COASTAL FLOODING

NEIGHBORHOODS TURN INTO OCEANS

Cars submerged in water up to their headlights. That's what Virginia Wasserberg and her neighbors saw on the street outside their homes after Hurricane Matthew followed an unexpected track through Virginia Beach, Va., in October 2016.[81,82] The home where she lived with her husband and two young children had lost power, and they realized the extent of the damage only when the Sun came up. Abandoned cars had washed into their yard. Their deck, still laden with furniture, had floated up—a sad, wayward raft prevented from sailing into open waters only by the backyard fence. Inside the house wasn't any better. Nearly 2 feet of water filled the first floor, a mess that would take months for a dedicated contractor to repair.

But this is not a story about extreme storms.

EVEN BEFORE HURRICANE MATTHEW STRUCK, FLOODING WAS A PERSISTENT PROBLEM IN WASSERBERG'S NEIGHBORHOOD.

Soon after she and her family moved to Virginia Beach in 2014, their yard flooded after it had rained the night before. Her son pointed to the waves lapping nearly at their doorstep and said, "It looks like the ocean."

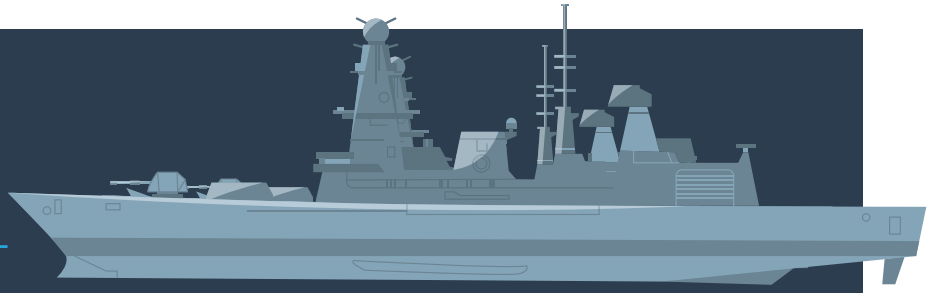
The intersection in front of their house flooded habitually, causing cars, and even school buses, to try to avoid the water by driving through their yard. She and her husband followed the lead of other neighbors and bought metal stakes to help drivers distinguish between yard and road. It didn't work, but it was better than just feeling helpless.

For Wasserberg, a stay-at-home mom who homeschools her children, Hurricane Matthew was the last drop in an already overflowing bucket. In March 2017, when city leaders told homeowners in the neighborhood to document the problem with photos, she created a page on Facebook called Stop the Flooding NOW, which has become a forum for demanding action from local lawmakers.

At the outset, Wasserberg was focused on solutions for her neighborhood, like city funding for tide gates on the tidal creek that her neighborhood's runoff flows into or pump stations that municipal engineers recommended. As the city considered ways to fund these projects, it responded to Wasserberg and her neighbors by cleaning storm drains and dredging ditches and canals in the area. The more Wasserberg learned, however, the more she understood that the problem was not as limited as she had once thought.

"THIS ISN'T JUST A NEIGHBORHOOD PROBLEM; THIS IS A CITYWIDE PROBLEM," SHE SAYS OF HER EPIPHANY. "AND THEN WE EVEN MORE QUICKLY REALIZED IT'S A REGIONAL PROBLEM."

NATIONAL SECURITY:
SEA LEVEL RISE



The Hampton Roads region encompasses the Virginia Beach, Norfolk, and Newport News metropolitan areas and is home to 1.7 million people.[98] Hampton Roads also contains, in the words of former secretary of defense Leon Panetta, "perhaps the greatest concentration of military might in the world."[99] Hampton Roads is home to a total of 38 military and supporting sites and 100,000 military and 40,000 civilian personnel.[100] Significant bases include Naval Station Norfolk, the largest naval complex in the world, which provides support for the entire U.S. Atlantic Fleet, and Joint Base Langley-Eustis.[100] Both bases are no more than 10 feet above mean sea level and already suffer from recurrent flooding, compounded by land subsidence.[80,100,101]

