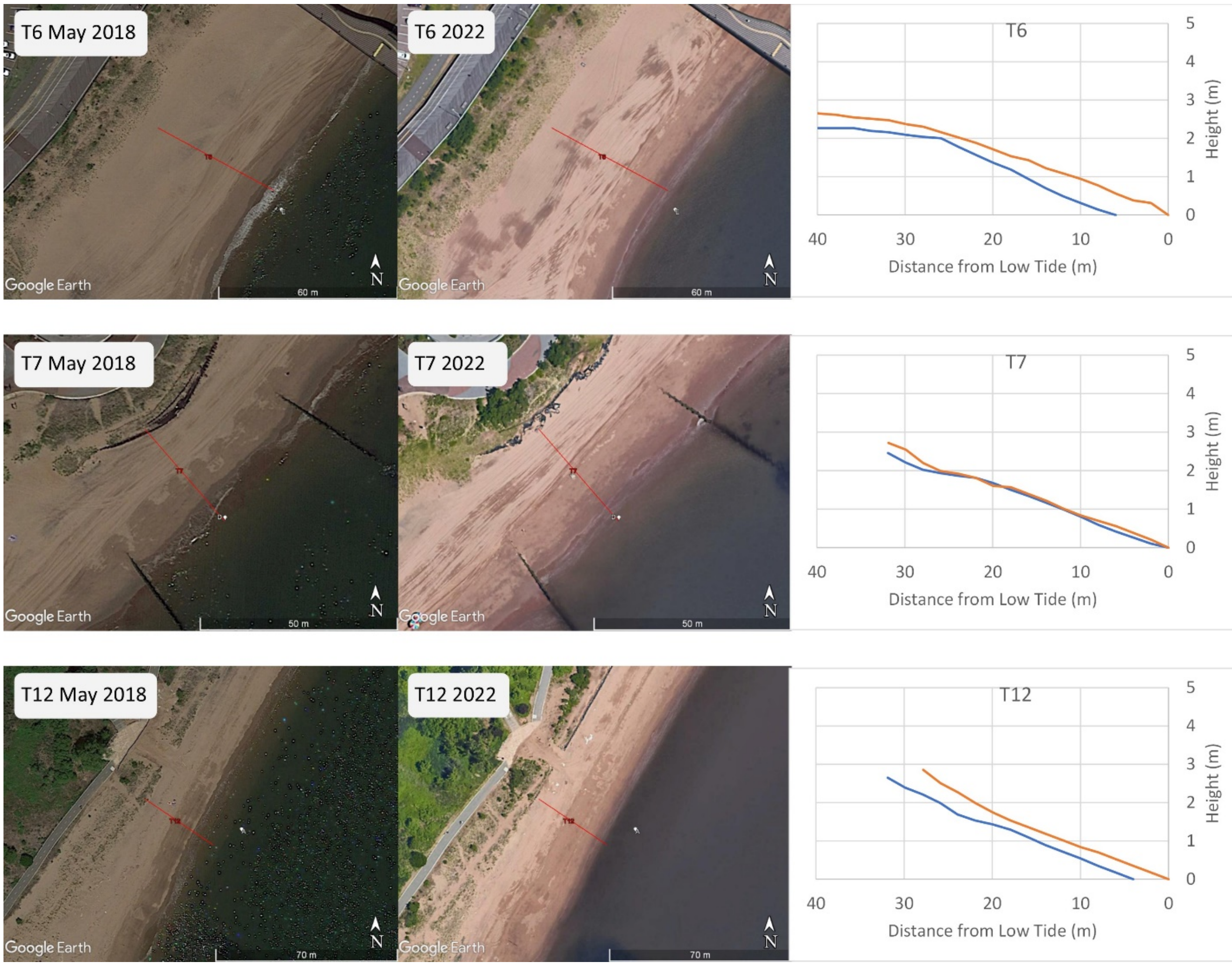

Figure 11. Google Earth images and measured transects showing areas where erosion has occurred (T6, T7 and T12). The white marks indicate the low tide point on the 2018 surveys, and the red lines mark the 2022 full transects from low tide to top of beach.

Future Work

The August 2022 survey will be repeated in November 2022, February 2023 and May 2023 to monitor changes over the course of a year. We expect these surveys to confirm the reflective beach morphology, and a lack of variation in the profiles and grain size distribution over the course of the year. We also plan to compare our measured transects with LiDAR data that is available for 2017.

In 2016, the Army Corps of Engineers published their plans for a series of structures along this part of the Staten Island shoreline, aimed at preventing future inundation. This will mostly consist of a buried seawall, covered in sand, which will replace the existing limited dunes and incorporate a new boardwalk. Concerns include the risk that such a structure may lead to increased beach erosion, although the plan is that the sand cover could "feed" the beach during storms. It is therefore important that the grain size of sand used is similar to that in the natural system, should this occur. While there is no date set for construction to begin, it is hoped that this study could assist with future monitoring, along with the extensive Army Corps of Engineers studies from 1995 and 2000 that are now somewhat dated.

Conclusions

Analysis of both morphology and sand grain sizes suggests that this is a reflective shoreline. Such shorelines develop where there is sandy sediment, a low tidal range, and an average wave height of < 1 m, typical of locations in the mouth of the Hudson estuary. Reflective beaches generally change little over the course of a year because of this low wave height, but are extremely vulnerable to erosion during major storm events when wave heights are greatly increased. More dissipative beaches are much more variable, but less vulnerable, not least because their variability discourages close proximity development. If we are to plan for future storm events on Staten Island, it is essential that these beach morphodynamics are well understood, so that it is not a surprise when a seemingly stable beach can suddenly move.

Acknowledgements

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Coastal Management Response to Superstorm Sandy (2012), Rockaway Beach Queens, New York

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The Rockaway Peninsula peritidal complex located on the coastal plain of Queens New York experienced a major Super storm (Sandy) in 2012, which resulted in billions of dollars in damage. The Peninsula is a classic barrier bar typical of the south shore of Long Island, sitting above glacial outwash gravel deposited after the Young Dryas, 11,000 to 13,000 years ago, also marked by a major rise (180 feet) in sea level , stabilizing 5000 years ago.

Sediment samples contain well sorted quartz and other mineral grains , reflecting multiple cycles of erosion, weathering and redeposition from the metamorphic Cambro-Ordovician Manhattan Schist, Fordham Gneiss , and Inwood Marble. Some quartz are ice-clear and contain diagnostic mineral inclusions. Provenance appears to be associated with transportation related the Hudson River during the Pleistocene when the river experienced significantly higher flow rates.

In 2013, a panel was assembled by New York City Mayor Bloomberg to study and predict future effects of climate change and its potential rise of sea level with increase category 4 and 5 storms. The study concluded the Rockaway Peninsula is in a 100 and 500 year flood zone, with a potential rise of up to 31 inches (78.7cm) from 2000 to the 2050's.Our previous studies published in the Journal of Carbonates and Evaporites (2007) ,focused on of tectonically stable low subsidence area of ancient aggregational carbonate rocks, sensitive to sea level (photic zone)in Florida and Bahamas demonstrate comparable rates of sea level rise of 6 inches (15 cm.) per 50 years . The NYC Climate Report also predicted storm surge sea level rises of most likely case of to 15 feet by the 2050's. New construction on the Peninsula requires 10 feet of elevation above street level.

Our field observations after Super storm Sandy demonstrate cross-beds and dune destruction at Rockaway Point, occurring as a depositional sedimentological feature in many ancient clastic deposits. As a consequence of the 2013 Bloomberg Climate Study, the U. S. Army Corps of Engineers began the construction of a dune field parallel to the coastline ($336 million) , and a series of sizeable metamorphic rock groins to baffle the transportation capabilities the longshore currents and direct oceanic waves with the associated storm surges. This major coastal management project will serve as a reference point of origin for future studies and responses.

The occurrence of warm water non-indigenous animal life, which we first observed off of Rockaway beach, in the Journal of Northeastern Geology and Environmental Science(2005), have become more pronounced , with the increased observations of hump back whales, various species of sharks , and dolphin pods spottings, and can be attributed the banning of baitfish harvesting by New York State in coastal waters, leading to a significant population increase and food source to the larger predators. Other contributions to the predatory migration to the shallow shelf maybe the cleaner Hudson River and increase in water temperatures. In the geological record periods known as greenhouses contain an explosion of specie diversification as evidenced in the Carboniferous, Triassic, Jurassic, Cretaceous, and Paleocene-Eocene ,when the evolution of new species and the rise of mammals.

Using a Hedonic Modeling Approach to Evaluate the Long-Term Benefits of Engineered Berm-Dunes along Long Beach Island, New Jersey

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Abstract

Developed coastal communities along the Mid-Atlantic region (USA) strive to adapt their shoreline mitigation strategies, given increasing threats of sea-level rise combined with more frequent and intense storm activity. In addition, long-term funding agreements pose challenges for state and local governments. Following the devastating storm surge impacts from Hurricane Sandy (2012), one of New Jersey's main coastal protection strategies was to engineer large-scale dune structures, in conjunction with pre-existing berm renourishment, particularly along the most highly developed beachfront communities. In 2013, the 113th Congress' Sandy Recovery Improvement Act funded the initial construction of the engineered berm-dunes, and as natural beach and dune erosion reduces the protection from storm surges, individual communities will need to pay their cost-share to renourish and sustain these structures. However, it is uncertain whether these New Jersey beachfront communities can afford the long-term maintenance. To investigate this, we use a hedonic modeling approach, built upon a coupled "geo-economic" framework, to quantify the long-term net benefits that three NJ beachfront communities in Long Beach Island, NJ (LBI), namely, Long Beach Township, Ship Bottom, and Beach Haven, would receive from the installation and maintenance of engineered berm-dunes as well as determine whether these communities can afford the long-term costs of renourishment.

As aggregate assessed property values of the three LBI communities increased in the year following berm-dune construction, a positive correlation emerges, wherein the increase in property value is a product of the added protection provided by berm-dunes. Our study also indicates that a decrease in property values within a beachfront community is correlated with a community's opposition towards the berm-dune construction, due to the potential losses of both ocean views and private access to the beachfront. Assuming plausible values for other model parameters, we used a hedonic pricing model that controlled for additional factors such as structural and neighborhood characteristics and ran a multi-linear regression analysis to solve for the implicit marginal price that constructing a large-scale berm-dune system would add to local property values, as a measure of stakeholder risk perception. Our results show that berm-dune construction had positive impacts on property values of 1% in Long Beach Township, 16% in Ship Bottom, and 21% in Beach Haven. In the cases of all three NJ beachfront communities we investigated, stakeholder risk perceptions strongly contributed to their ability to afford engineered dunes in the long-term, even as the sediment demand for renourishment has greatly increased.

