

Measuring and assessing the impacts of chronic coastal roadway flooding to inform adaptation

Thomas Thelen¹, Katherine Anarde¹, Casey Dietrich¹, Miyuki Hino²

UNC University Research Week – October 26, 2023

1

NC STATE
UNIVERSITY

2



THE UNIVERSITY
of NORTH CAROLINA
at CHAPEL HILL

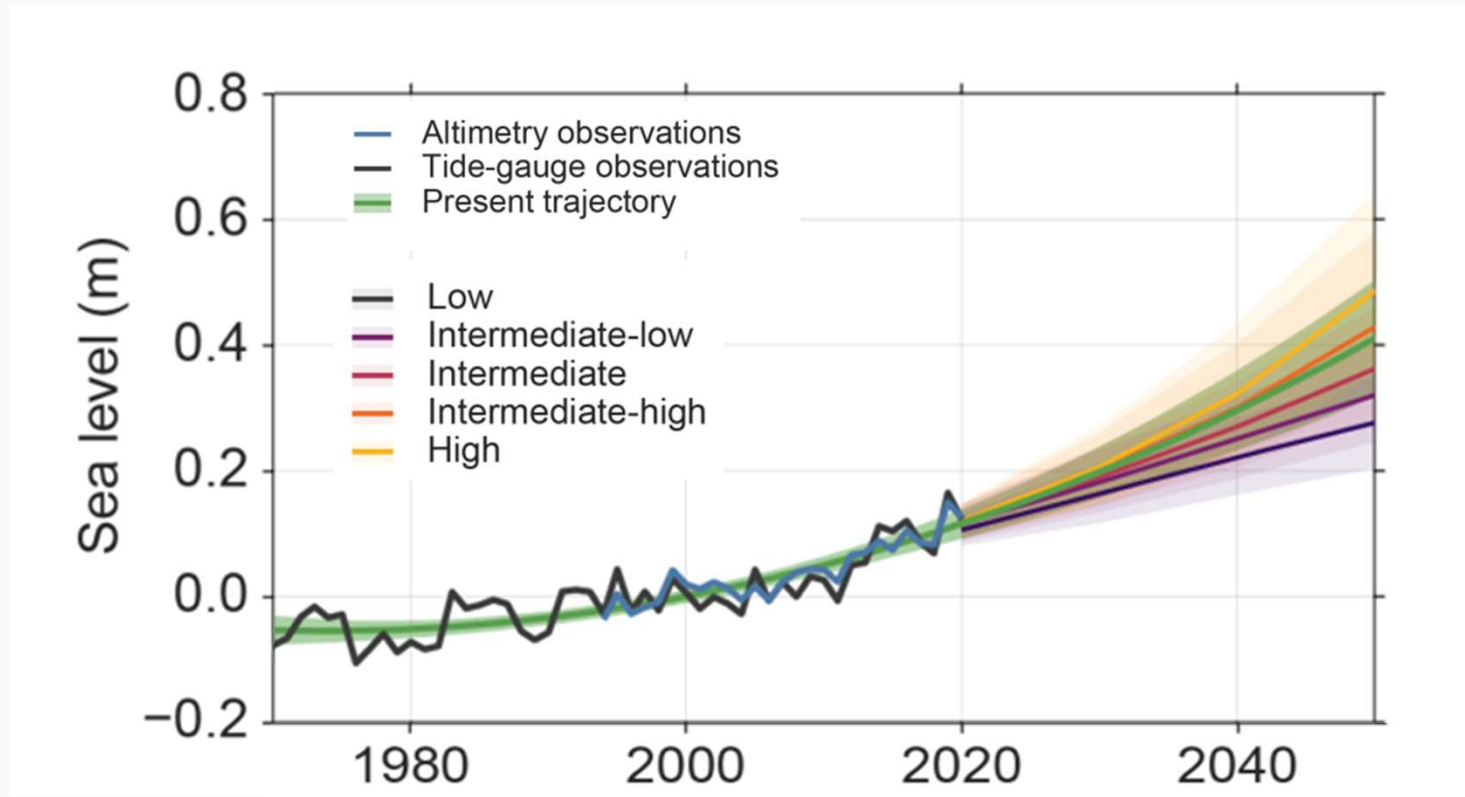
(Photo credit: Coastal Observer app)