The Air Force rated Joint Base Langley-Eustis as one of the top 10, out of 36 considered priority bases, currently affected by extreme weather, including coastal and inland flooding, extreme heat, and drought.[102] A study by NASA found much higher than average land subsidence rates at Norfolk Naval Shipyard, likely driven by construction during the study period.[101] For the U.S. military in Hampton Roads, flooding and sea level rise in the region pose a dire and immediate threat. As stated by retired Rear Adm. David Titley, who led the Navy's Climate Change Task Force, "I think Norfolk is, in the long term, fighting for its existence, its very existence."[103]

USING SCIENCE TO GIVE OTHERS A VOICE

Michelle Covi, an assistant professor at Old Dominion University and a staff member for the Virginia extension of NOAA's Sea Grant program, played a significant role in this realization. Covi, whose research focuses on climate change and sea level risk perception and risk communication, specializes in framing scientific messages for a variety of audiences. She is currently working with the city of Virginia Beach to engage residents as the city develops a response plan to sea level rise and recurrent flooding.

Not only does she strive to inform residents about the challenges posed by sea level rise, but also she helps to inform city officials on the best ways to incorporate data into flood adaptation decision-making, effectively giving a voice to more Hampton Roads residents. For example, research conducted by Covi and a Ph.D. student in the city of Portsmouth, where, according to Covi, some residents express a high level of distrust of government, found that...

...LOW- TO MODERATE-INCOME HOUSEHOLDS WERE MORE LIKELY TO EXPERIENCE STREET FLOODING THAN HIGHER-INCOME HOUSEHOLDS.[83] THEY WERE ALSO MORE LIKELY TO HAVE A LIMITED ABILITY TO GET OUT OF THEIR NEIGHBORHOODS DURING FLOODING.[83]

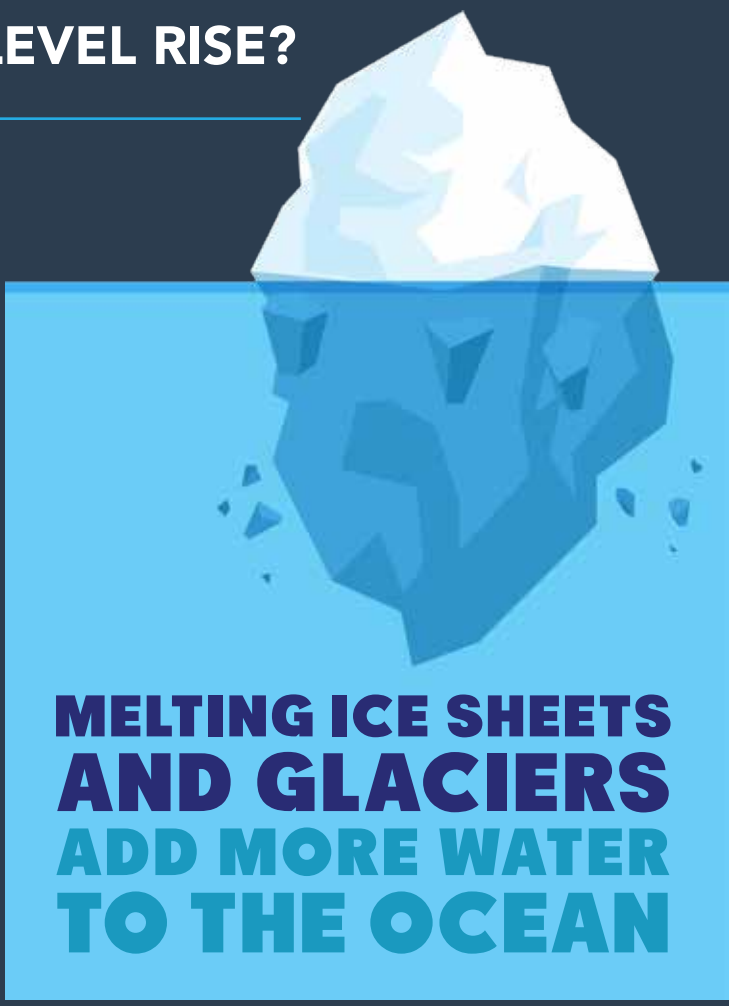
Covi and her team provided a set of recommendations to the city of Portsmouth to enhance communication with these households through their preferred communication avenues.[83] These results could also have the potential to inform future flood mitigation and emergency response plans in Portsmouth as a whole.