As communities may or may not adjust their municipal budgets to meet the demands of maintaining a properly fortified shoreline in the long-term, an intriguing aspect uncovered within our datasets demonstrate the changes in property characteristics and attributes before and after

the 2016 dune installations which may be a result of stakeholders building toward greater resiliency. Our descriptive statistical analysis shows that single-family dwelling footprints are becoming larger in communities with higher marginal implicit prices while, across the board, property structure heights are being raised, potentially in response to the obstruction of views cause by dune installation. Furthermore, patios and decks are being swapped for balconies and roof porches while detached attributes (i.e., sheds and pools) are becoming more common. We argue that these changes sought by coastal homeowners demonstrate a sense of resiliency when building a new home, including a sense of security from the dune's added protection, thereby promoting a positive feedback cycle of greater, yet, more vulnerable, development amongst these sensitive landscapes.

Hurricane Sandy was a Wake-up Call & NJ Listened

Stewart Farrell

Director, Stockton University Coastal Research Center

With overall damage assessments in the billions of dollars, the NJ governor Christie overcame political party issues and worked with the Obama federal administration to obtain emergency funding for recovery and rebuilding. In January 2013 Congress passed the Sandy Recovery Act authorizing approximately $2 billion in recovery aid. One critical aspect was the funding for the US Army Corps Engineering Districts (NY and Philadelphia) to proceed to restore their authorized coastal shore protection projects to the design specifications at 100% federal cost. This funding was extended to all constructed projects and those authorized but not yet constructed. Devastated portions of Northern Ocean County have been greatly upgraded in shore protection as of 2019 with these funds. The NY District returned to Monmouth County and restored the beaches from Sea Girt to Manasquan starting in 2013. Unfinished portions of Long Beach Island were completed under the 100% federal funding. Detailed studies were undertaken along the Monmouth County Raritan Bay shoreline where tidal-surge flooding had been extensive. Projects have been built in Keansburg (beach restoration) Port Monmouth, and Union Beach with dikes and tide-flow gates to restrict surge water from the local tidal creeks. New Jersey established “Blue Acres” funding to purchase seriously damaged private properties at pre-storm market value from willing sellers and convert the properties into open space. This work was concentrated around the Raritan Bay and Raritan River drainages. The US Army Philadelphia District put together a state-wide coastal bay initiative to seek stakeholder input and develop in-house methodologies to mitigate the storm surge flooding along the barrier island and four county mainland edge developed shorelines. This regional project reviewed the need for consistent elevation bulkheads, flood dikes, and open Bayshore space acquisition. The big item was consideration of inlet tide gates to keep storm surge floods out of the bays and lagoons. New Jersey has eleven tidal inlets making this a very expensive solution. New Jersey resilience initiatives have sprung up with groups seeking to educate, urge municipalities, and seek grant funding for multiple ways to reduce flood hazards and storm damage from future storms.

Climate Change Issues and Regional Flooding in New Jersey and New York

Jonathan Peters, Ph.D.

The CUNY Graduate School and The College of State Island

Abstract

The Metro Region of lower New York State and New Jersey is located at the Western terminal end of the geological feature known as the New York Bight. This geological realty, coupled with the existence of cycloidal storms that periodically impact the region causes a significant baseline risk from coastal storm surge. Faced with potential storm frequency and intensity increases coupled with sea level rise, the region is generally subject to increased risk and damage caused by flooding and storm events. With significant population centers located in at-risk areas, the question as to how we solve the significant challenges presented by increased risk from coastal flooding. In this study, we will explore the various alternatives that communities can adopt to address these risks and prepare for further climate change impacts. These alternatives may include various flood control systems, resilient housing and facilities and structured retreat. Discussion of the various options for the financing and construction of resilient housing and public facilities as well as funding models to provide for critical infrastructure.

Looking at the changes now made to protect the East Coast of New York and New Jersey from Future Storms since Hurricane Sandy

Abstract
By
Dennis Askins, P.G.,
M & J Engineering P.C.

Hurricane Sandy, was the second largest storm recorded along the Northeast Coast of the Atlantic Ocean, made landfall on October 29, 2012, and damaged these Coastal Communities.

Hurricane Sandy caused flooding to the NY and NJ Coastline including Sandy Hook-Raritan Bay, South Beach of Staten Island, Lower New York Harbor, and South Brooklyn (Coney Island, Manhattan Beach, etc.), and Queens (Jamaica Bay - Rockaway Beach). The flooding exceeded the 100 year base flood and is the second largest storm recorded in this metropolitan area.

Beaches, Dunes, Barrier Islands, and Wetlands were damaged from Hurricane Sandy. Estuarine coasts along the rivers and streams were also affected by this storm. Erosion, inundation, and flooding were the most damaging processes affecting the shoreline from Hurricane Sandy.

Today, 10 years later, the installation of tidal gates and flood gates, new seawalls and bulkheads, groins and jetties, new storm sewers, etc., will prevent future storm damage.

Key Words: Beaches, Dunes, Barrier Islands, Wetlands, Estuarine, Erosion, Inundation, Flooding

Learning from the Impact of Superstorm Sandy: A review

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”Human beings function efficiently by assuming, largely unconsciously,
that the situations we face now are similar to those we have faced before.” …..Cited by Adam Sobel ..from
Daniel Kahneman, 2011….*Thinking Fast and Slow*
“When something truly unprecedented happens , we usually don’t see it coming.”…..Adam Sobel “Storm Surge” 2014”

Such was the case with Superstorm Sandy and Hurricane Ida. In the case of Superstorm Sandy, never has a Hurricane taken a track perpendicular to the coast of New Jersey(Sobel, 2014) and in the case of Hurricane Ida on Staten Island 8.44 – 9.64 inches of rain is an extremely rare event.

So when the Army Corps of Engineers proposed a 22 foot sea wall on Staten Island, Benimoff, Kress and Fritz commented on their DEIS.

How is the Army Corps of Engineers plan going to address what is termed “compound flooding”? This is flooding due to storm surge and rainfall from coastal storms at the same time (Wahl et al. 2015). Will the proposed ponds be able to hold storm water from 12-16 inches of rain at the same time that a 14 foot storm surge is present? How would the storm water drain? In September 1999 Hurricane Floyd dumped 12-16 inches on adjacent New Jersey. Our weather station at CSI recorded 6.08 inches of rain. If the storm track from Floyd moved about 5-10 miles east Staten Island could have received 12-16 inches of rain. Suppose this event were to happen again with a 14 foot storm surge. How would this plan deal with the compound flooding?

Now on September 26, 2022 we have Hurricane Ian and according to Dr. Rick Knabb of the Weather Channel the concern is in addition to storm surge flooding there will be rain induced flooding. The projections for the west coast of Florida are 12 – 24 inches of rain. If the wind is blowing the storm surge on land the rain can’t drain out at the same time. So this is what is termed Compound Flooding.

On October 29, 2012, Superstorm Sandy delivered a devastating blow to the New York City area, with particularly severe consequences for Staten Island. The tragedy is not only loss of life, but loss of vehicles and property. Following is the work done and published by the CSI team consisting Alan I. Benimoff, William J. Fritz , Michael E. Kress and several CSI students.

Benimoff et al. (2016) have been studying hurricane storm surge since 2011 and in 2014 Benimoff et al. (2016) noted in our Northeastern GSA abstract and presentation: “Throughout history geologists have given warnings and in many cases no one listens”. Furthermore, Benimoff et al. (2016) cited the GSA Position Statement Draft in GSA Today, June 2013: “Geoscientists have a professional responsibility to inform government, the private sector, and the public about coastal hazards and the risks they pose, thereby encouraging and supporting responsible and sustainable policies and actions.” Staten Island has a hurricane history. Severe storms (Extratropical and Hurricane) experienced in the New York Harbor Area occurred during the years; 1635, 1638, 1720, 1781, 1811, 1815, 1861, 1888, 1889, 1893, 1896, 1897, 1901, 1903, 1914, 1920,1927, 1932, 1935, 1938, 1944, 1953, 1954, 1955, 1960 and 1962 (Army Corps of Engineers, 1964). The summer storm of 1988 caused severe flooding in the Sweetbrook Drainage Basin. The winter storm of 1992 resulted in extensive flooding from storm surge. Severe flooding occurred during Tropical Storm Floyd (1999) when 154.43 mm of rain fell as recorded at the CSI weather Station. Benimoff (2010), in his GIS study, reported on extensive urbanization of the SLOSH zones during the period of 1898 through 2008. Maps produced from this study, showing progressive urbanization, are very useful in analyzing the development in SLOSH zones on Staten Island.

The hydrologic response to Hurricane Irene was: Extensive flooding in the Richmondtown area where the gaging station (USGS 01376534) at the Richmond creek Bluebelt BMP3 recorded a stage of 1.54 m instead of the normal stage of 0.3048 m; Extensive flooding in the Willowbrook area, Extensive flooding in the South, Midland and Fox beach areas. DEM's utilized in this GIS study show the effects of Sea level rise on Staten Island, NY.

Furthermore, Benimoff et al. (2013) noted whereas hurricane Irene was primarily a rain event for Staten Island, Sandy was a storm surge event. In both cases the wind damage was small compared to most hurricanes. Hurricane Sandy is responsible for 43 deaths in NYC of which 53 % came from Staten Island. It is also responsible for massive destruction in the coastal region of Staten Island, NY. In natural settings, tidal marshes, bays, estuaries, coastal dune fields, and barrier islands dissipate the storm's energy. In the New York area, marshes and bays, like Jamaica Bay, act as a natural "sponge" to absorb the energy of the wind and storm surge. Unfortunately, in New York, and on the eastern shore of Staten Island, like many urban areas, we have "hardscaped" the sponge with roads, parking lots, housing developments, stores, hospitals, schools, bridges, trains and all elements of urbanization. This comes at a cost when these structures absorb the energy. There is a place for seawalls, barriers, storm doors and other engineering marvels. However, often the best way is to preserve as many natural sponges - wetlands, barrier islands, and dune fields -- as possible. Particularly devastated are the South Beach, Midland Beach and Oakwood areas of Staten Island. Benimoff (2010) studied the urbanization of Hurricane SLOSH zones in Staten Island, NY. According to the 1900 topographic maps these areas were once wetlands. The GIS analysis shows that the storm surge (approximately 12-14 feet) from Sandy exceeded the boundaries of SLOSH Zone 1 and NYC Hurricane Evacuation Zone A. Certain creeks in this low-lying mid-island bluebelt area served as "storm surge waterways" bringing the surge into areas a mile from the shoreline. As we rebuild following Sandy, we need to be mindful of natural processes.