Sea level rise (SLR) is projected to increase flood frequency



NOAA projections for the Southeast: ~27 cm (11 in) from 2020-2050



Sweet et al., 2022

Because of SLR, coastal flooding already occurs outside of extreme storms



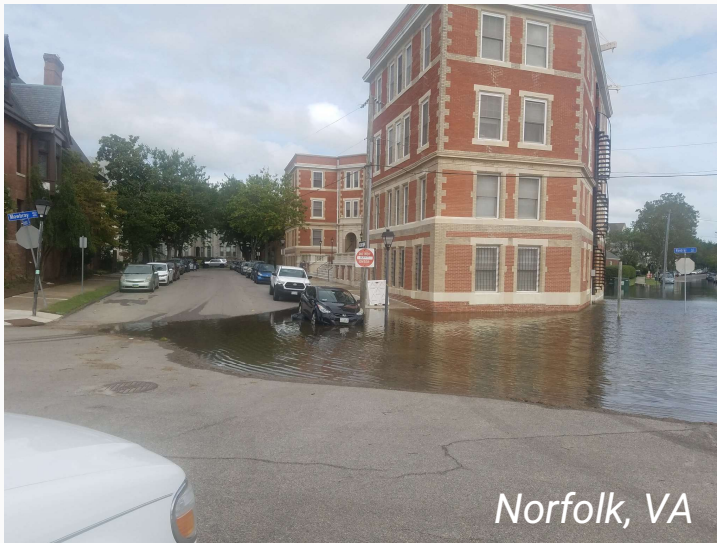
Jamaica Bay, NYC



Hollywood, FL



San Francisco, CA



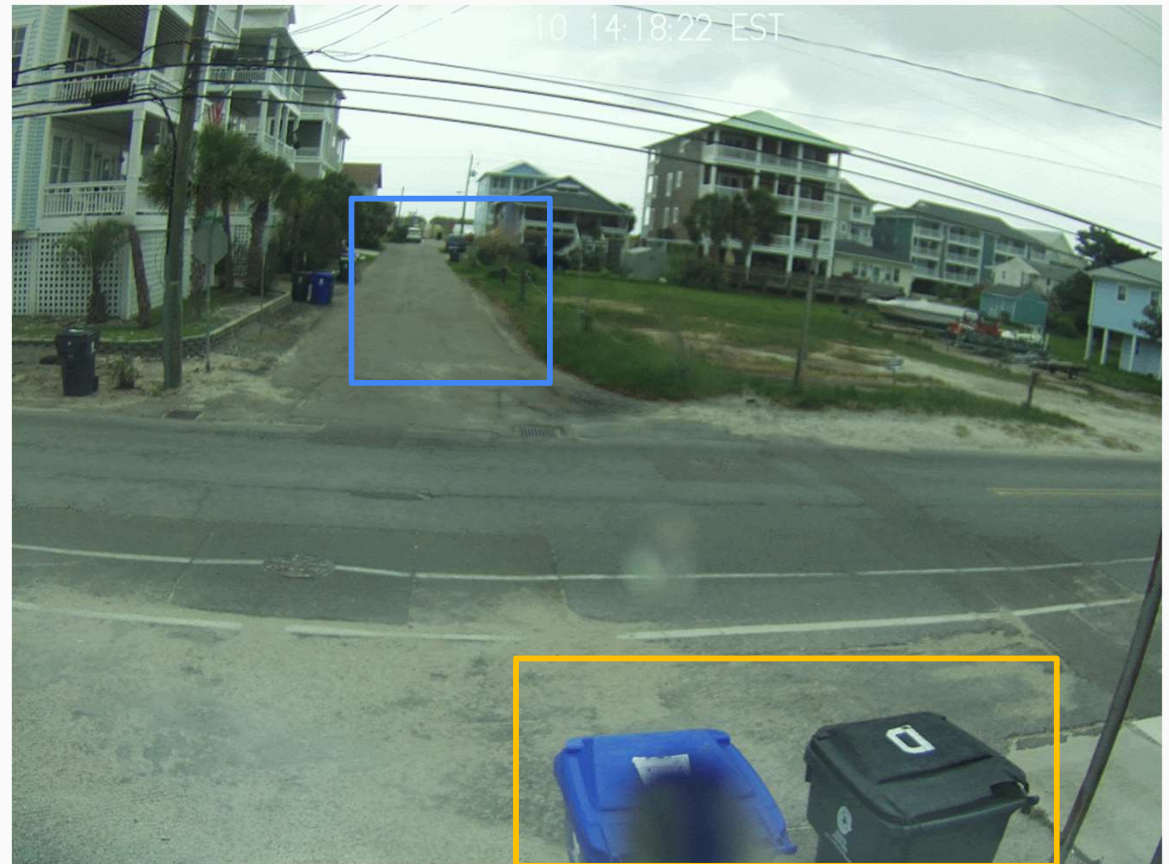
Norfolk, VA



Honolulu, HI

(top left: NY Sea Grant
bottom left: WAVY 10 news,
bottom right: Circle of Blue,
top center and top right:
Business Insider)

These floods impact individuals and infrastructure



*Chronic coastal flooding driven by **rainfall at high tide** in Carolina Beach, NC (Source: Sunny Day Flooding Project camera)*

These floods impact individuals and infrastructure



Present day impacts

US East Coast:

- **100 million vehicle-hours** of traffic delays;
7500 miles of roadway (Jacobs et al., 2018)
- **2 million people** living in census blocks with roadway flooding (Gold et al., 2022)

Future impacts

Residents of US coastal counties:

- **200 to 650 minutes** of yearly traffic delays by 2060 (Hauer et al., 2023)



*Coastal flooding driven by **rainfall at high tide** in Carolina Beach, NC (Source: Sunny Day Flooding Project camera)*

Knowledge gap: limited data and models of multi-driver flooding



Spatial scale: several city blocks

Temporal scale: minutes to hours

Multi-driver flooding:

- Tides
- Wind setup
- Groundwater
- River discharge
- Infrastructure
- Rainfall – in Beaufort, NC: 25% of floods occur during rain events (Gold et al., 2023)




Coastal flooding driven by **rainfall at high tide** in Carolina Beach, NC (Source: Sunny Day Flooding Project camera)



Canal Drive flooding woes due to handful of properties. A proposed solution? Expensive bulkheads



**Private problem, public nuisance?
Carolina Beach committee pinpoints 9
properties causing flooding on Canal**

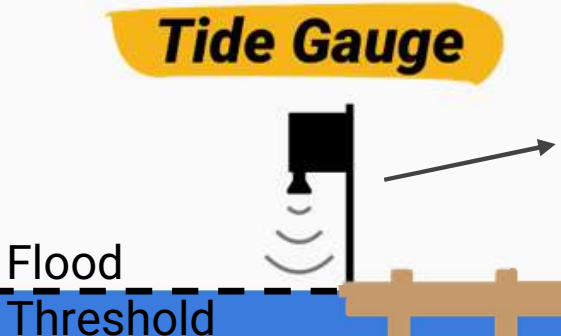
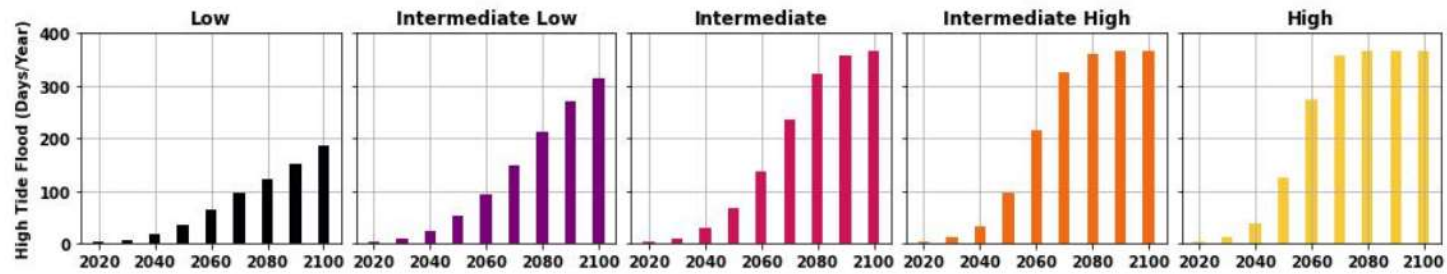
 By Johanna F. Still June 29, 2021

Tide gauge data are often used as proxies for floods

8656483 Beaufort, Duke Marine Lab

(State of High Tide Flooding and 2022 Outlook)

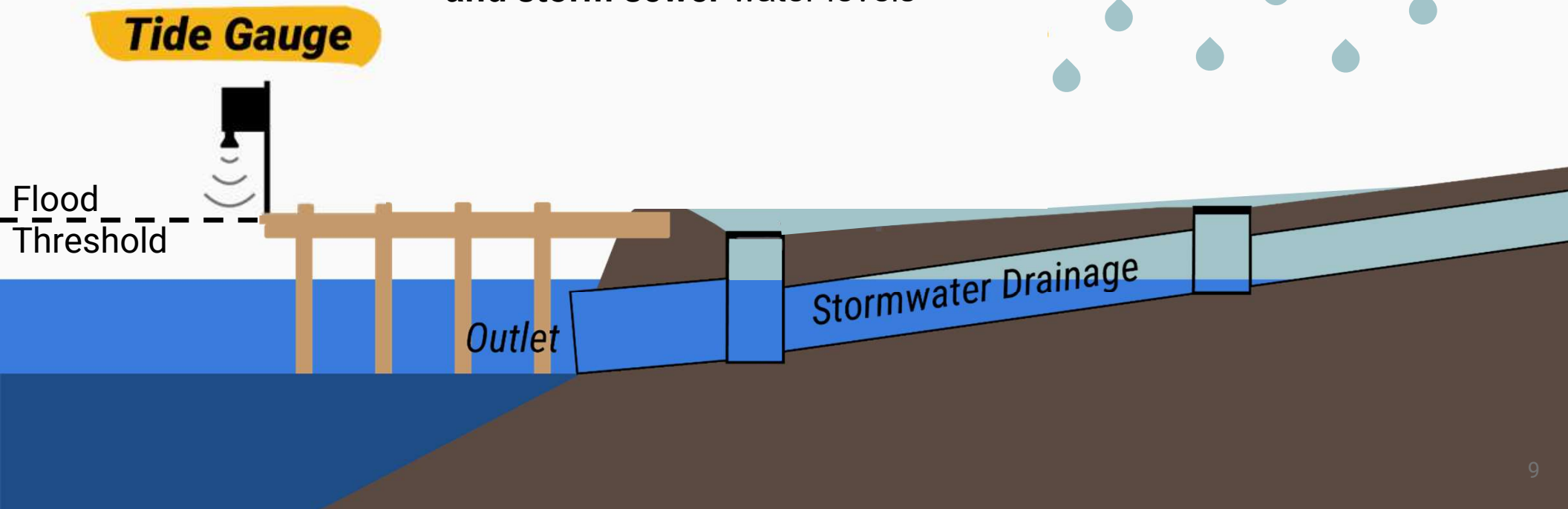
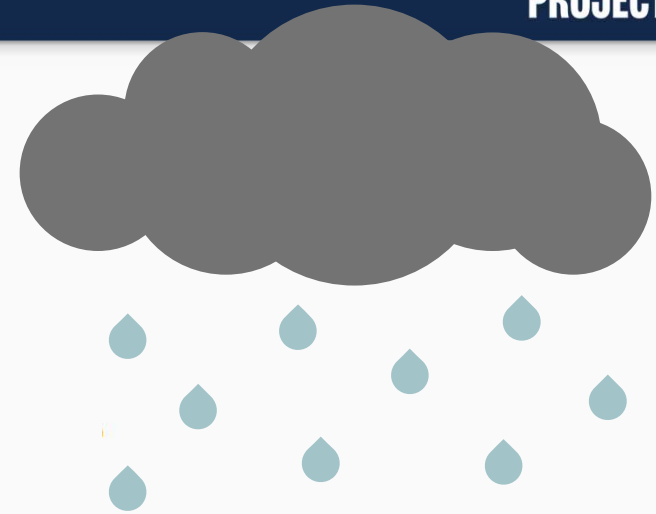
Projected Annual Average High Tide Flooding by Decade