Because of her expertise, Covi was tapped by AGU's Thriving Earth Exchange program as a resource for Wasserberg and Stop the Flooding NOW. She has worked with Wasserberg on what has become a public education project, helping her explain the scientific basis behind Virginia Beach's flooding:

As water is withdrawn from the Potomac Aquifer for drinking water for the region, the land sinks, which is exacerbated by global sea level rise.

CLIMATE SCIENCE:
WHAT IS GLOBAL SEA LEVEL RISE?

Global sea level rise is caused by two main factors, both of which are connected to human-caused climate change: (1) existing ocean water expanding as it increases in temperature, and (2) melting ice sheets and glaciers adding more water to the ocean.[9] Global mean sea level is measured by satellites and through NOAA's global tide gauge network, as an average of the sea level height at multiple locations around the globe.[104] Since 1900, the global mean sea level has risen 7–8 inches, with 3 of these inches occurring since 1993.[9] In specific locations, the sea level may be rising faster or slower compared with the global mean.[105] Human-caused climate change contributed to mean sea level rise during this entire period, contributing to a rate of mean sea level rise that hasn't been seen in at least 2,800 years.[9] As a direct result of sea level rise, the number of minor, or "nuisance," floods occurring in coastal cities has increased fivefold to tenfold since the 1960s.[9]



Wasserberg, in turn, has become both a voice and a resource for her community on flooding and climate science, and Covi credits her with helping to promote real change in local resident populations who may be apprehensive of outside experts. "Virginia engages with a different group than what I would get to come out if I organized a meeting," she says. "She has really been out there talking to people in a different way than I could talk to [them] about this." While Wasserberg is still lobbying city officials for funding for flood mitigation projects, she understands that science education, effective communication, and grassroots activism are also essential for progress to be made on flood mitigation in the region.

Individually, Covi and Wasserberg brought flooding and sea level rise to the attention of their community—as a team, attention turned into knowledge that could improve lives.

UNDERSTANDING RISK REQUIRES A SEA OF DATA

In the same way that communities facing river flooding can begin to understand their risk by measuring the frequency of different water level heights with a stream gauge, coastal communities can quantify their likelihood of flooding using tide gauges. NOAA maintains the National Water Level Observation Network—a network of 210 permanent water level gauges on both coasts and the Great Lakes to observe tide levels and make tide predictions for the nation.[84]

NOAA's tide gauge network is supplemented by local gauges installed by USGS. In response to coastal flooding concerns in Virginia, USGS installed approximately 2 dozen tide gauges in 2015 and 2016, including 10 in Virginia Beach.[85,86] The organization sends data from these gauges directly to NOAA's National Weather Service.