More than half the deaths in NYC from Superstorm Sandy occurred on Staten Island. In addition, thousands of cars on Staten Island were submerged in the floodwaters of Superstorm Sandy. Not only did some residents lose their home but they also lost their only means of transportation and an emergency shelter. They were not able to get to work because of poor public transportation. In our experience in disaster planning we have taken an interdisciplinary approach in order to deal with the issues of human impact, and the economic and political aspects. Therefore, our interdisciplinary team has developed a storm surge survival guide. Modeled after the "Living On Shaky Ground" guide for the Oregon coast which focused on tsunami survival this guide focuses a different geologic hazard, namely hurricane storm surge. The guide includes a map that shows the inundation area from hurricanes and the high ground "safe" areas of Staten Island. Also shown on the map are some high ground parking areas. We have even delineated some potential high ground parking areas. In addition to material which is available from the New York City office of Emergency Management we have provided measures to protect families and properties. Included is signage that one of our authors (WJF) has developed that would warn residents to go to high ground with their cars in case of hurricane storm surge. Throughout history geologists have given the warnings and in many cases no one listens. Here is a chance to educate the residents of Staten Island in order to better prepare for evacuation from storm surge zones. Staten Island has topography on its side. High ground is close by.

With an interdisciplinary approach, decision makers on the local, regional and nation scale have joined forces to prepare for future storm surges and rising sea level. In this process it was important to include scholars from various disciplines (e.g. creative writing, sociology, psychology, economics), elected officials (city, state, and national), community leaders, urban planners, offices of emergency management, public transportation leaders. Benimoff et al. (2016) cannot emphasize enough that to effect change in public perception of natural disasters, geologists cannot speak alone. Change requires an interdisciplinary voice. Hurricane Sandy resulted in 23 fatalities on Staten Island and millions of dollars in property damage. The CSI team used GIS and ADCIRC in modeling the effects of hurricane storm surge on a Cray XE6^{tm} super computer in the College's Interdisciplinary High Performance Computer Center. In 2013 the College of Staten Island held an interdisciplinary forum in which the college brought together community experts and stake holders to deal with a number of aspects of storm surge and flooding. In addition to the geologic issues Benimoff et al. (2016) also dealt with issues such as the human impact, the economic and political aspects and the need for more education. A key regional activity was the formation of the governor's task force for storm recovery where Benimoff et al. (2016) presented our hurricane storm research. In 2015, the College of Staten Island received a grant from the Governor's Office of Storm Recovery titled "Go To High Ground". The CSI team modeled evacuation strategies for automobiles. In this study Benimoff et al. (2016) collaborating with the NYC office of emergency management and as a result of this collaboration the evacuation signage has been changed on Staten Island. Benimoff et al. (2016) hope that other geologists can learn from our experience.

On August 28, 2011 Hurricane Irene dumped an average of 131.6 mm of rain on Staten Island with very little storm surge (Benimoff et al. (2015). On October 29 - 30, 2012, Hurricane Sandy inundated the coastal areas of Staten Island with a 4.27 m storm surge with very little rain. If both of these events occurred at the same time, the resulting storm surge would inundate coastal regions of southeastern Staten Island at the same time that rainfall runoff would increase the flood levels in this area. The 1902 USGS topographic map of Staten Island shows very little urbanization in these coastal wetland areas which were below sea level even in 1902 when sea level was 0.3 m lower than today. Subsequently, these hurricane prone areas became urbanized over the last 113 years. Most of this area now sits in a "bowl". There are two problems that must be solved. The first is to keep the storm surge out and the second is to allow for drainage from the higher elevation areas. The NYC DEP recently developed the Mid-Island Bluebelt for storm water management and recently, the United States Army Corps of Engineers issued the South Shore of Staten Island Coastal Storm Risk Management Draft Environmental Impact Statement. Their "goal is to manage the risk of damage from hurricane storm surge flooding and to manage the risk to local residents' life and safety" (USACE, 2015). Total project cost is $578.9 million. Planners and policy makers need to plan for storms which could potentially include storm surges, rainfall and winds all occurring simultaneously and in excess of either Irene or Sandy magnitudes.

The tragedy of Superstorm Sandy is not only loss of life, but loss of vehicles and property. Benimoff et al. (2017) developed a robust and resilient response plan entitled "Go to High Ground". Benimoff et al. (2017) utilized the ARCGIS Geographic Information System and Transmodeler software in developing this plan which defined transportation routes, high ground parking areas, possible bottlenecks and clearance times.

The plan is commissioned by the New York Governor's Office of Storm Recovery and developed by the College of Staten Island of the City University of New York. For those in a hurricane evacuation zone then the plan has a central message: *Going to high ground, early, is your best and only option in a hurricane. Get in your vehicle and go as soon as you are ordered to leave*. Strategies develop include changes to public education, alterations to signage, expansion of wayfinding and communication, traffic modeling of safe movement of vehicles and people not just from flood zones but to adequate refuge on high ground and ways to enhance overall ongoing and continuous coordination between community stakeholders and government before, during and after emergencies. The effort has already yielded changes to evacuation sign design and placement on Staten Island and other policy and practice changes are being considered now. A key takeaway is that that the public must understand that they are always at risk from hurricanes every season (ambiguous terms such as 'hundred year events notwithstanding) and that they must be ready and willing to evacuate when ordered and provided the means to do so.

As a result of the research Benimoff et al. (2017) present a follow-up in the changes in evacuation strategies that were implemented due to the results of our work. We modeled hurricane storm surge even before hurricane Sandy occurred. We developed a process in communicating with the issue of dealing with local, state, and federal agencies. We published "Learning from the impact of Superstorm Sandy on Staten Island, NY." We also modeled and simulated storm surge on Staten Island in order to understand inundation strategies where we dealt with a berm that was constructed on the east shore of Staten Island. We also addressed compound flooding issues in comments to the Army Corps of Engineers for their plan to build a seawall on the eastern shore of Staten Island.

Evacuation signage in place before Sandy directed residents to specified shelters. The post sandy evacuation by New York City Emergency Management signage directs residents to high ground. This change in evacuation signage will reduce the risk of residents choosing an evacuation route parallel to the shoreline. It is important for residents to have a plan in place before a hurricane occurs. Most Staten Island's residents will go to family and friends, others to hotels or motels or even others off Island. Our community outreach involves addressing "Go To High Ground" on shows on Staten Island Community Television. During this live show residents can call-in or email their questions.

During September 1-2, 2021 Staten Island experienced very heavy rainfalls from Hurricane Ida that resulted in extensive flash flooding. The National Weather Service reported rainfall amounts ranging from 5.81 inches(147.6 mm) to 9.64 inches(244.9 mm) for Staten Island (Richmond County, NY). The NYS Mesonet weather station at the College of Staten Island recorded 8.44 inches (214.4 mm)of rain. Benimoff (2022) plotted the following on a LiDAR DEM in a GIS: Pre-1900 Staten Island streams; present day streams; Staten Island Bluebelts; NYC contour lines with a 2 foot contour interval; data from NYC recently published stormwater maps; and Staten Island streets and buildings with blocks and lots. Since many of the Staten Island streets slope, the intersection of the streets with the contour lines provided flow directions for the storm water. Much of the flooding can be explained by this GIS study.

Each hurricane is different, Camille in 1969 was different than Katrina in 2005, Irene (2011) was different than Sandy and Sandy was different from Ida(2021). Recently Hurricane Ian(2022) showed us the effects of Compound Flooding.

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INVESTIGATING PAST OCEAN TEMPERATURES AND INDIAN MONSOON VARIABILITY FROM Ba/Ca AND Sr/Ca PRESERVED IN PORITES CORALS FROM BANGLADESH

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Department of Environmental Science,
William Paterson University
Co-authors: Erika McNally, Riovie Ramos, Michael DaSilva, Peri Burton, Mark Yu, Hannah Varkey,
Linda Godfrey, Richard Mortlock
Advisor: Michael Griffiths

The Indian monsoon affects the lives of over a billion inhabitants living in southern Asia via the hydrological cycle. Agricultural practices and freshwater discharge into the Bay of Bengal are directly tied to the monsoon system and can impact marine productivity in this fragile ecosystem that is home to the second largest fisheries industry in the world. Therefore, better understanding the mechanisms for monsoon variability and connections with marine productivity in the past will help to assess the sensitivity of the region's hydroclimate to future climate change. In preliminary work, oxygen isotope ratios (18O/16O; δ18O) in Porites coral records (conducted at Rutgers University) from Saint Martin's Island, Southeast Bangladesh have been used to compare the relative strength of the summer monsoon rains during two different climate states, the Little Ice Age (1450-1750 C.E.) and the modern. During both climate states, corals recorded large variations in δ18O (up to 2 parts per thousand or ‰), which are attributed, in part, to local salinity changes which are reflected by isotopic variability in seawater (δ18Osw) from local riverine discharge. One potential caveat to this interpretation, however, is that changes in the δ18O of the coral aragonite can also be influenced by sea surface temperatures (SST). To help overcome this limitation, we aim to deconvolve the SST and salinity (due to rainfall) components in the δ18O record through tandem measurements of strontium and barium to calcium ratios. These analyses are being performed on coral aragonite powders micromilled at 0.5 mm resolution (~weekly resolution) using the newly installed Inductively Coupled Plasma Optical Emission Spectrometer (ICP-OES) housed in the Department of Environmental Science at William Paterson University.