But tide gauges measurements cannot capture all sources of flooding

Tide gauges *do not* capture

- Flooding from **rainfall**
- Flooding from **high groundwater**
- Difference between **ocean/bay** and **storm sewer** water levels



Sunny Day Flooding Sensors (SuDS) capture multiple causes of flooding



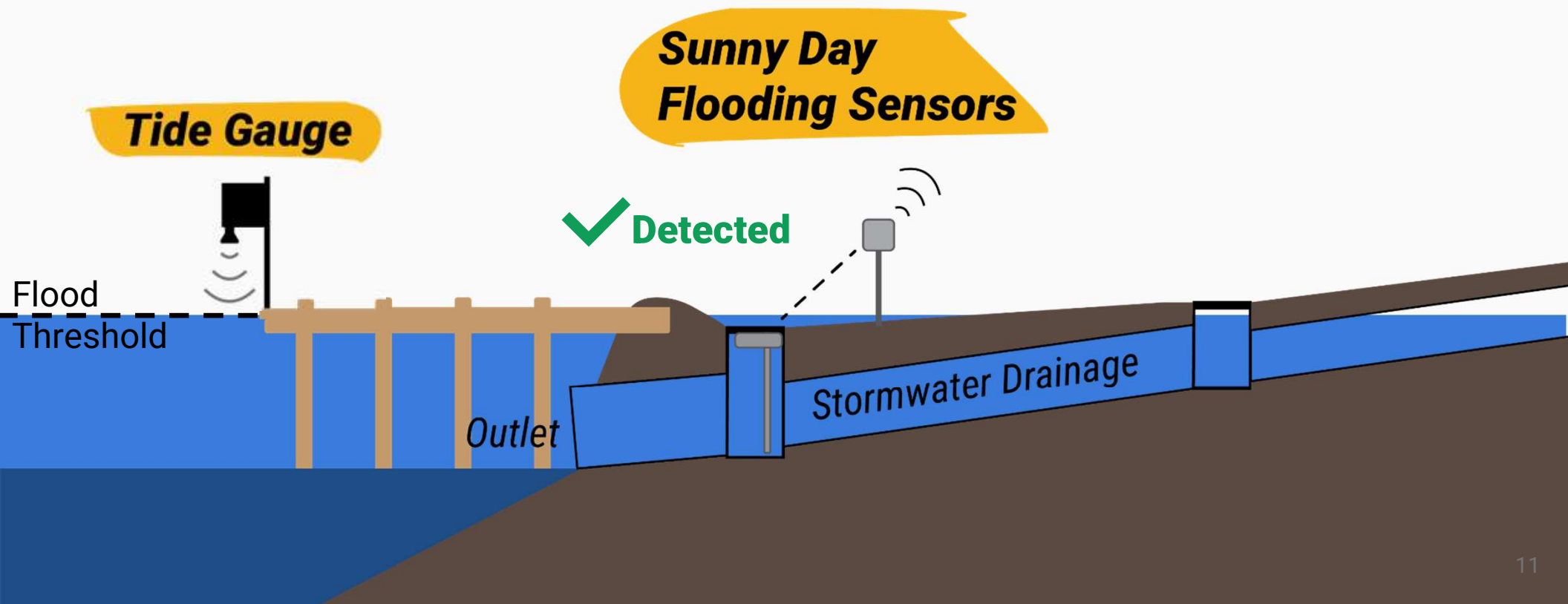