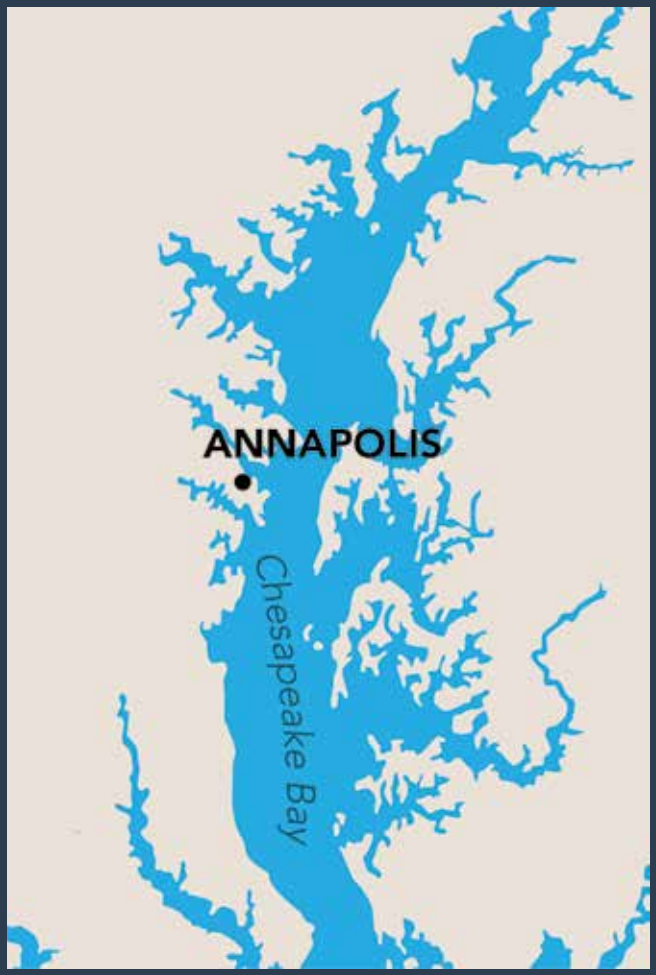
These data help to produce more accurate local forecast and allow emergency managers to make location-based decisions, like determiing evacuation routes.[85] Other groups in the state are also motivated to address the problem of flooding from sea level rise and improve the accuracy of local forecasts. The Commonwealth Center for Recurrent Flooding Resiliency (CCRFR) and the Virginia Institute of Marine Science (VIMS) maintain additional tide gauges in the so-called "Tidewatch" network in the Chesapeake Bay and along Virginia's seaside Eastern Shore. The network makes forecasts in the Hampton Roads region at the scale of individual roads and structures,[87] predicting tide heights and associated flooding 36 hours into the future.[88]

Forecasts of tide and coastal flood height require both elevation data and models to predict how water will flow over the land. Tidewatch forecasts, for example, use topographic maps from USGS and multiple models including NOAA's SLOSH model, which is shorthand for Sea, Lake, and Overland Surges from Hurricanes.[89] In addition to considering variables like water depth and physical features of the shoreline, SLOSH incorporates data about a storm's atmospheric pressure, size, and movement to create a model of how wind and atmospheric pressure affect the height of the storm surge.[90] SLOSH applies all along the East Coast of the United States and the Gulf of Mexico coastline.[90]

ECONOMY:
IMPACT OF "MINOR" FLOODING

A single extreme flooding event can cost several billion dollars, but the probability of such an event is, fortunately, very small. While a single minor flooding event along the coast, also called "sunny day" or "nuisance" flooding, causes less economic damage, the costs add up over time for the frequent, recurring events. In a study of the possible economic losses from extreme and minor flooding events for 11 coastal U.S. cities, five cities—New York, Washington, D.C., Miami, San Francisco, and Seattle—had a larger cumulative cost risk from minor flooding than from extreme flooding events.[106]

Minor floods can also have a significant economic impact on individual residents and businesses. Maryland's capital, Annapolis, is located on the Chesapeake Bay and relies on tourism to its historic downtown. A study of high-tide flooding in a downtown Annapolis parking area found that flooding led to a loss of nearly 3,000 annual visitors to the parking lot and to between $86,000 and $172,000 in losses for nearby businesses, or 0.7%–1.4% of their annual revenue.[107,108]



TECHNOLOGY:

DIGITAL COAST

Since 2007, NOAA has supported coastal managers on the Atlantic, Pacific, and Great Lakes coasts through its freely available Digital Coast products.[109] Digital Coast serves as a central repository of vetted coastal information and products generated by many sources and provides users with more than 70 terabytes of data and 50 tools, like the popular Sea Level Rise Viewer, which helps users easily visualize data.[109,110] These tools make data accessible and more easily digestible for the state and local coastal managers responsible for strategic planning decisions.