The ratio of strontium to calcium (Sr/Ca) in coral aragonite skeletons has been an established paleothermometer for several decades. Cooler SSTs result in an increased Sr/Ca (and vice versa) as greater amounts of Sr2+ ions from the surrounding seawater substitute for Ca2+ in the coral aragonite crystal lattice. The ratio of barium to calcium (Ba/Ca) in coral skeletons is broadly used as a proxy for near-shore changes in water quality driven by terrestrial and/or river runoff. Transport of freshwater plumes towards the ocean brings Ba-rich terrestrial-sourced particulates (e.g., clay minerals), which desorb Ba upon contact with more saline waters and contribute to the total dissolved Ba in seawater. In coastal regions affected by coastal upwelling, Ba from enriched deeper waters can also constitute a significant source of Ba to surface waters in addition to riverine inputs. Barium concentration in seawater has a nutrient-type distribution that generally increases with depth thus, high concentration of barium in the upper ocean may result from coastal upwelling. Our novel isotope and trace metal records will therefore provide the first high-resolution records of both monsoon-related riverine discharge and SSTs from the only remaining coral outcrop in Bangladesh.

ANALYSIS & CONTRAST BETWEEN NATURAL AREAS AND LANDSCAPED AREAS OF NYC

Drew Stillman

Department of Engineering and Environmental Science, College of Staten Island/CUNY

Advisor: Jane Alexander

As anthropogenic influences continue to impact and influence the amount of CO_2 and other greenhouse gasses in the atmosphere it has become more important than ever to develop strategies to sequester these gaseous chemicals and mitigate their climate effects. Research into new modes of carbon sequestering have unearthed different methods, including carbon sequestering in not only above ground biomass, but also to include soils and underground biota. Staten Island in New York City, provides a unique case study for this environment due to the high ratio of natural areas adjacent to traditional urban, landscaped green spaces, both areas are managed by NYC Parks. As a result of this study, I have observed that the chemical composition of natural areas is more conducive to supporting biological activities than that of landscaped areas. The implications of this study could provide evidence to support the increased investment into the conservation of natural areas, as an efficient method of carbon sequestration, while supporting healthy soil chemical compositions for native species in the NYC region.

GENESIS OF ATYPICAL MELT LAYER FROM COUNTRY ROCK AND IGNEOUS INTRUSION

Amaury Acevedo
Department of Engineering and Environmental Science, College of Staten Island/CUNY
Advisor: Samantha Tramontano

Tectonic forces have shaped the east coast of the United States over Earth's history, in particular the rifting that occurred during the early Mesozoic associated with the Central Atlantic Magmatic Provence has left its mark on the New York City area. The goal of this paper is to examine a xenolith in a Diabase intrusion, found at the Palisades Sill which formed during the rifting of Pangaea, which was found in Staten Island. A thin section has been made of a diabase sample and will be given a preliminary petrographic analysis which includes identifying individual minerals, phase changes, size of grains within the thin section, and comparing it to past research and previous thin sections from said research in order to have a more complete look at the xenolith. This will be followed up with an investigation of said exposure at location, and with time permitting, basic geochemical analysis as needed. This will look into the idea that the formation, found in the Graniteville quarry, is a xenolith which has been believed to have been baked and partially melted by the magma which would eventually become the Palisades sill. This section of the xenolith is made of 3 distinct parts which would be Diabase, Trondhjemite, and a baked hornfels. This investigation will show if the Trondhjemite layer was formed due to the partial melting of the xenolith, which is described as being part of the Lockatong formation (lacustrine in origin), if it was formed due to melting unrelated to the Palisades magmatic event or another unrealized process. This work will serve to shed more light on the Trondhjemite which has been described in the past, as well as add on to the study of the geology of the local area.

Field Trip Guide

Stop 1: Drone demonstration at 459 Ocean Avenue N, Long Branch NJ

Long Branch NJ
Lat 40.3221214° N Lon 73.976506° W
Jesse Kolodin Montclair State University
Field Trip Description
Former remote sensing techniques employed by research scientists along coastal landscapes have historically produced low-resolution imagery. However, recent advances in the use of unmanned aircraft vehicles (UAV) or "drones" have enhanced the ability to capture more adequate pixelation, allowing scientists to measure subtle geomorphic changes occurring along berm-dune systems. As increasing rates of anthropogenic-induced sea level rise, combined with the exacerbation of storm frequency and intensity, continued to increase the rates of coastal erosion along New Jersey's highly-developed coastlines, the use of spatially high-resolution monitoring is essential to guide a wide range of scientists, engineers, and politicians in making more informed decisions when attempting to protect these fragile landscapes.

Our team of researchers at Montclair State University's Coastal Dynamics Laboratory has been working on various drone data gathering methods at a privately accessible berm-dune system in Long Branch, NJ. At this site, the team has employed drones to capture data of topographic changes with the use of LiDAR (Light Detection and Ranging), oblique structure for motion (3D) imagery, and multispectral imagery that uses machine learning techniques to quantify the vegetation indexes that help sustain the overall health and continued growth of these berm-dune systems. We will be demonstrating these techniques with real-time flight missions while showcasing previously post-processed imagery within a 30-45 minute window.

Stop 2 Sandy Hook Unit, Gateway National Recreation Area
Lat 40.4284° N Lon 73.9850° W
Old Dune Trail
Jane Alexander, College of Staten Island/CUNY
Introduction
Sandy Hook is a barrier spit, located at the northern end of the New Jersey shore. The entire spit is 18 km long and formed by the northward littoral drift of sand by longshore currents (Psuty and Pace, 2009). The Sandy Hook lighthouse provides evidence for this, having been constructed in 1764 only 500 feet from the end of the spit, a distance that has increased to 1.4 miles today. This constantly shifting sand makes the area vulnerable to erosion, especially during storm events. While the northern end is expanding, other areas further south on the spit are eroding, and without human intervention it is likely that the northern end of the spit would become an island (Psuty and Pace, 2009).
The Old Dune Trail provides a transect through the natural dune system that is present on Sandy Hook, from the holly forest, through shrub thicket to the grass covered dune front at the top of the beach). This is one of the areas that is vulnerable to erosion, and we can observe the natural regression of the dune vegetation over time, with the most dramatic movement immediately after Superstorm Sandy.

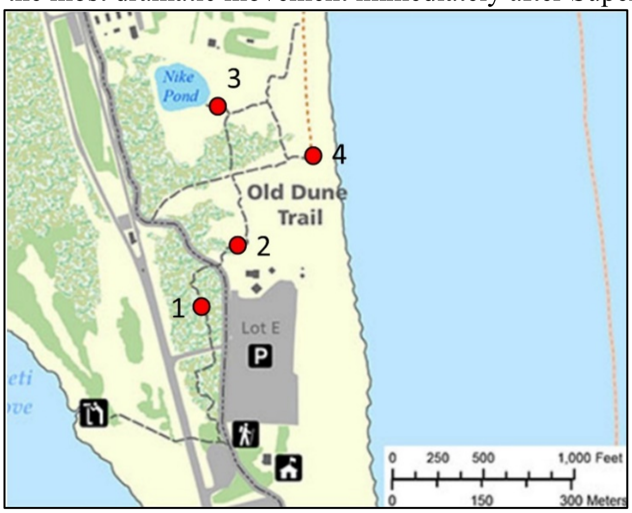

Figure l. Modified from Sandy Hook Trail Map, showing field trip locations (https://www.nps.gov/gate/planyourvisit/maps_shu.htm)

The series of Google Earth images (Figure m) shows how the dune front has been eroded over time, and vegetation has shifted landward. The trail is no longer complete in its original extent, having been covered by washover fans during Superstorm Sandy in October 2012. The Old Dunes Trail takes us through the changing plant communities, from the maritime holly forest (1), to mixed maritime forest and shrub thicket (2) and on to the dune front and beach (4). Additionally, there is a freshwater pond and marsh environment at the Nike Pond (3).

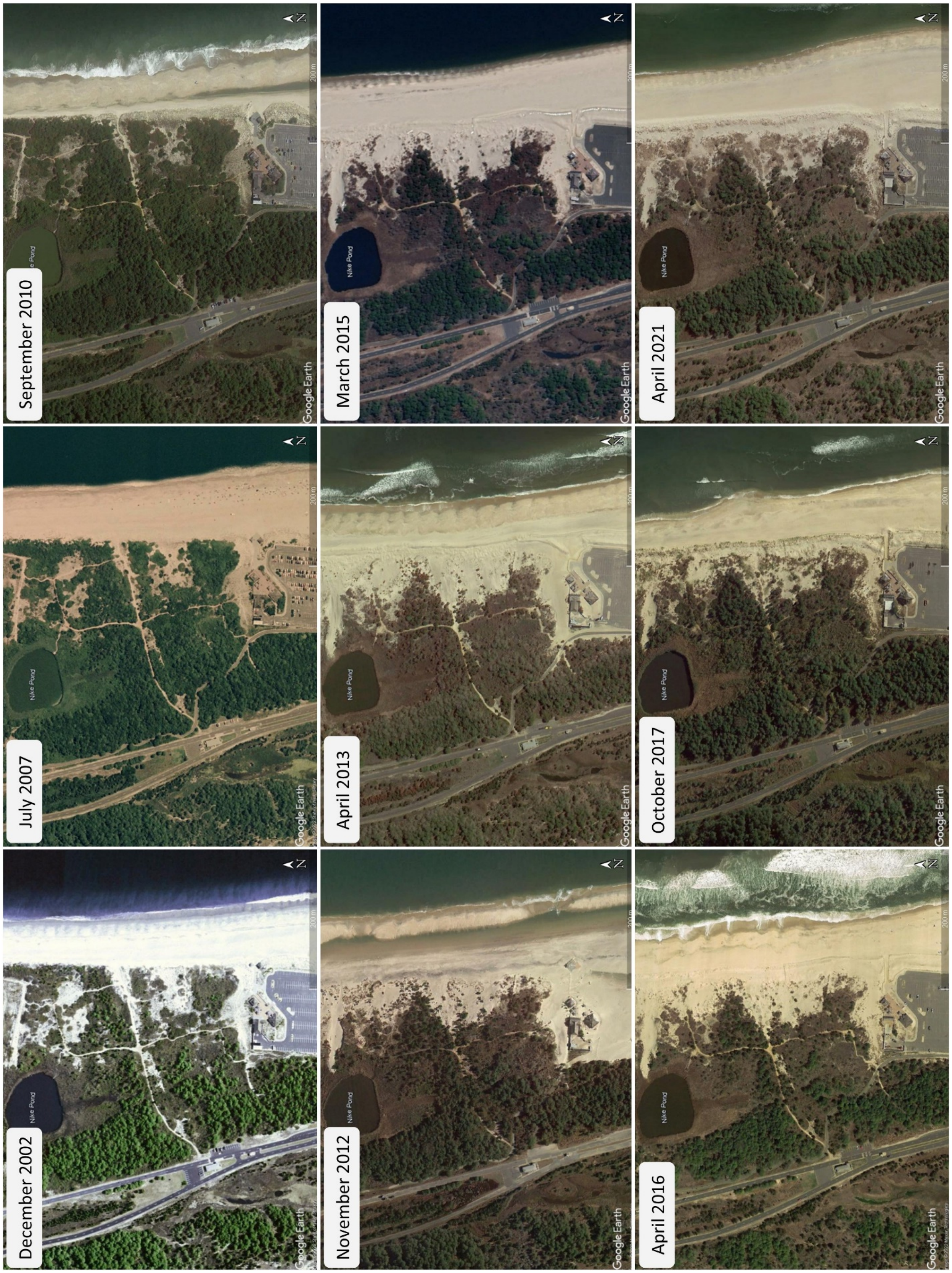

Figure m. Aerial imagery from Google Earth showing vegetation changes in the Old Dunes Trail area from 2002 to present.