Sunny Day Flooding Sensors

Communication gateway with camera

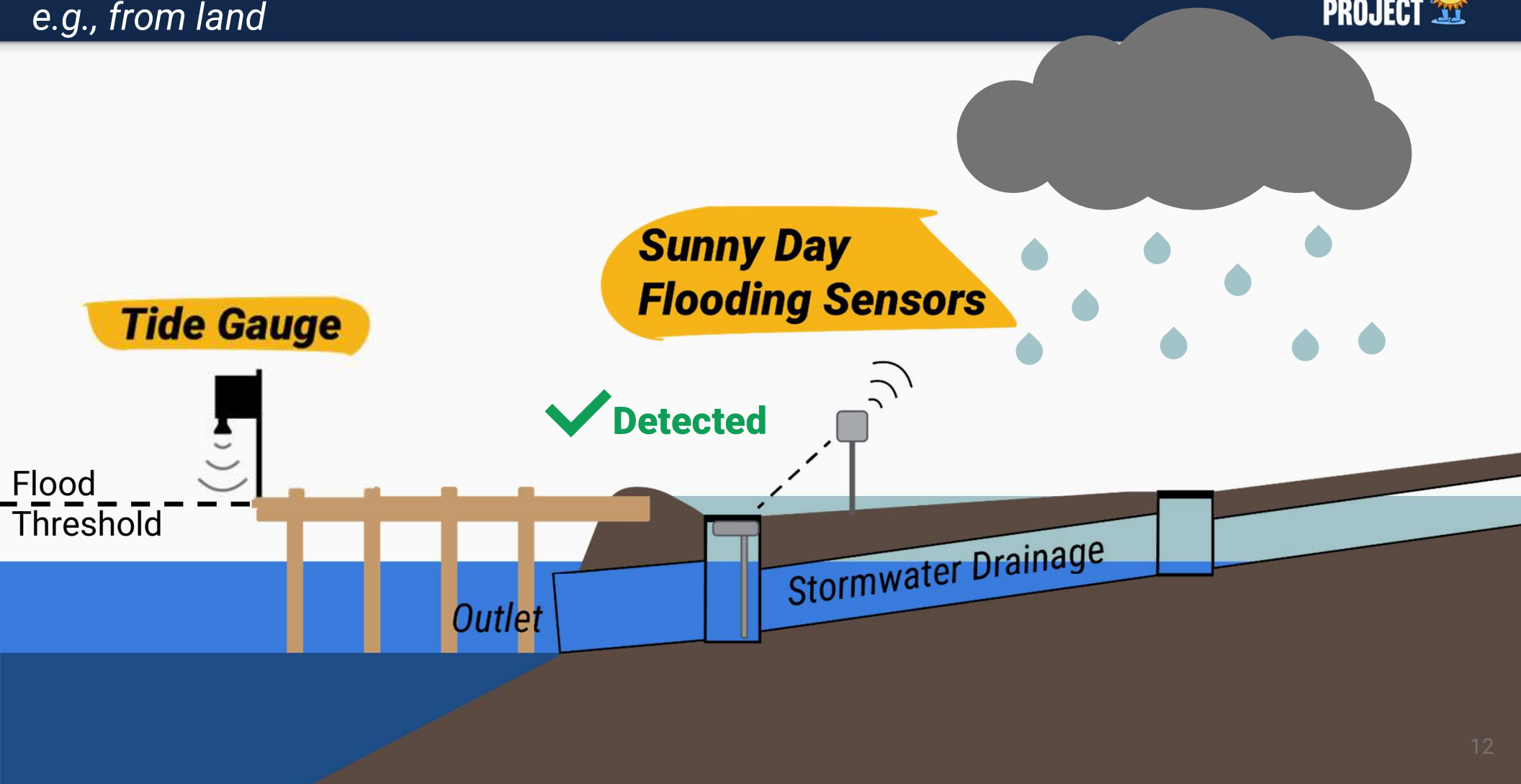
Storm drain pressure logger

Stormwater Drainage

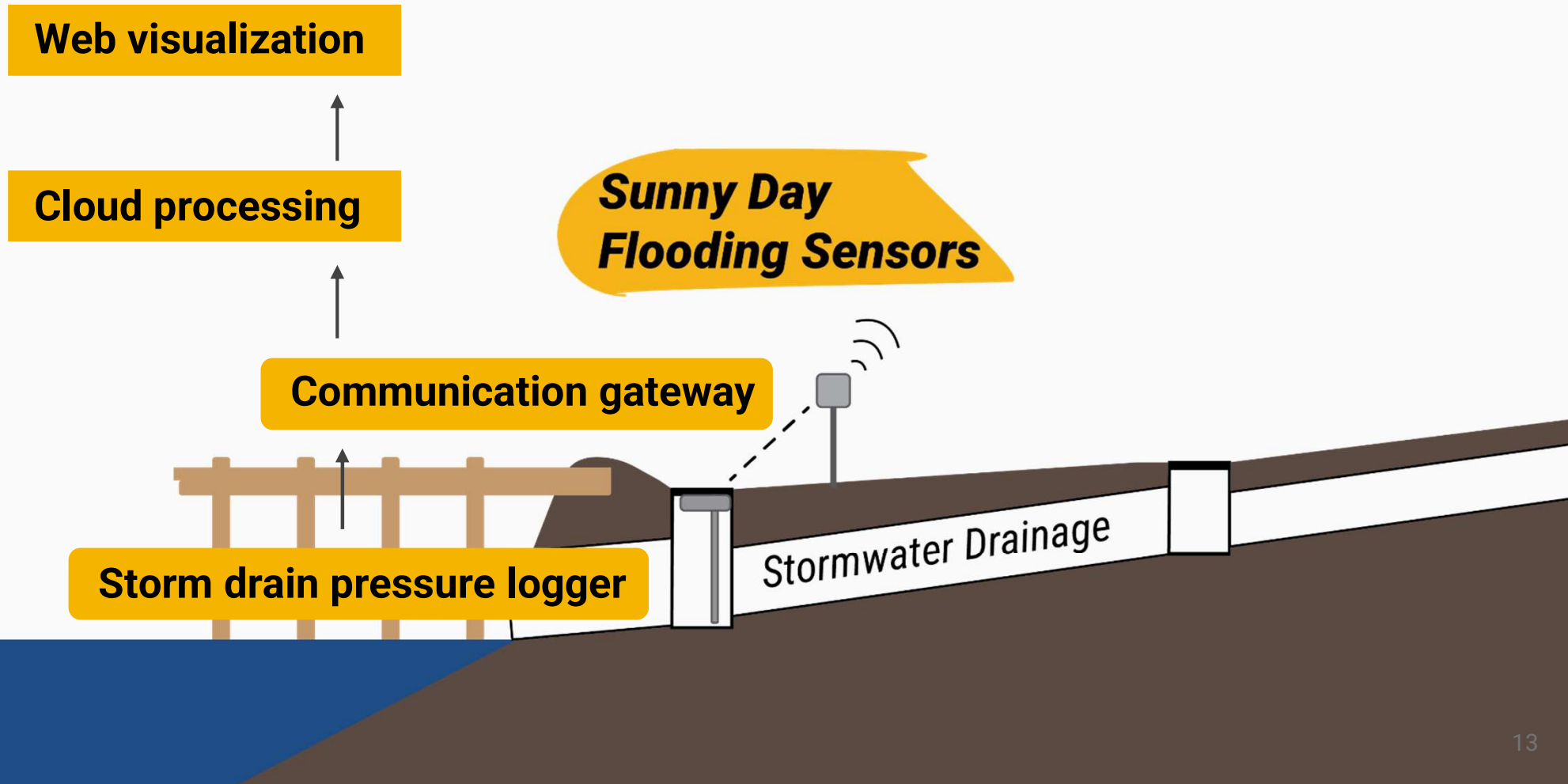
SuDS capture multiple causes of flooding
e.g., from the ocean



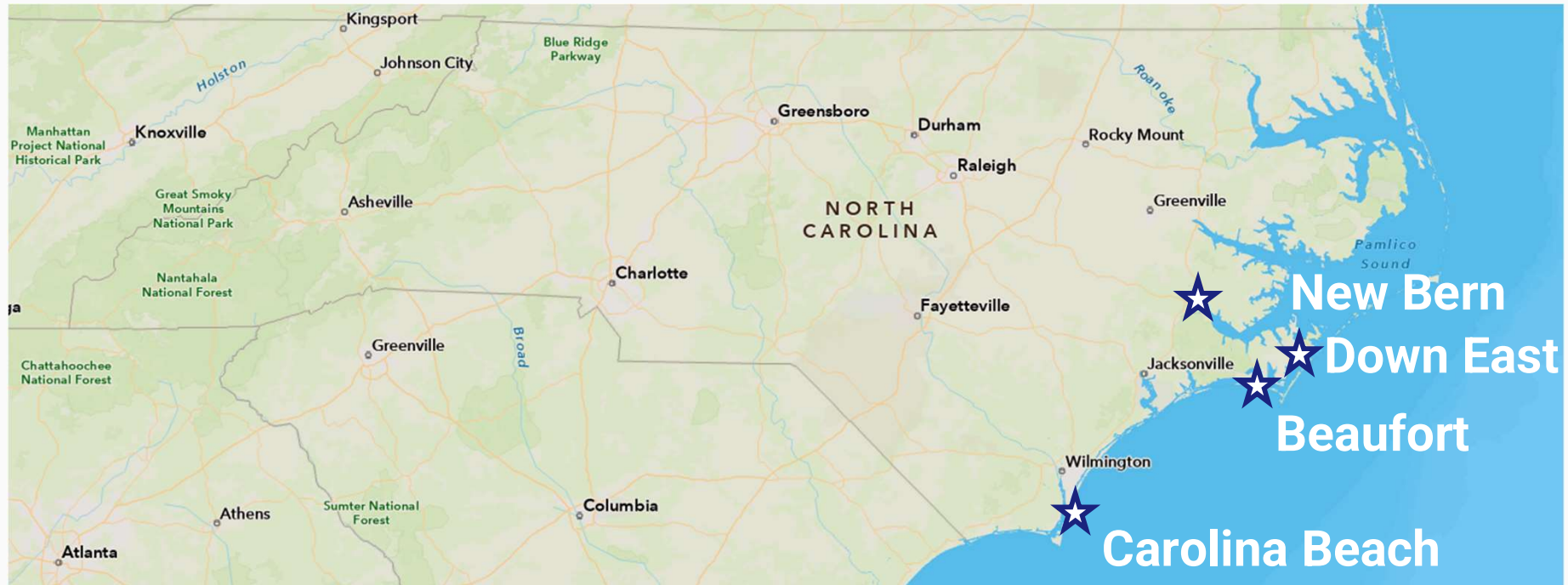
SuDS capture multiple causes of flooding
e.g., from land