Digital Coast also serves a wide range of users. For example, the Department of Defense used it in its initial assessment of military bases and their risk of inundation from sea level rise.[110] Within 2 years of its creation, the digital data clearinghouse already had proved its worth; the net economic benefits surpassed its net costs.[110] By 2028, the net benefit of Digital Coast is expected to reach $117 million, representing a 411% return on investment.[110]

RISING SEAS, PROTECTING CULTURES

On the U.S. West Coast, the Coastal Storm Monitoring System model, or CoSMoS, provides predictions of flooding and wave impacts from current and future storms in combination with sea level rise driven by climate change.[91,92] CoSMoS integrates wind and pressure data from various sources (including the National Weather Service) with data on sea level rise, tides, and stream flooding to predict the impact of storms that are actively occurring. CoSMoS relies on global climate models to project future storms.[93,94]

CoSMoS was originally developed by USGS for the high wave-energy environment along California's coast. In a partnership with the EPA, USGS has also developed a version of CoSMoS to apply to the coastline of the Salish Sea, a complex network of inland waters spanning Washington State and parts of Canada. One of the Salish Sea's main bodies of water is Puget Sound in Washington State. The Skagit River delta at the northern end of Puget Sound has been the homeland of the Swinomish people for thousands of years.

The Swinomish weathered three destructive storms in 4 years. The last, in December 2018, destroyed shoreline structures and left the Swinomish looking to understand how often they could expect storms of this magnitude in the future. The intensification of stream and coastal flooding has not only flooded Swinomish homes, but also threatens their access to important fishing areas and cultural sites as well as their very identity.[85] Tribal elder Larry Campbell told USGS that the tribe's traditional seafood diet is more than nutrition alone. "They're also spiritual foods for us," Campbell explained. "We call it feeding our spirits when we eat these foods."[85] The Swinomish, like other tribes with reservations, face the additional impact of a shrinking land base since reservation boundaries are static and do not shift with rising sea levels.[95]

Out of these concerns grew a unique collaboration between Eric Grossman, a Research Geologist with USGS, and Jamie Donatuto, the environmental scientist employed by the Swinomish tribe. Grossman and his team adapted CoSMoS to predict what land areas and valued habitats within the Swinomish Reservation were at risk from future sea level rise and future major storms and how the frequency of storm disturbances will increase because of sea-level rise and affect planning thresholds and tipping points. However, the Swinomish concerns were about much more than land and resource conservation. As Donatuto describes it, for the Swinomish, "[h]ealth comes from culture, and culture comes from land, water, and air." Donatuto therefore worked with the Swinomish to identify tribal health priorities, which included both conservation of their traditional foods, including clams, crab, and salmon, and reviving intergenerational land-based education. These health priorities allowed the Swinomish to take the CoSMoS results and prioritize areas for protection. It also led to an informal curriculum that emphasized elders teaching tribal youth about land stewardship The combined values and science-based decision-making used by the Swinomish are not new.

As more scientists like Grossman and Donatuto take the time to understand the priorities of the communities they are working with, we can expect to see more collaborative, sustainable, and effective solutions to the climate challenges facing our nation.