Plant Communities in in the Sandy Hook Dunes
Different parts of the dune system are populated with different communities of plant species (Figure n).

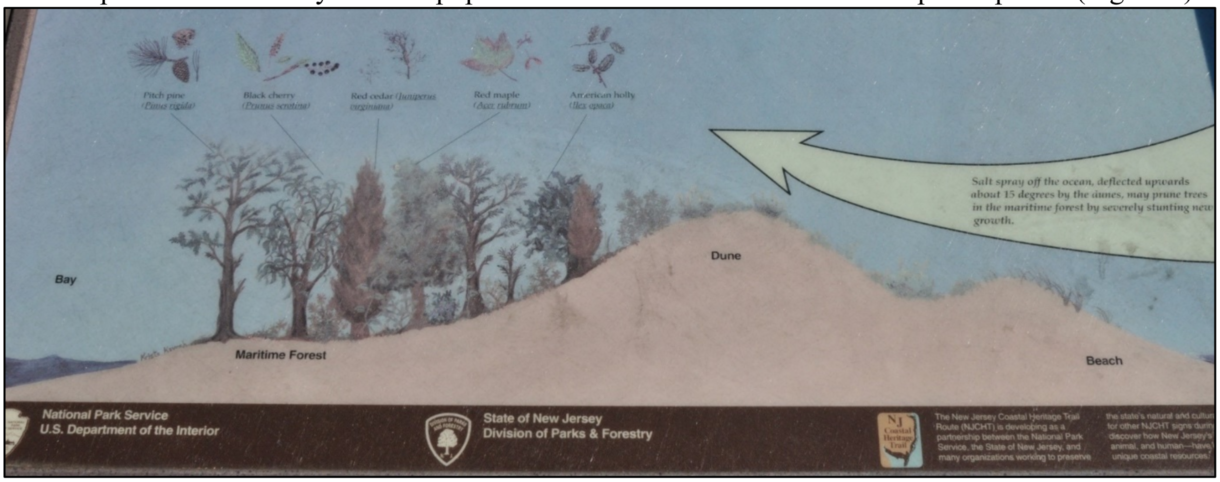

Figure n. Image of a sign on the Old Dunes Trail showing a transect through the dunes and the changing plant communities.

The front of the dune (i.e., closest to the beach), is dominated by sand rather than soil and subject to salt spray and erosion. Any fresh water from rainfall quickly percolates through the permeable sand. Here, the plants are low growing and resistant to both drought and salt water. The dominant species is beach or dune grass (*Ammophila breviligulata*), and other common plants include saltwort (*Salsola kali*) and sea rocket (*Cakile edetula*). Moving slightly further from the beach, golden heather (*Hudsonia ericoides*), poison ivy (*Toxicodendron radicans*), seaside goldenrod (*Solidago sempervirens*) and prickly pear (*Opuntia compressa*) become more common (Stalter, 2003). All of these plants have deep root systems, which help to stabilize the dunes and protect them from erosion.
Behind the largest dune crest, where the environment is less-likely to be subjected to salt spray, the plant community develops into a shrub thicket. Here there is enough organic matter to develop an extremely thin soil, which retains limited freshwater during rainfall and supports larger plants. This plant community includes beach plum (*Prunus maritima*), poison ivy (*Toxicodendron radicans*), bayberry (*Myrica pensylvanica*), winged sumac (*Rhus copalina*), Virginia creeper (*Parthenocissus quinquefolia*) and the non-native Japanese honeysuckle (*Lonicera japonica*).

Beyond the shrub thicket, in the most established part of the dune system, a full maritime forest has developed. In this area, a true soil has formed due to the greater abundance of organic matter. However, it is still only a few inches thick, sitting on top of permeable sand. The trees require deep roots that reach towards fresh groundwater. In the mixed forest, common tree species include eastern red cedar (*Juniperus virginiana*), black cherry (*Prunus serotina*) and shadbush (*Amelanchier canadensis*), with the continued presence of vines, such as poison ivy (*Toxicodendron radicans*) and Japanese honeysuckle (*Lonicera japonica*). The holly forest is dominated by American holly (*Ilex opaca*) and greenbrier (*Smilax rotundifolia*), and is considered to be the “climax maritime forest” in the succession of plant communities (Stalter, 2003).

Freshwater on Sandy Hook
All freshwater on Sandy Hook comes from rainwater; in other words, there is no connection with fresh surface or groundwater on the mainland. The rainwater rapidly percolates through the permeable sand, until it reaches the subsurface water table. This fresh water forms a freshwater lens, sitting on top of

higher density salty groundwater from the surrounding ocean (Figure oFigure l; Carleton et al., 2021).

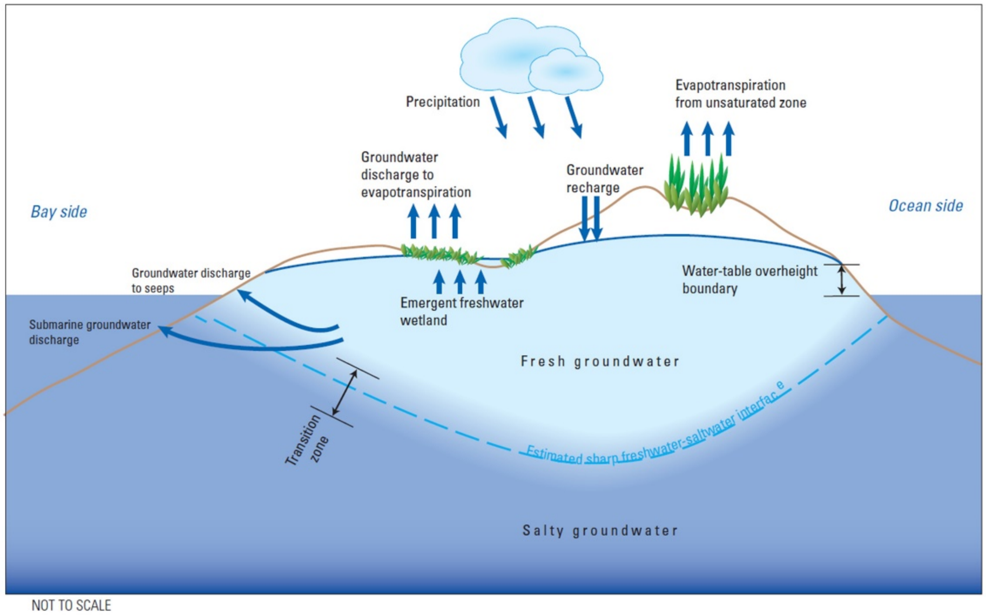

Figure o. Simplified cross-section through Sandy Hook from the ocean to the bay, showing the structure of the freshwater lens beneath the surface. Reproduced from Carleton et al., 2021.

The water table sits above sea level, and in places intersects the land surface. Where this happens there is a freshwater pond, such as the Nike Pond on the Old Dunes Trail. The level of the freshwater lens is controlled by both the balance of freshwater addition and loss, and by changes in sea level. As sea level rises, the boundary between fresh and salty water at the base of the lens will also rise, leading to two potential adverse consequences. There will be saltwater intrusion into areas that are currently fresh, and the surface of the freshwater lens will also rise. This will lead to permanent flooding in areas that are currently dry. Potential future changes in response to sea level rise at Sandy Hook have been modeled by Carlton et al. (2021).

Location 1. Holly Forest

The area of the holly forest on the Old Dunes Trail was inundated during Superstorm Sandy, but suffered limited damage beyond an influx of debris. This can be seen in the photo from May 2013, and the trees appear to have suffered some leaf-loss (Figure p). In the long term, the trees have recovered well, probably because American holly has been found to have a higher tolerance for salt spray than all other trees typically found in the maritime forest (Statler, 2003).

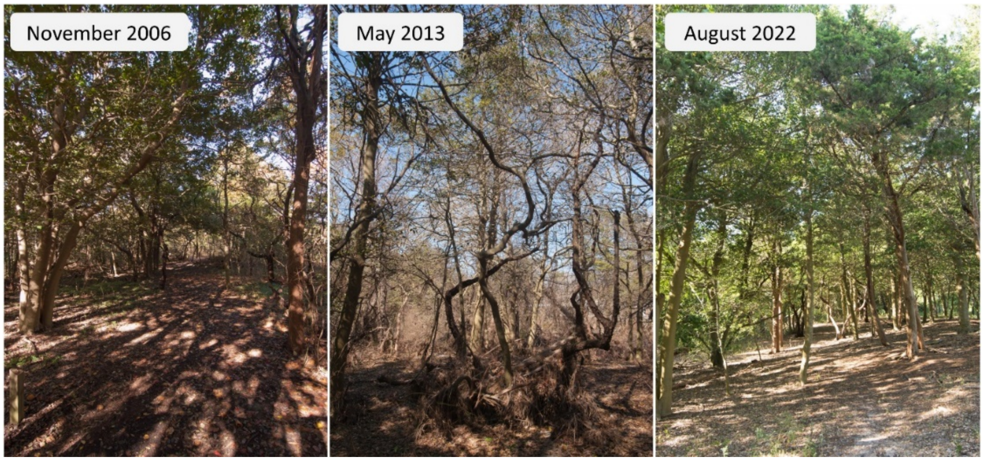

Figure p. Holly Forest on the Old Dunes Trail.