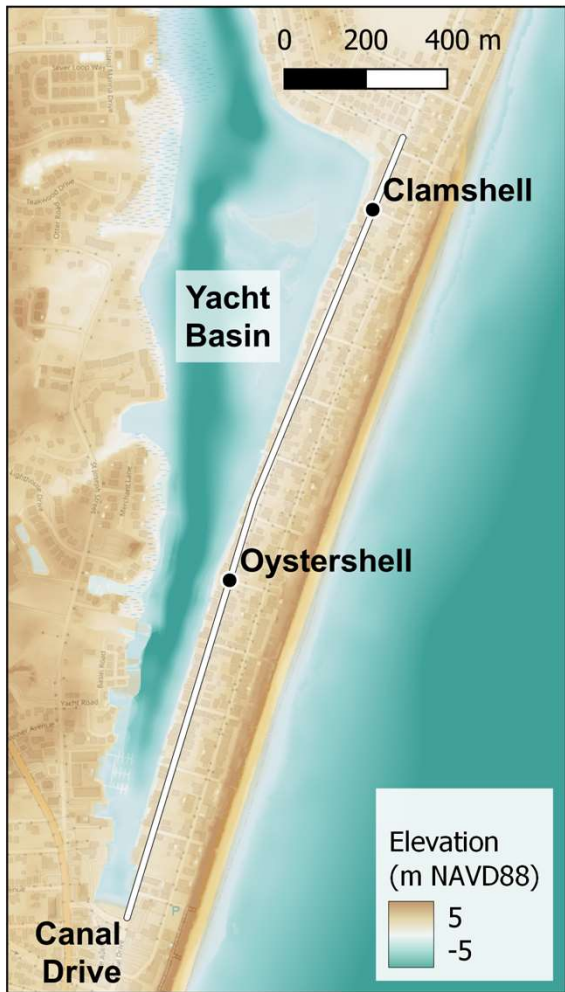
SuDS photos and water levels are available in real-time



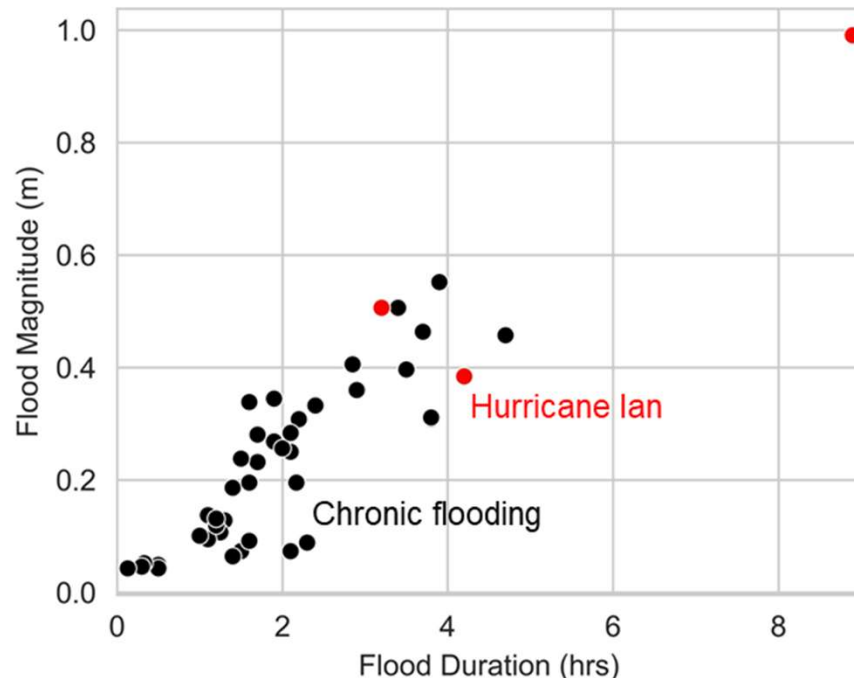
SuDS are deployed in four partner communities



Carolina Beach: overland flooding and stormwater networks



Year in review: we measured standing water on road 45 times at Clamshell



Challenges/data gaps:

- February 2022 - August 2022: 50% of time record missing
- August 2022 - May 2023: 9% of time record missing

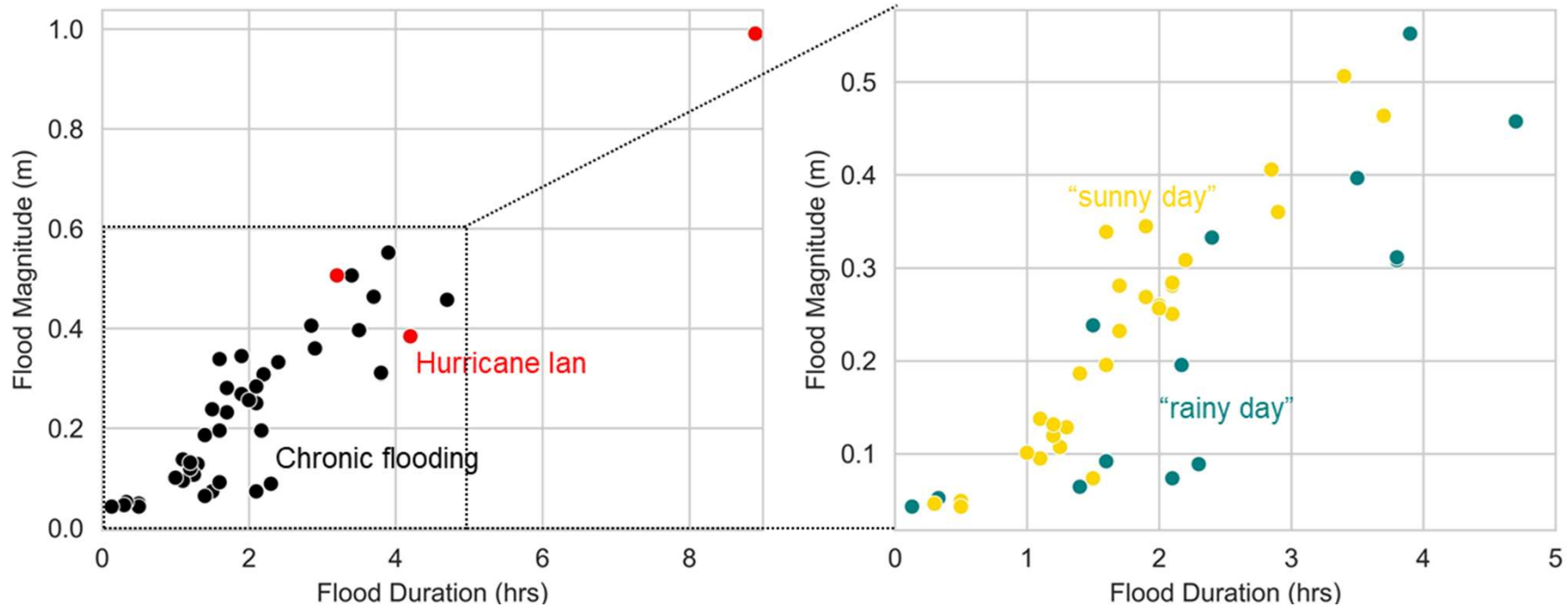
Takeaway: 45 is a low (preliminary) estimate!

Data from April 2022 - April 2023

Of the 42 non-hurricane events, 14 were caused by rain events (plus tides)



1 m = 3.3 ft

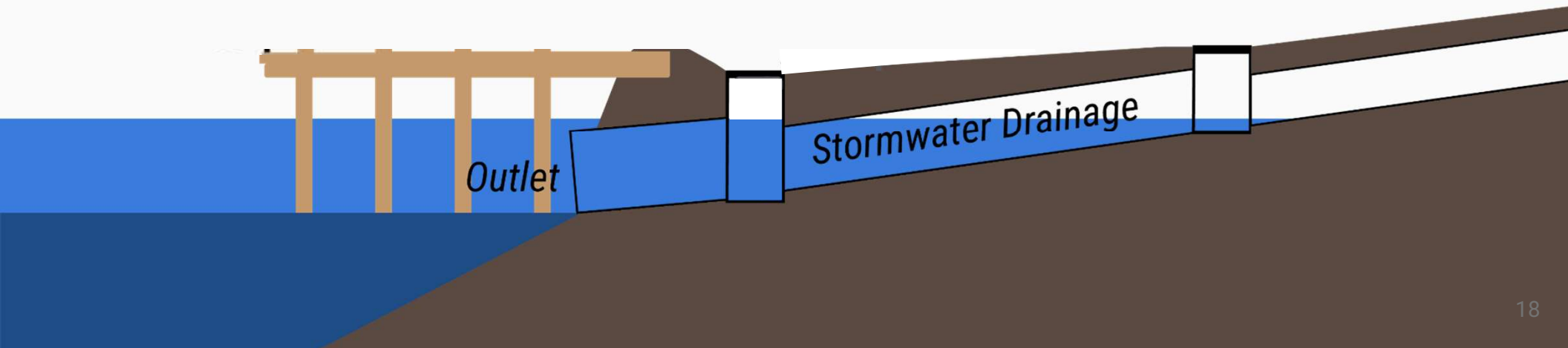


Data from April 2022 - April 2023

Modeling goal: simulate ocean-scale and local flooding drivers

Ocean-scale flooding drivers:

- Tides
- Atmospheric effects (wind)



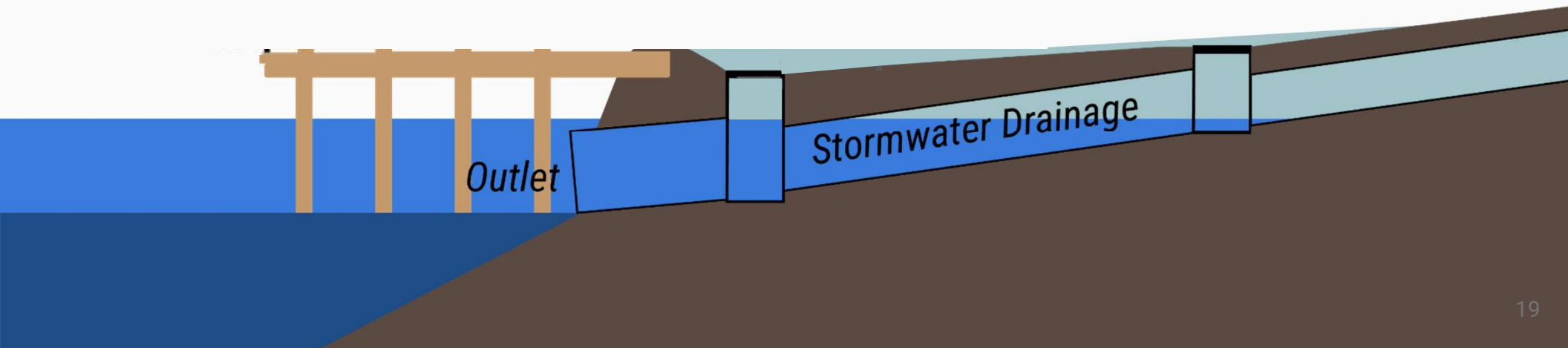
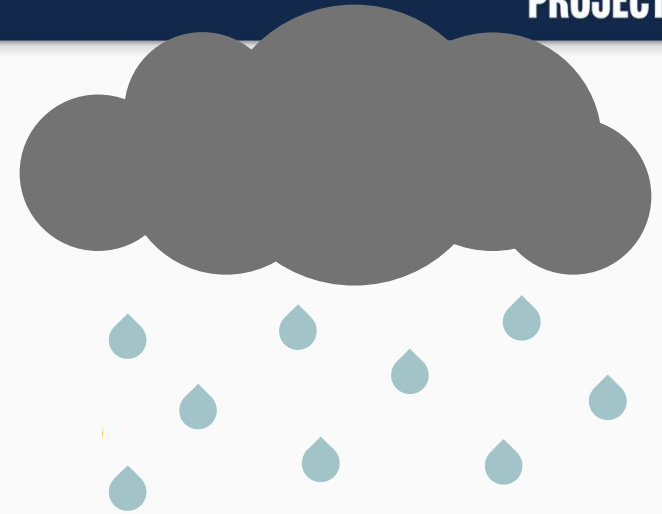
Modeling goal: simulate ocean-scale and local flooding drivers

Ocean-scale flooding drivers:

- Tides
- Atmospheric effects (wind)

Localized flooding drivers:

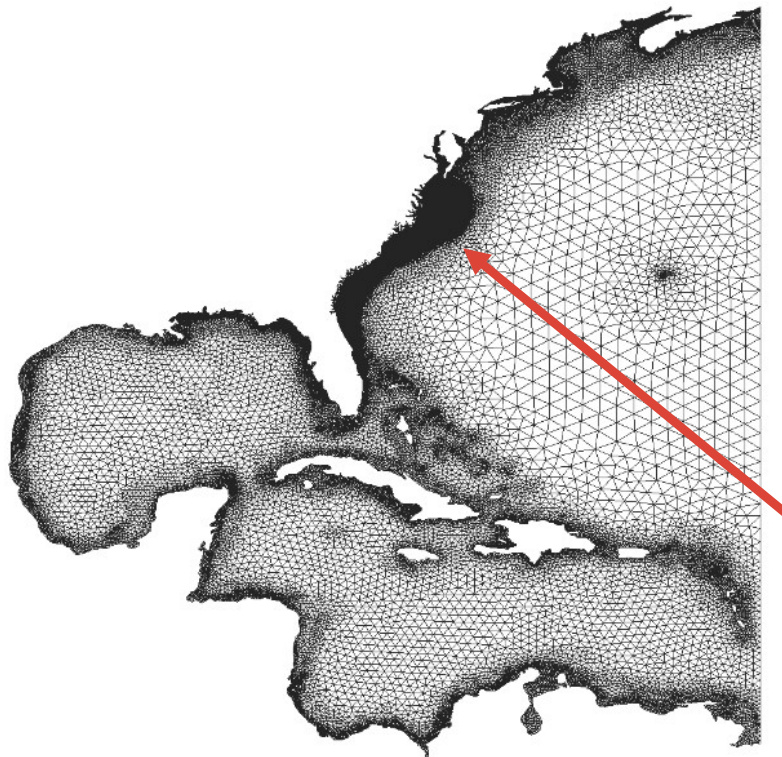
- Rainfall runoff
- Stormwater infrastructure



A coupled hydrodynamic and stormwater model to simulate coastal flooding



Hydrodynamic model: ocean-scale circulation

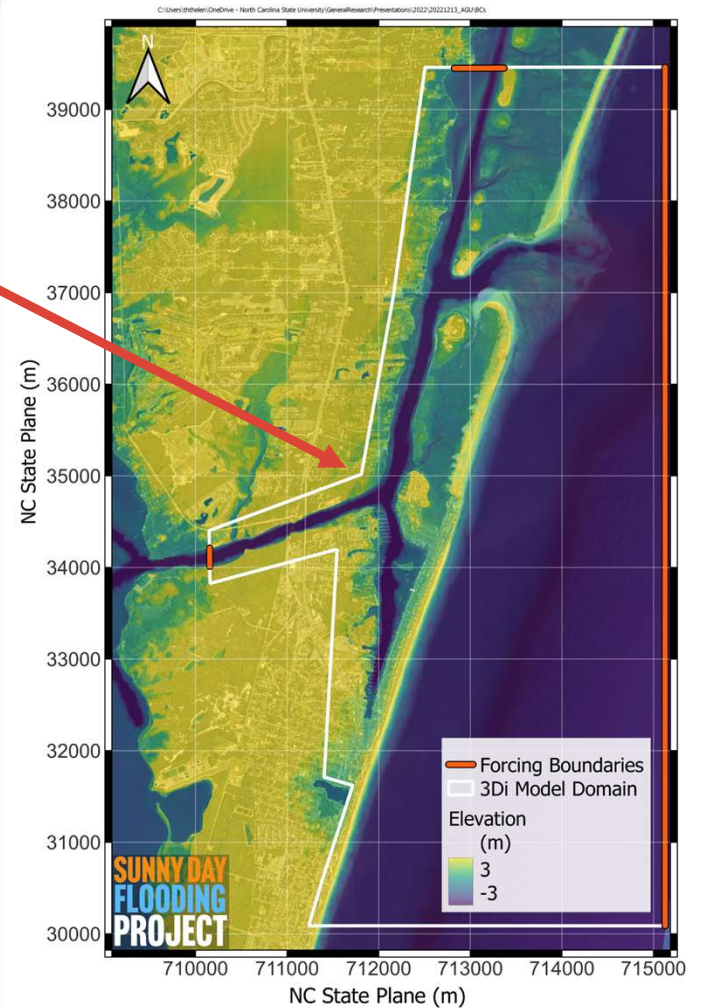


(Luettich and Blanton, 2008)