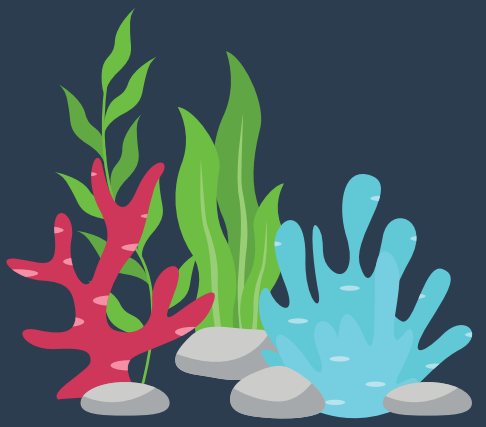
POLICY PLAYS A PART

In Virginia Beach, some political change is starting to take root. The city hired an engineering firm to complete a rainfall study for the region. On the basis of analysis of 70 years of historical rainfall, the engineers found that rainfall intensity increased by about 5% per decade in the Virginia Beach area, as well as similar increases in rainfall intensity along the entire northeastern U.S. coastline.[96] Therefore, they recommended that Virginia Beach increase by 20% the rainfall value used in the design of infrastructure intended to last for the next 40 years, a typical design lifetime.[96]

The report also contributed to the Virginia Beach City Council incorporating scientific predictions of flooding into their zoning and development decisions. Recently, the City Council's decision to deny a developer's request to rezone flood-prone land for a housing development was upheld in court,[97] affirming the lawmakers' legal right to consider climate data and pursue evidence-based policies around flooding. Victories like this demonstrate how a coordinated effort between scientists, everyday citizens, and elected officials to empower a community through data and science can lead to positive change.

TECHNOLOGY OF A DIFFERENT KIND:

NATURE-BASED COASTAL FLOODING MITIGATION



CORAL REEFS PROVIDE NATURAL PROTECTION

The Eglin and MacDill Air Force bases in Florida are experiencing the effects of coastal flooding and erosion. In 2019, the Air Force ranked Eglin and MacDill in the top 10 of bases at risk of extreme weather impacts like inland or coastal flooding, extreme heat, or drought.[102] Eglin was ranked second and MacDill, eighth.[102] In partnership with local community groups, both bases turned to oyster reefs to mitigate coastal erosion.[80] These bases are not alone in turning to "nature-based" coastal flooding mitigation—interest is growing along with research that shows that nature-based mitigation methods, such as the presence of marshes and reefs, provide valuable shoreline protection from flooding damage.[111,112]

During Hurricane Irene, approximately 76% of seawalls—made of concrete and other hard materials—on North Carolina's Outer Banks were damaged, while no damage occurred to the shorelines with marshes within 15.5 miles of the hurricane's landfall.[111] Coral reefs provide another form of natural protection. A recent quantification of the benefits from all coral reefs in the states of Hawaii and Florida, and the territories of Guam, American Samoa, Puerto Rico, and the Virgin Islands, and the Commonwealth of the Northern Mariana Islands, found that coral reefs provide an annual value of $1.8 billion in avoided flood damages.[112] They also prevent 18,000 people from experiencing flooding each year.[112]

Wasserberg is still active in advocating for the residents of Virginia Beach but has moved out of her neighborhood because the investment—financial and emotional—was too great. The family could not sustain another flood like the one in 2016, and, at the same time, another flood seemed inevitable. On the Stop the Flooding NOW Facebook page last fall, Wasserberg shared her story and urged fellow Virginia Beach residents to cast a ballot in the upcoming election.

"FLOODING IS MORE THAN A HOUSE FILLED WITH WATER," SHE WROTE. "IT'S A MUCKED AND GUTTED HOME STRIPPED OF ITS BEAUTY, A FAMILY DISTRESSED AND DISPLACED WITH MOUNTAINS OF STRESS ON THEIR BACKS, A LIFETIME WASHED AWAY IN A MOMENT."

She thanked her community and then ended on a positive note: "We flood and we VOTE!"

SUMMARY

High-tide, "sunny day," or "nuisance" flooding is a problem on the east, west, and Great Lakes coasts of the United States.

Federal agencies like NOAA and USGS work to collect the data required for the best predictions of future coastal conditions.

The issue of adaptation is as much a social issue as it is a technical one—it will require scientists and communities coming together to understand priorities and possible solutions.

We are beginning to see science as a basis for flood policy across the country, a promising sign for our nation's future.