In other locations on Sandy Hook, the holly forest has suffered the loss of many trees in recent years. This does not appear to have been related to Superstorm Sandy, but may be a consequence of changes to groundwater described above, as a consequence of sea level rise.

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Location 2. Mixed Forest and Shrub Thicket

The area around the border between mixed forest and shrub thicket has seen major changes as a result of Superstorm Sandy (Trees in this area were more sensitive to the seawater inundation, and many did not survive. Additionally, large amounts of sand were brought in as washover fans, burying the thin soil that was previously present. This sand can be seen in the photo from May 2013 (Figure q). Along with the sand, seeds and root fragments of beach grass (*Ammophila breviligulata*) and other plants from the dune front were deposited by the storm. These have now taken hold in this area. This illustrates how the vegetation would move with the whole dune system in an environment not controlled by human influence.

Figure q. Photos of changes to the mixed forest and shrub thicket over time.

Location 3. Nike Pond

The Nike Pond is an example of a location where the freshwater lens intersects the land surface. This area has long been subjected to human disturbance, and as is typical of such environments, the rims of the pond are dominated by phragmites (*Phragmites communis*), with few other plant species (Figure r). Prior to Superstorm Sandy, there was a boardwalk with a bird viewing hide at the edge of the phragmites, providing a clear view of the pond year-round. This was destroyed during the storm, and the replacement path and hide end in the middle of the tall grasses.

Figure r. Photos of changes to the Nike Pond over time.

Location 4. Dune Front and Beach

The dune front was the area that sustained the greatest inundation and erosion during Superstorm Sandy. The first set of photos (Figure s) illustrate the changes in the area of the boundary between the shrub thicket and plants of the dune front. Much of the vegetation was covered in the sand of large washover fans, and most of the larger shrubs, such as the red cedars (*Juniperus virginiana*), were killed. While the occasional shrub still survives, most of the area is now dominated by beach grass (*Ammophila breviligulata*) and other plants of the dune front, showing a marked shift in the plant communities.

Figure s. Photos of changes to the shrub thicket over time.

The edge of the dunes at the top of the beach was completely washed away during Superstorm Sandy. This area has been subject to erosion during storms since long before Sandy, but there was also usually a period of natural sand build-up after each storm and the beach grass (*Ammophila breviligulata*) recovered. The landward movement of the dune front was apparent, but slow (Figure t, March 2010 and April 2012). During Superstorm Sandy, this area was destroyed, with much of the sand being redeposited further onshore in the dune system as washover fans. Despite this natural movement, an attempt has been made to recreate this front part of the dune system. However, the sand was simply bulldozed into piles, and no attempt was made to recreate the natural dune shape (Figure t, May 2013 and June 2015). Natural aeolian processes have redistributed the sand, however this had led to an unnatural patchy variation of grain size in the dunes, with the smaller sand grains being picked up by the wind and redeposited in the hollows. The area was planted with beach grass (*Ammophila breviligulata*) which has taken hold and the dunes have regained a more natural shape (Figure t, March 2019 and September 2022).

Figure t. Photos of changes to the dune front over time.

The combination of the natural movement of beach grass (*Ammophila breviligulata*) and other dune front plants to the interior of the dune system, along with the recreation of the dune ridge at the top of the beach, has led to a widening of the zone occupied by this plant community. As the holly forest has remained unchanged, this has essentially resulted in the reduction in the areas of shrub thicket and mixed maritime forest. These changes are clearly visible in the Google Earth imagery (Figure m).

Fishing Beach

From the top of the beach at the end of the Old Dunes Trail, the area of Fishing Beach is visible to the north. This is one of the most rapidly eroding areas on Sandy Hook, beginning well before the impact of Superstorm Sandy.

The rapid rate of erosion is demonstrated by the loss of human infrastructure, including a parking lot and buildings (Figure u and Figure v). This erosion was accelerated by Superstorm Sandy, but unlike the area at the end of the Old Dunes Trail, the rapid erosion has continued in recent years. The photos in Figure u illustrate the fate of a building that was in the dune front in 2012, and is now barely visible in the surf at low tide.

Figure u. Photos of changes to Fishing Beach over time.

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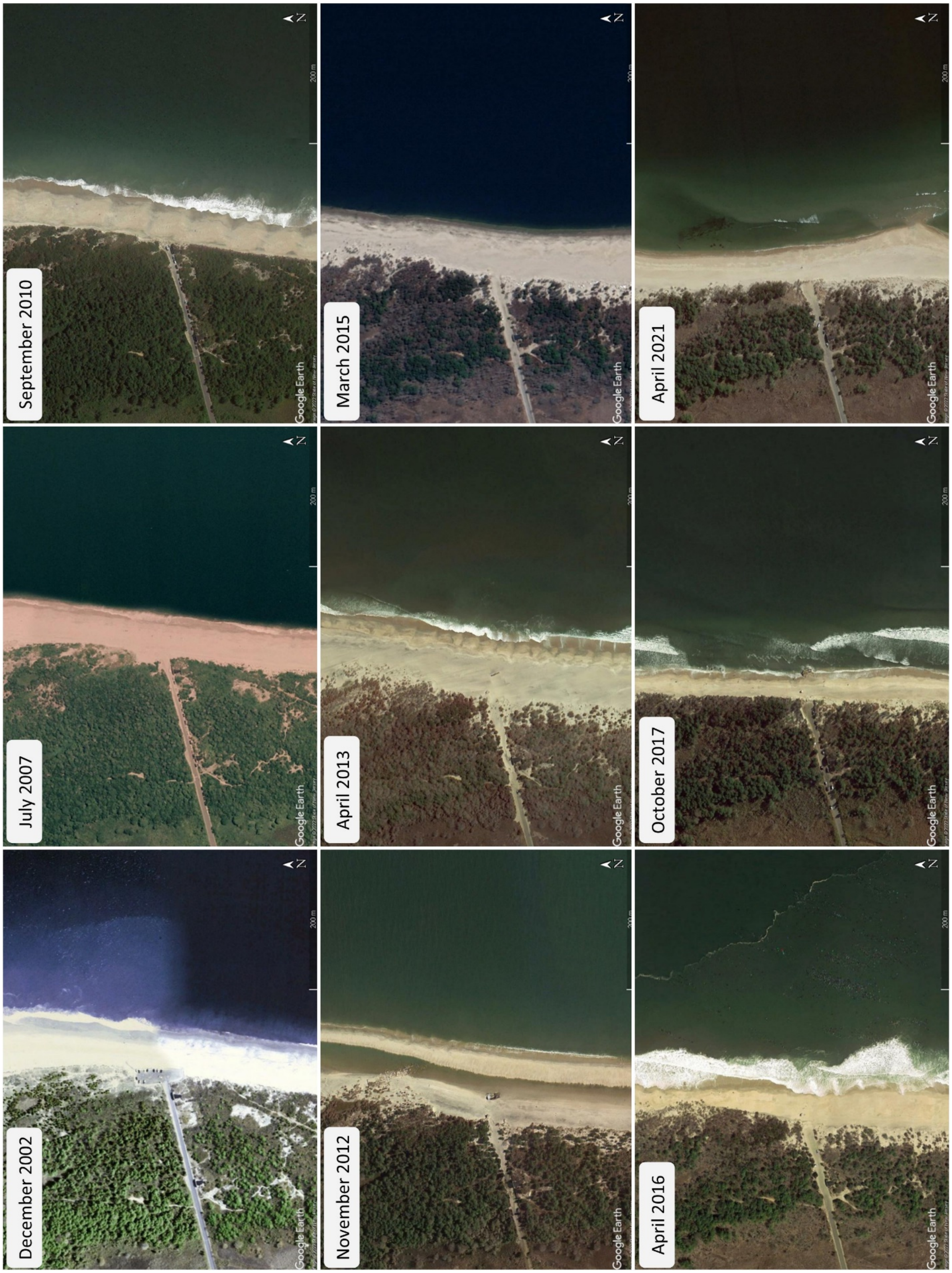
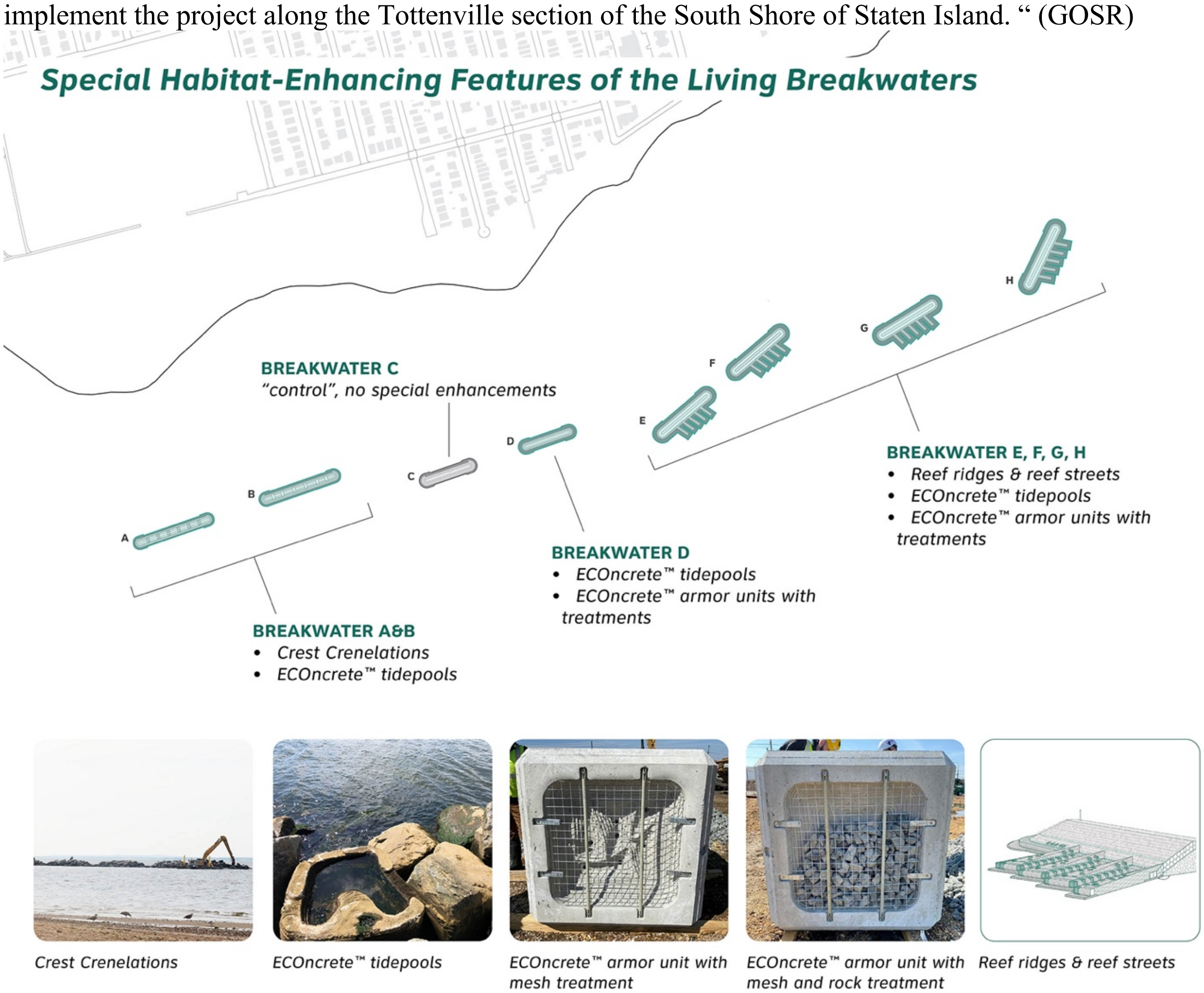