Stormwater model: local flooding

Model domain:
Carolina Beach

Model domain:
Western Atlantic

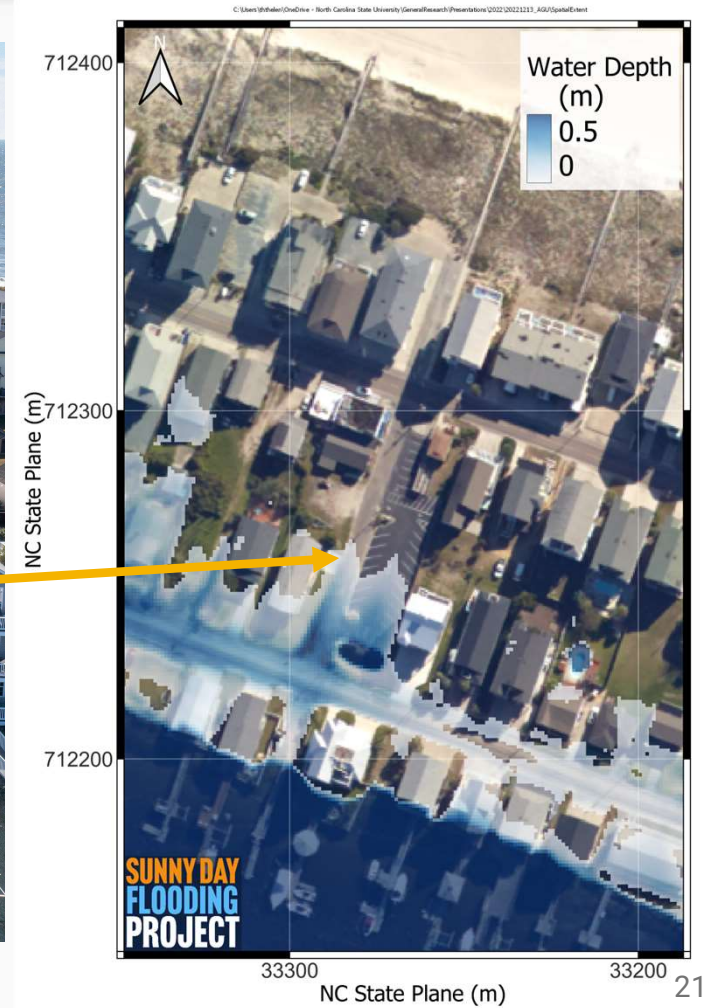


Coupled model resolves flooding at 1-meter spatial resolution

November 2021



(Photo credit: Coastal Observer app)



Jan. 22, 2023: if the forcing was **tides only**, water would not have reached Canal Drive

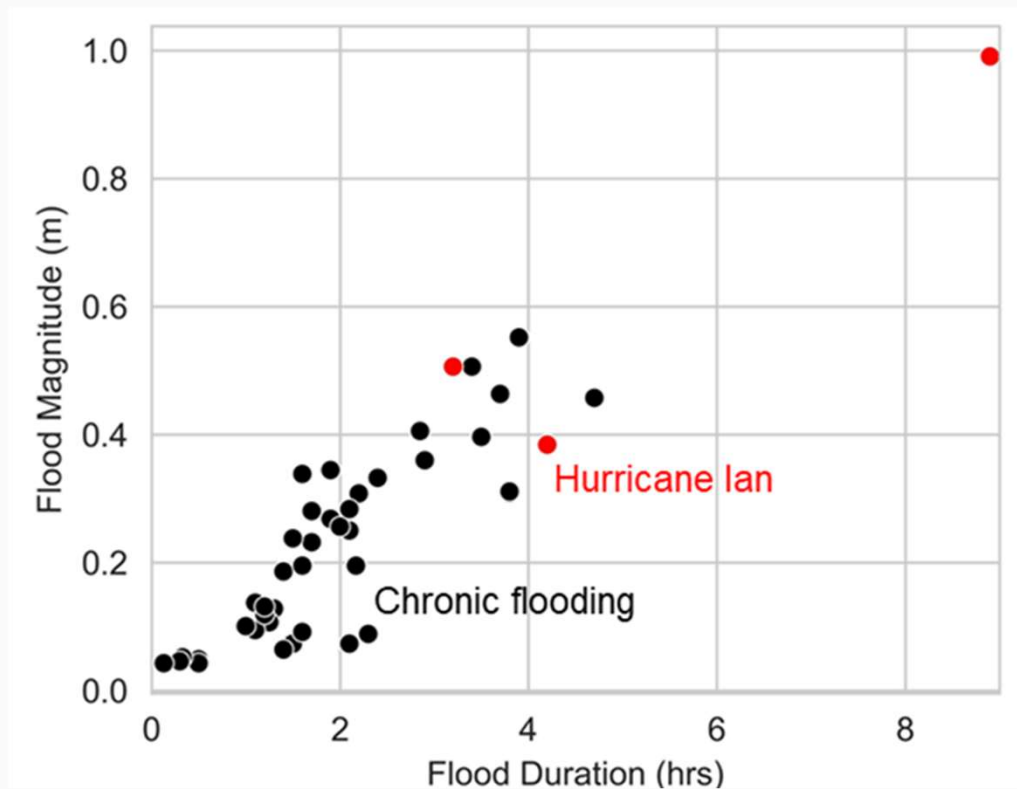


Jan. 22, 2023: the addition of **wind forcing** results in flooding of Canal Drive