Figure v. Aerial imagery from Google Earth showing shoreline erosion in the Fishing Beach area from 2002 to present.

Stop 3: Lunch Stop and View of the Living Breakwaters Project from Sprague Ave and Surf Avenue
Lat 40.500183° N Lon 74.236421° W
Alan Benimoff, College of Staten Island
Here we are going to view the Living Breakwaters Project and the Eroded installed dunes.
(All Living Breakwaters by GOSR, Rebuild by Design and SCAPE)
"In June 2013, the U.S. Department of Housing and Urban Development (HUD) launched Rebuild by Design (RBD), a competition to respond to Superstorm Sandy's devastation in the northeast region of the United States and promote a design-led approach to proactive planning for long-term resilience and climate change adaptation The winning proposal would be implemented using Community Development Block Grant Disaster Recovery (CDBG-DR) funding as well as funding from the State of New York. In June 2014, following a year-long community-based design process during which the design teams met regional experts, including government entities, elected officials, issue-based organizations, local groups and individuals, HUD announced the winning proposals. The Staten Island Living Breakwaters Project which proposed a layered resiliency approach to promote risk reduction through erosion prevention, wave energy attenuation, and enhancement of ecosystems and social resiliency, was one of the selected projects. As a result, New York State has been allocated $60 million of CDBG-DR funds to help implement the project along the Tottenville section of the South Shore of Staten Island. " (GOSR)



Overview of the Living Breakwaters Project(GOSR)

On Breakwaters A and B, “crest crenulations” will help facilitate habitat space for marine life. The crests of these breakwaters contain a series of low saddles (“crenulations”) located a foot below mean high water. The rest of the crests are about 3 feet above mean high water. These crenulations create intertidal habitat (between high and low tide) where species that thrive in shifting tidal conditions can exist. They also include artificial tide pool units made of ecologically-enhanced concrete—these units retain water between tides, providing additional space for more micro-scale marine life.

The Living Breakwaters are designed to reduce or reverse erosion throughout the project site. This is a significant and important risk reduction function of the project because without intervention, the beach would continue to be lost to the combined effects of erosion and sea level rise. Eroded beaches lose their ability to support activities and leave on-shore assets more vulnerable to coastal risks.

The primary function of breakwaters is to break waves prior to reaching the beach and reduce their energy. This reduced wave action also slows the transport of sediment along the shoreline, also known as “long-shore sediment transport”. Slower sediment movement helps prevent sand from being lost “down-drift” (the destination of long-shore transports) therefore stabilizing or even growing the beach behind breakwaters.

If waves are reduced too much and an excess of sediment is being trapped behind a breakwater, a “tombolo” may form, connecting the breakwater to the shoreline. In contrast, the Living Breakwaters Project creates a “salient” formation, which is a condition where the breakwaters cause some beach growth behind them but still allow for long-shore transport to continue. Maintaining slower sediment movement reduces the risk of erosion down-drift and allows important shoreline processes to continue.

The breakwaters are located about 1000 ft from shore. Current construction activities can be observed from the beach of Conference House Park. You will see the red W537 e-crane picking up stone from the material barge and placing it onto the Breakwater ‘A’ and ‘B’. The crane is equipped with a grapple to lift armor stone and a bucket to handle smaller core stone. You will also see two yellow amphibious excavators working alongside the W537 to make adjustments to the stone placement. These excavators work like land-based excavators except that they are affixed to pontoons and float!

“In October 2012, Superstorm Sandy devastated Staten Island’s east and south shore neighborhoods. The driving wave action battered the coastline, damaging or destroying an unprecedented number of Staten Island homes and businesses, resulting in loss of life and significant harm to the local economy. Tottenville, a community at the southernmost point of Staten Island, experienced some of the most destructive waves in the region. Much of the shoreline has also experienced ongoing erosion over the last 35 years; in many locations, erosion rates average more than one foot per year and in one area of Conference House Park, they reach an average rate of more than three feet per year, leaving the area increasingly vulnerable. Historically known as “The Town the Oyster Built,” Tottenville was once protected by a wide shelf and series of oyster reefs, which in turn supported a robust oyster farming industry. Over time, due to siltation, overharvesting, channel dredging, and human pathogens in the water, the once abundant oyster reef collapsed. Today, the Raritan Bay lacks not only the oysters, but the complex habitat their reefs provided and the species richness and biodiversity that they supported. Without these natural systems, the shore of Staten Island remains exposed to wave action and coastal erosion and lacking this rich environmental resource. The Living Breakwaters are designed to:

- **Risk Reduction**: address both event-based and long-term shoreline erosion in order to preserve or increase beach width; attenuate storm waves to improve safety and prevent damage to buildings and infrastructure.
- **Ecological Enhancement**: Increase the diversity of aquatic habitats in the Lower New York Harbor / Raritan Bay (e.g., oyster reefs and fish and shellfish habitat), particularly rocky / hard structured habitat that can function much like the oyster reefs that were historically found in this area.
- **Foster Social Resilience**: Provide programming that builds a community around education on coastal resilience and ecosystem stewardship; foster and encourage community stewardship and citizen science, and enhance access to the water's edge and near-shore waters for recreation, education, research, and stewardship activities.

The System

The Living Breakwaters function as a system of elements that work together to reduce risk and enhance habitat in the Raritan Bay. Each segment was individually designed to contribute to the overall system and achieve the desired performance. The breakwater system consists of a series of nine ecologically enhanced breakwater segments. and will include approximately 2,400 linear feet of breakwaters located between 790 and 1,800 feet from shore and in water depths of between two-and-10 feet below mean low water (NAVD88). In addition to the breakwaters themselves, the design includes a limited, strategic, one-time placement of shoreline restoration that will add needed sediment to the system and provide initial protection to the most vulnerable stretch of beach as the breakwaters work over time to accrete beach elsewhere. This layout was refined through the process of design and computer modeling, where scenarios were iteratively developed, modeled to evaluate impacts on shoreline change and storm wave attenuation, and the results analyzed to help inform the design refinement and optimize the design to reduce or reverse erosion (grow beach) and reduce coastal storm risk through wave attenuation.

Individual Breakwaters

The breakwaters are rubble mound (rock) structures with a stone core, a base layer (bedding stone or marine mattress, depending on the breakwater) to protect against scour, and outer layers consisting of armor stones and ecologically enhanced concrete armor units. These ecologically enhanced concrete units are located in the intertidal and subtidal areas of the breakters and are specially designed to promote biological activity and promote recruitment of marine species. This is achieved through both the specialized concrete mixture and the design of the textured surfaces of the units.
In addition to the main (traditional) breakwater segment, the Living Breakwaters will have "reef ridges"—rocky protrusions on the ocean-facing sides of the breakwaters—and "reef streets"—the narrow spaces between the reef ridges. These features create localized modifications to wave behavior and provide a diversity of habitat characteristics to generate opportunities for species recruitment. Habitat diversity is further enhanced on the reef ridges through greater variation in rock sizes and the spaces between them, the textured surfaces of the ecological concrete armor units, and the inclusion of ecological concrete tidepools in the intertidal zone.

Oyster Restoration
Once the breakwaters are constructed, the Billion Oyster Project will install live oysters on the breakwaters. Techniques may include placing spat (baby oysters) on some of the ecologically enhanced concrete units, installing oyster shell gabions (non-structural units), placing spat on shell in the reef streets, and in-situ setting pilots. The oyster gabions and spat-on-shell installation will use designs and techniques that have been employed on other oyster restoration projects throughout the Harbor.

The Living Breakwaters incorporate a variety of integral features to enhance ecological benefits. These features include "reef ridges" and "reef streets" (the narrow spaces between reef ridges), "crest crenelations," and artificial tidepools and armor units made of ECOncrete™. These features will enhance the breakwaters' ability to attract and maintain aquatic species and increase biodiversity by providing various ecological niches and improving the ecosystem services provided by the breakwaters. Once the structures are completed, some breakwaters will also be seeded with live oysters!

After construction is complete, the performance of the Living Breakwaters' ecologically enhancing features will be monitored to understand how they are performing, determine if they should be modified to enhance performance (adaptive management) and to inform their use in future ecologically-enhanced breakwaters. By using a variety of different types and combinations of enhancements as well as a "control," the project will provide valuable information on the relative effectiveness of these ecological enhancements. With no specific enhancement features, Breakwater C acts as our control area and will serve as the reference for measuring the effectiveness of the enhanced breakwaters structures.

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Stop 4 Midland Beach, Staten Island
Lat 40.5796°N Lon 74.0758 W
Ocean Breeze Fishing Pier
Jane Alexander, College of Staten Island/CUNY

Ocean Breeze Fishing Pier

The Ocean Breeze fishing pier was constructed in 2003 at the northern end of Midland Beach (Figure w). It is a popular destination for fishing and recreation, and is accessed via the boardwalk.

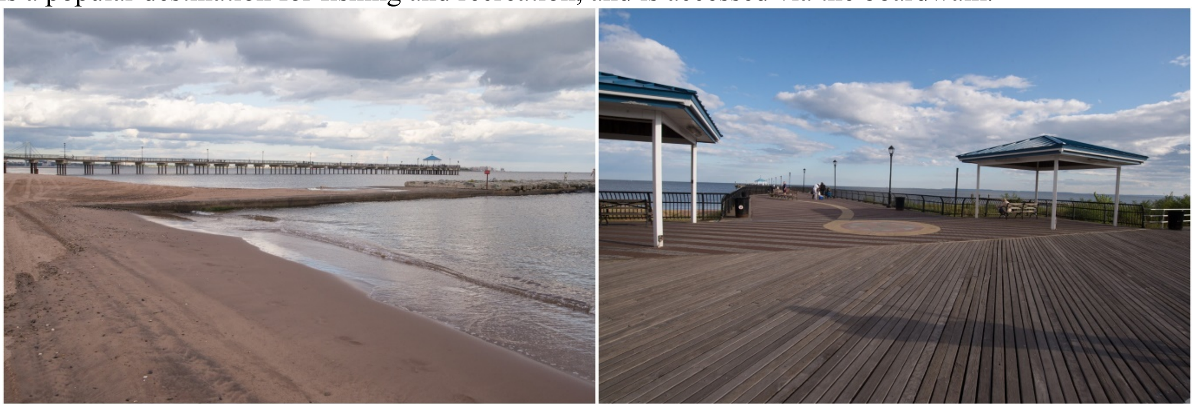

Figure w. Ocean Breeze fishing pier

From this vantage point, it is easy to observe the direction of longshore currents and littoral drift from the way the sand builds up on the up-current side of the many groins – to the north of the pier the currents move sand towards the north, whereas south of the pier the littoral drift is towards the south (Figure x). This leaves the area particularly vulnerable to erosion.

Figure x. The direction of the longshore currents, interpreted from the buildup of sand behind groins on the shoreline.

The area of greatest erosion is just to the south of the pier where currents change direction (Figure y). The dune at this location was reconstructed with a reinforced core after Superstorm Sandy, but the fabric bags of the core are now exposed as the covering sand has been removed by wave action during storms.

Figure y. Area of dune erosion

Damage and Flooding during Superstorm Sandy
Due to the low dune height and large low-lying areas behind the boardwalk, this area was extremely vulnerable to storm surge flooding during Superstorm Sandy (Figure z). Many populated areas were flooded resulting in 14 deaths and damage to thousands of homes (Army Corps of Engineers, 2016).

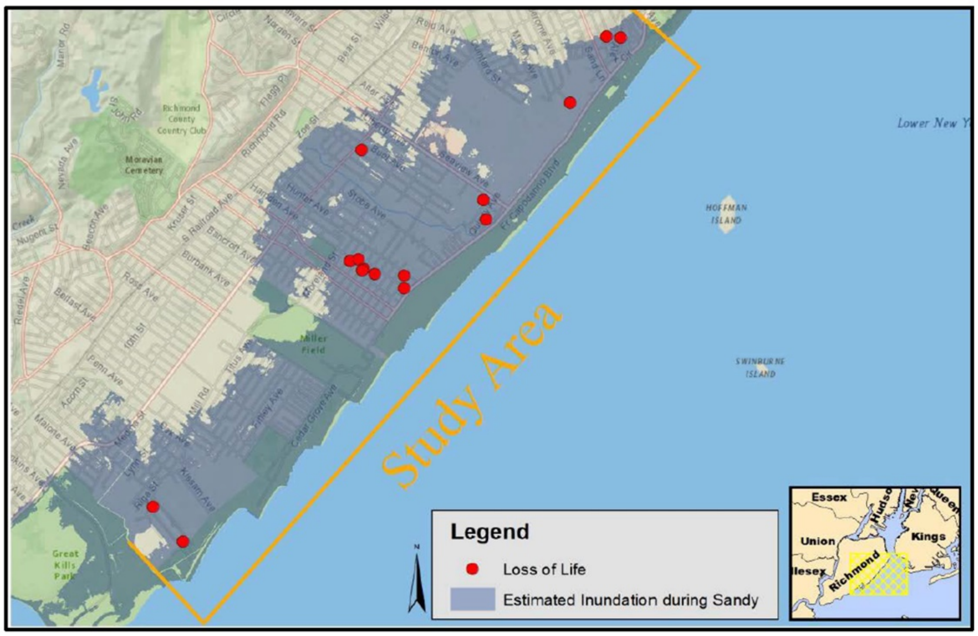

Figure z. Map showing areas of inundation and locations of deaths during Superstorm Sandy. Reproduced from Army Corps of Engineers, 2016.

Plans for Coastal Storm Risk Management by Army Corps of Engineers
The Army Corps of Engineers have proposed a plan to manage future storm surge events (Figure aa). This includes improving water storage and drainage in interior areas prone to flooding by excavating ponds and maintaining natural areas. There is also a plan to build a series of structures along the shoreline to prevent inundation from occurring.

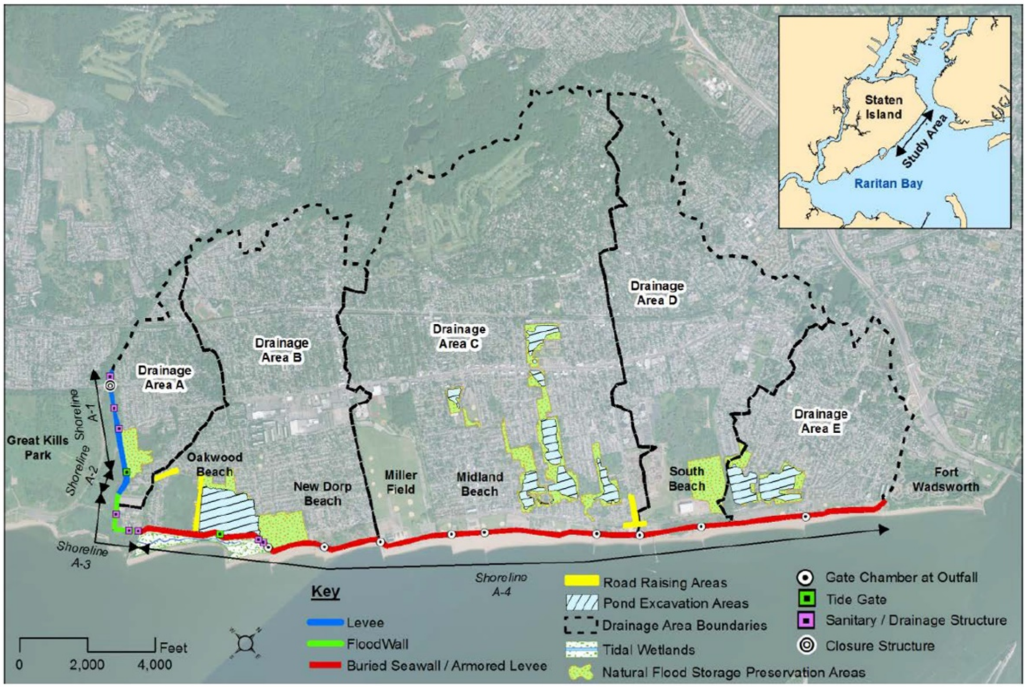

Figure aa. Map of risk management structures proposed for the South Shore. Reproduced from Army Corps of Engineers, 2016.

Most of the South Shore will have buried seawalls in along the top of the beach. South of Fishing pier, this structure will be topped with a promenade (Figure bb).

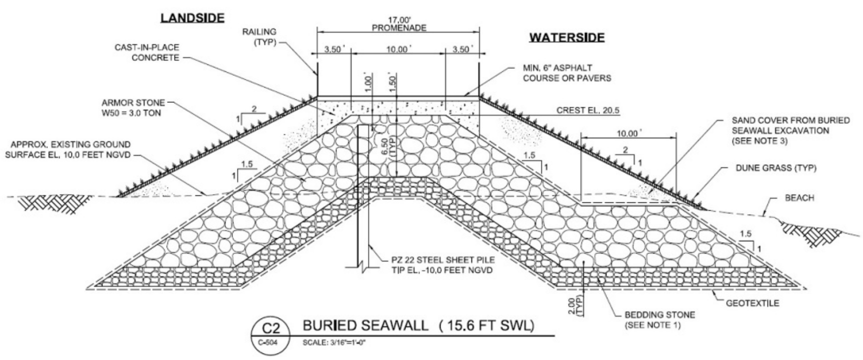

Figure bb. Planned structure of buried seawall. Reproduced from Army Corps of Engineers, 2016.

In the area of the current boardwalk, from the Ocean Breeze fishing pier north, the buried seawall will include a new boardwalk on the landward side ().

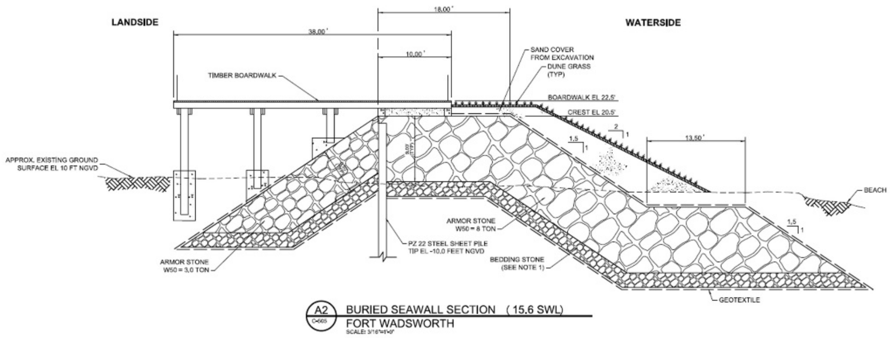

Figure cc. Planned structure of buried seawall with boardwalk. Reproduced from Army Corps of Engineers, 2016.

The interior drainage part of project is due to start in Fall 2022 (drainage area E) and Spring 2023 (drainage area C). There is no schedule as yet for the buried seawall and other coastal defenses.

References Cited

US Army Corps of Engineers, New York District and New York State Department of Environmental Conservation (2016) South Shore of Staten Island, New York Coastal Storm Risk Management Interim Feasibility Study for Fort Wadsworth to Oakwood Beach: Final Report