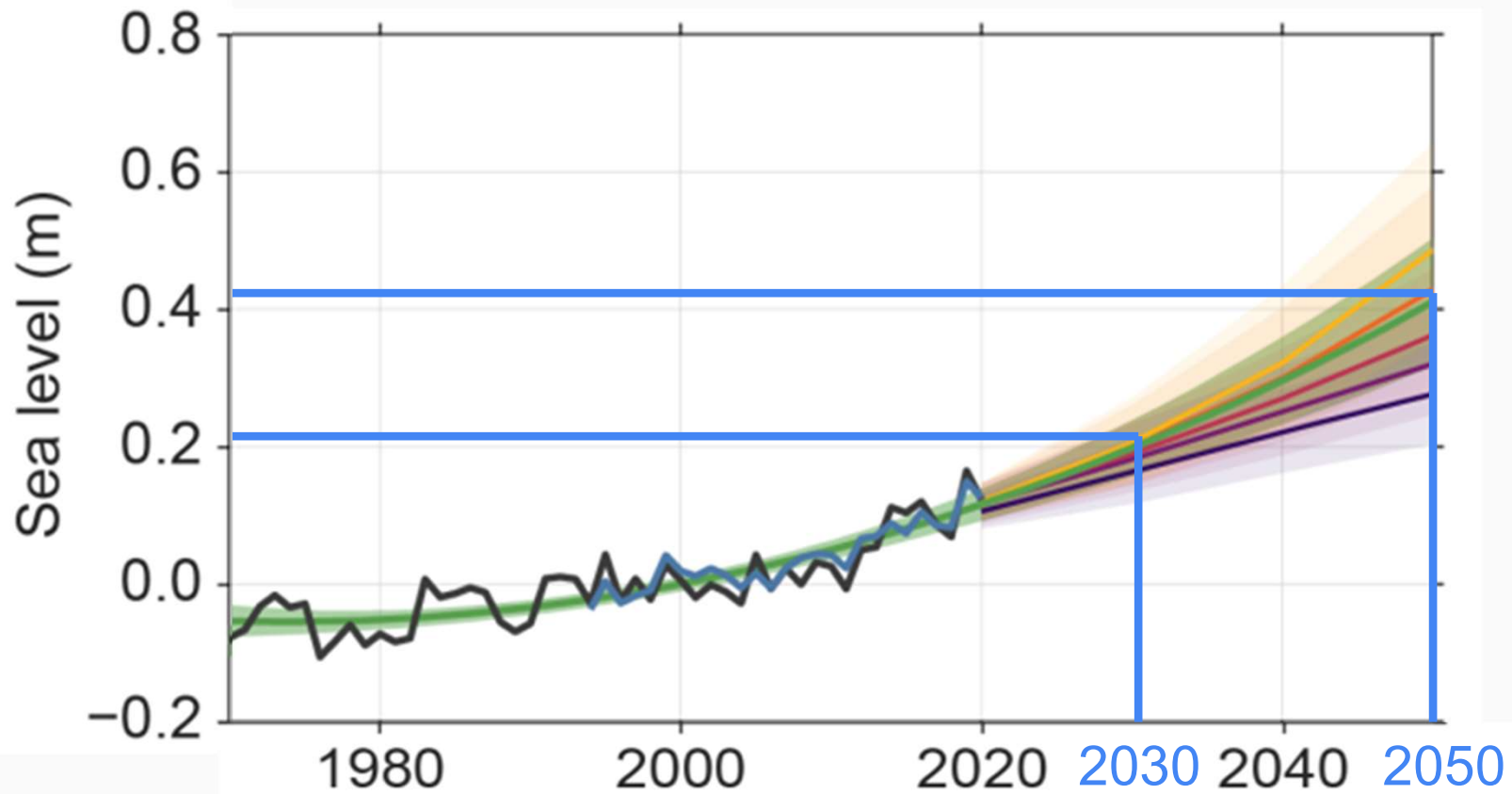
Knowledge gaps

1. Data and model of multi-driver flooding

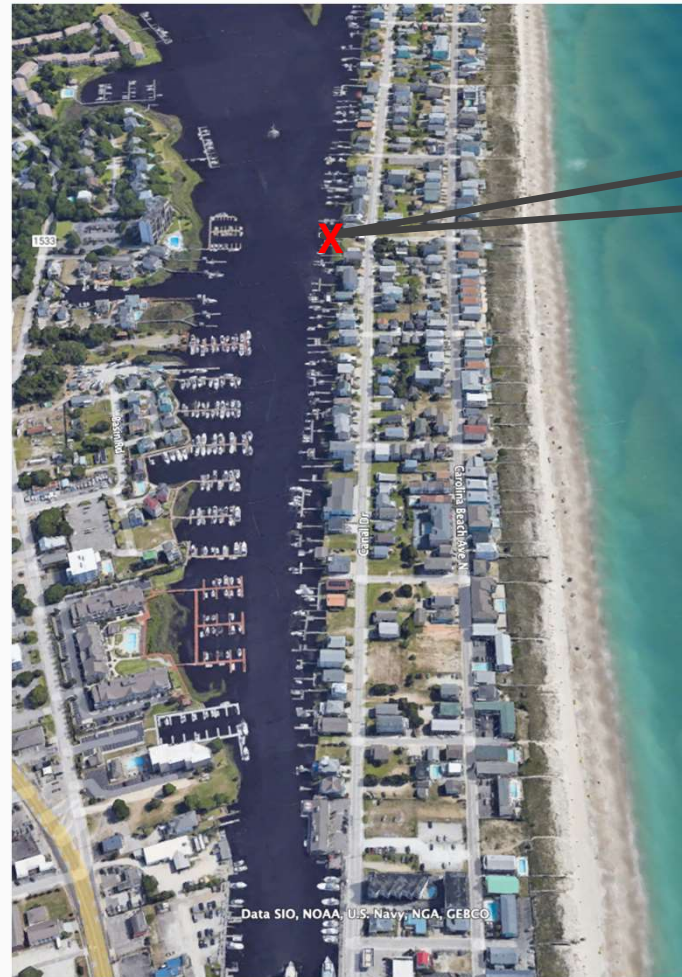


- ✓ 1. Data and model of multi-driver flooding
2. Framework for testing effectiveness of chronic flooding solutions

Testing the effectiveness of chronic flooding adaptation measures



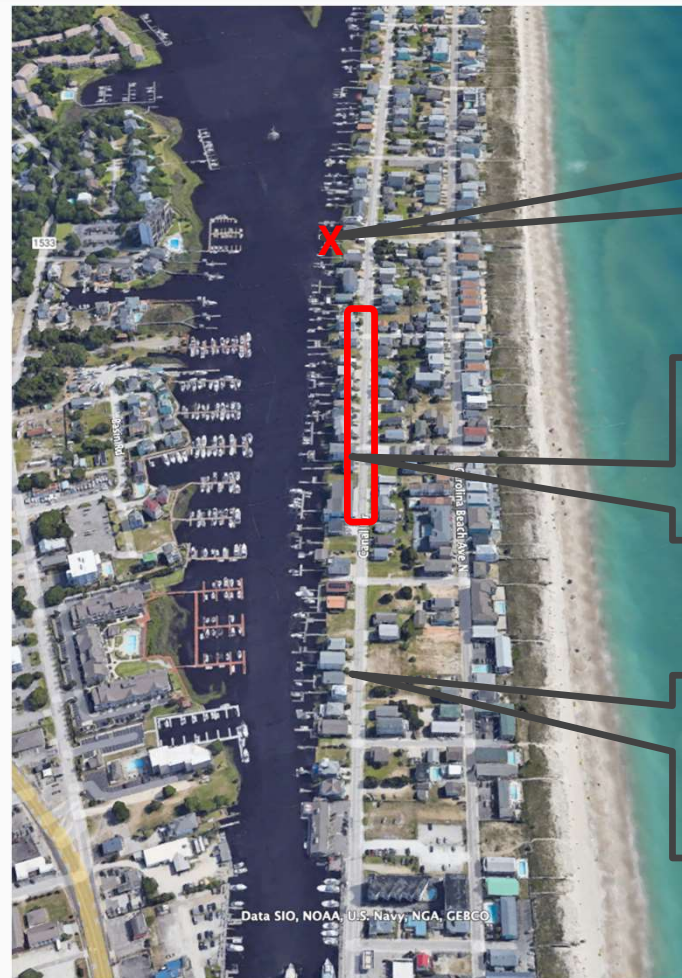
What adaptation measures to test?



Raise bulkhead?

What adaptation measures to test?

Depends on community perception of flooding impacts and adaptation preferences



Raise bulkhead?

Elevate road segment?

Add stormwater pump?

Community engagement to understanding chronic flooding impacts and preferred adaptations



Flooding survey mailer

Adaptation strategies that do not align with community goals often get rejected

Steve Koller reposted

Rep. Dan Goldman @RepDanGoldman

After years of planning, @USACEHQ is proposing a \$52 billion program that fails to address the full scope of flood risks facing NY and NJ.

Our coastal communities deserve better. @NydiaVelazquez and I are leading the call for USACE to protect them from ALL flood threats.

Rep. Nydia Velazquez @NydiaVelazquez · Sep 13

Today, @RepDanGoldman and I led 12 members to call for a complete flood protection plan for NY & NJ.

@USACEHQ's current plan only protects from storm surge flooding.

To protect communities from climate change, we can't ignore threats like heavy rainfall and rising sea levels!



Miami-Dade County Rejected An Army Corps Plan To Fight Storm Surge – Here's What The Corps Says Is Up Next

WLRN 91.3 FM | By **Jenny Staleto**
Published September 2, 2021 at 2:52 PM EDT



2:55 PM · Sep 14, 2023 · 10.2K Views



Thanks for your attention!



ththelen@ncsu.edu
sunnydayflood@gmail.com



@coasthelen
@sunny_day_flood



go.ncsu.edu/sunny

Check out real-time
SuDS data here →

